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

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**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)**

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## **FOREWORD**

Presented number of Silesian University of Technology. Scientific Papers. Organization and Management Series. Contemporary management. Presented papers contain result of researches conducted by various universities from Poland. The number consists of 43 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: changes management, tourism management, knowledge management, information management, logistics, supply chain management, Industry 4.0, production management, Corporate Social responsibility, quality management, human resource management, sustainable development, e-commerce, economics, public management, knowledge management, Smart City, business analytics, lean management, and innovation management.

*Radosław Wolniak*





## DETERMINANTS OF CHANGES IN REVENUES IN POLISH COMPANIES DURING THE PANDEMIC

Adam ADAMCZYK<sup>1</sup>, Sławomir FRANEK<sup>2</sup>, Tomasz WIŚNIEWSKI<sup>3\*</sup>

<sup>1</sup> University of Szczecin, Institute of Economics and Finance; Adam.Adamczyk@usz.edu.pl,  
ORCID: 0000-0002-0491-5502

<sup>2</sup> University of Szczecin, Institute of Economics and Finance; Slawomir.Franek@usz.edu.pl,  
ORCID: 0000-0002-9698-4918

<sup>3</sup> University of Szczecin, Institute of Economics and Finance; Tomasz.Wisniewski@usz.edu.pl,  
ORCID: 0000-0003-3423-5572

\* Correspondence author

**Purpose:** The article aims to identify factors that influence changes in revenues in Polish companies during the COVID-19 pandemic and to improve the efficiency of the allocation of state aid.

**Design/methodology/approach:** The paper uses a logit model to analyze data from a survey of 10950 medium-sized Polish non-financial enterprises, reviews the relevant literature, and focuses on the Polish market. For the purposes of the survey, in addition to the sector breakdown, we proposed measures based on financial data to qualify companies according to their business profile.

**Findings:** The revenues of companies responding to the lockdown are driven by the sector and the company profile. Service companies were more vulnerable to the negative effects of the pandemic, while manufacturing companies and those selling to final retail customers were more resilient.

**Research limitations/implications:** Future research could focus on developing more accurate models to predict the decline in revenues during a pandemic. The study focused on medium-sized enterprises in Poland.

**Practical implications:** The paper suggests that state aid policies should consider not only the sector but also the company profile. It also implies that companies must adapt to market changes and consumer preferences due to the pandemic.

**Originality/value:** This article provides new information on factors that affect changes in revenues in Polish companies during the pandemic. It is valuable for policy makers, researchers, and companies seeking to improve their pandemic response strategies.

**Keywords:** pandemic, state aid, economic policy.

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

## Introduction

The outbreak of the COVID-19 pandemic significantly affected the financial situation of companies. This forced a response from the government, which became involved in providing pandemic state aid. A key problem in the provision of state aid is the selection of companies requiring support. Improperly provided support can be a source of distortions such as deadweight loss and substitution effects (Santarelli, Vivarelli, 2002). Previous research indicates that, in the case of Poland, even 40% of COVID-19 state aid funds went to companies that did not need it. At the same time, more than a third of the companies that experienced a sales drop during the pandemic period did not receive this aid (Franek et al., 2023). In view of this, the key issue is to correctly define the criteria for granting aid. In Poland, the decisive criterion was a decrease in sales. Our intention is to identify other financial criteria that could improve the efficiency of state aid allocation. On the basis of the literature review, we considered that the sales response of companies to the lockdown caused by COVID-19 is explained not only by the sector in which the company operates, but above all by the company profile characterized by: type of business (production or services), type of business relationship with customers (B2B or B2C), position in relation to suppliers (ease of financing the business with liabilities to suppliers), type of product (mass or luxury), stability of sales. We used variables based on financial indicators to quantify these characteristics. We surveyed 10 950 medium-sized enterprises in Poland. We built a logit model in which the explained variable takes the value 1 if sales in 2020 were higher than or equal to sales in 2019 and 0 if there was a decrease in sales, and the independent variables are the financial ratios describing the indicated characteristics. The aim of our study is to identify such characteristics of companies that allow for the identification of companies vulnerable to the negative effects of a pandemic. We formulate the following research hypotheses. H1: asset turnover ratios are positively related to the direction of sales volume changes during a pandemic; H2: companies with higher revenue volatility are more sensitive to the negative effects of a pandemic; H3: companies selling to ultimate retail customers (B2C) performed relatively better during a pandemic; H4: the gross margin ratio is positively related to the direction of sales volume changes during a pandemic.

## Literature review

The outbreak of the COVID-19 crisis required swift action from the EU authorities to implement extraordinary state aid regulations in response to the potential threat of mass unemployment and partial or complete shutdown of various sectors. Bloom et al. (2021) emphasize that the impact of the pandemic varied across different sectors, with some requiring

little or no support, while others faced urgent and substantial challenges. Sectors such as the food industry, food trade, and certain segments of the medical sector involved in COVID-19 protection were relatively unaffected. E-Commerce and IT companies, particularly those providing remote working tools, also experienced benefits from the pandemic.

Certain entities encountered short-term repercussions, with their operations swiftly returning to prepandemic levels once lockdown restrictions were lifted. These entities experienced a significant decline in revenue and liquidity problems. However, there were also businesses, such as hotels, airlines, and cinemas that faced persistent shock throughout the pandemic. Analysis of data from five EU countries (Croatia, Finland, the Netherlands, Slovakia, Slovenia) reveals a notable short-term decline in productivity, as measured by the ratio of value added to employment (Bighelli et al., 2023).

In the Asian context, (Liu et al., 2020; Qiu et al., 2021) focused on the decline in firm value of companies operating in the hospitality, transportation, lodging, and catering industries. Research conducted by del Rio-Chanona et al. (2020) highlights that the negative impact of the pandemic on the economic condition of entities stems from both the demand and the supply sides. On the one hand, the lockdown measures and restrictions imposed to mitigate the spread of COVID-19 resulted in temporary closures, production reduction, and supply chain disruptions, leading to supply shocks that affect firm performance. On the other hand, numerous sectors experienced a sharp reduction or complete disappearance of demand. The service sectors, including airlines, restaurants and tourism, saw a decrease in customer numbers and the risk to workers' income became a driving force for reduced consumption.

In such a situation, the state intervention aimed at supporting companies that have suffered the negative consequences of the pandemic is justified. Government support for private businesses is legitimized when their condition would have been worse without these interventions (Harberger, 1971). Therefore, the selection of entities to which state aid should be granted plays a key role, and a detailed analysis of their economic and financial situation should play an important role in assessing the potential effects of aid and its impact on the competitiveness of firms (Robins et al., 2020).

The effectiveness of state aid is most pronounced when implemented simultaneously and coordinated, with the backing of government subsidies (Durst, Henschel, 2022). As part of efforts to mitigate the adverse effects of COVID-19, many countries provided financial support to companies through various instruments such as targeted subsidies for the sectors most affected by the pandemic, loans, tax relief, deferrals, and even temporary regulations suspending the possibility of company bankruptcies. These measures played a crucial role in saving numerous businesses and preserving jobs in the short term. The assistance was particularly directed at small and medium companies (SMEs) due to their smaller cash reserves compared to larger companies, their limited adoption of digital tools and technologies, and their higher representation in industries heavily impacted by the pandemic.

Employment subsidies or short-term work schemes (including part- and full-time) were the most widespread and substantial measures implemented in EU countries (Bighelli et al., 2023). Lalinsky & Pál, 2022) note that government support in the form of wage subsidies has a positive and statistically significant impact, albeit relatively mild compared to the magnitude of the economic shock. These measures alleviated firms' liquidity needs amidst a sudden decline in sales while enabling them to resume operations more quickly by maintaining employment levels. Such actions are justified as corporate liquidity management policies undergo changes during times of crisis (Campello et al., 2010), and companies with weaker financial capacities tend to face greater challenges as banks and financial institutions are inclined to reduce funding to them (Ivashina, Scharfstein, 2010). Hence, it becomes essential to design liquidity support and employment subsidies specifically targeted at firms negatively affected by the shock (Motta, Peitz, 2020). This implies that companies not affected by the pandemic shock should not benefit from liquidity support schemes or state aid intended to cover labor costs.

A systematic literature review conducted by (Dvouletý et al., 2021) reveals that government support for companies in EU countries has a positive effect on firm survival, employment, sales volume, labor productivity, and overall productivity of production factors. However, the authors highlight variations due to differences in the time horizon of the analyzes (including short-term and long-term effects) and the influence of factors such as firm size, lifespan, geographical region, sector, and the extent of support provided.

Bennedsen et al. (2020) find evidence that government support policies announced in Denmark - like those in several European countries - were effective in reducing unemployment during the pandemic. These authors also showed that firms that experienced the largest revenue declines were the most likely to benefit from support measures. An assessment of the first months of public aid directed to Portuguese firms shows that those entities that benefited from public aid were in a relatively more precarious situation, both in terms of business status (closures) and turnover losses during the period analyzed, and in terms of liquidity conditions. In July 2000, the liquidity situation improved significantly, with the improvement being more pronounced in firms that benefited from aid (Van Hove, 2020; Manteu et al., 2020).

This review indicates that the provision of government support to businesses during the COVID-19 period was necessary. However, it is questionable whether it was properly targeted. This is evidenced by the significant geographical variation in the amount of state aid provided across EU countries. The scale of state aid provided in France in 2020 was several times higher in relation to GDP compared to Italy and Spain. There were similarly large differences between Belgium and Greece, or Austria and Bulgaria. Finally, in the first year of the pandemic, Germany and France represent 66 per cent of total aid among all EU countries (Agnolucci, 2022). The geographic unevenness of the aid entails the risk of unequal support for companies similarly affected by the pandemic but operating in different countries. In view of this, it is crucial to define the aid criteria in such a way that it is not a source of distortion of competition for the EU internal market (Motta, Peitz, 2020). To avoid this risk, aid has been

targeted in most EU countries at all those affected by the pandemic. This approach is assessed as more neutral and less market-distorting (Van Hove, 2020). This approach can be accompanied by two well-known problems: deadweight loss and substitution effects. These factors should be taken into consideration when implementing business support measures. Deadweight loss may occur when taxpayer funds are allocated to firms that would have survived the crisis even without government support (Santarelli, Vivarelli, 2002). This implies that resources are being allocated inefficiently, leading to a loss of economic welfare. In the long run, there is a risk of substitution effects. If public assistance is not selectively provided to firms with a higher chance of survival, it allows less viable firms to continue operating at the expense of more viable ones. This lack of selection hampers the reallocation of production factors, which is crucial for economic efficiency (Barrero et al., 2021). Additionally, the persistence of non-viable firms can result in a loss of organizational capital. Organizational capital refers to the accumulated knowledge, skills, and structures within a firm that are lost when the firm ceases to exist. Therefore, it is essential to examine to what extent state aid related to COVID-19 is reaching the companies that truly need it to avoid deadweight loss. In addition, consideration should be given to whether such an aid contributes to long-term productivity and avoids substitution effects. Providing state aid to entities that are unlikely to survive, especially in declining sectors, raises questions about its effectiveness and efficiency. There are studies that indicate what factors determine the effectiveness of public assistance in times of pandemic.

Groenewegen et al. (2021) indicate that misdirection of state aid was avoided in the Netherlands, as it went to companies with low turnover expectations and high turnover uncertainty. However, in Poland, it was observed that more than one third of the companies that experienced a sales drop in 2020 did not receive COVID-19 state aid (Franek et al., 2023), although at the same time, entities with a low probability of survival, i.e., those whose financial situation was already bad before the pandemic crisis, also did not receive aid (Wiśniewski et al., 2022). Data for the world's most admired companies provide valuable insights into the impact of the economic shutdown on corporations (Mooney, 2021). It reveals that businesses with lower returns were primarily concerned with credit losses, restructuring efforts, and maintaining cash reserves. The sectors most heavily affected by COVID-19 were those relying on face-to-face consumer interactions and those dependent on business-to-business demand for profitability. Additionally, businesses that complemented each other, such as hospitality and airlines, experienced significant impacts. On the other hand, companies that fared well were those that had already implemented online services and focused more on business-to-consumer transactions to generate profits. A study conducted by Fairlie and Fossen (2022) provides evidence on the impact of the COVID-19 pandemic on sales across detailed business types in California. The study found that businesses directly affected by mandatory lockdowns, such as accommodations, experienced the largest sales losses, reaching 91%. These sectors were severely affected by restrictions and reduced consumer mobility.

On the contrary, certain types of business made substantial gains during this period. Online sales, for instance, saw a remarkable growth rate of 180%, as consumers switched their purchasing behavior away from in-store transactions to online platforms. This substitution effect contributed to the surge in online sales.

Bloom et al. (2021) reached similar conclusions, who found a significant negative impact of COVID 19 on small business sales. These authors further noted significant variation in the impact of the pandemic on business performance depending on the type of business (offline and online) and also the socioeconomic characteristics of the owners (gender, race, education).

OECD studies indicate that crises such as the COVID-19 pandemic affect various sectors of the economy differently, with some being more vulnerable and others more resilient (OECD, 2021). These variations can be attributed, in part, to the structural characteristics inherent in each sector. These characteristics encompass the methods of production, procurement, and supply of goods and services, as well as the interconnectedness of firms and industries, including their relationships with other sectors such as the financial industry. Furthermore, the demand structure for their products also plays a significant role. It is crucial to note that the impact of different restrictions and support measures can vary depending on these characteristics, which is important to consider when formulating policy responses. Therefore, when conducting research on the effects of COVID-19 on businesses, it is crucial to incorporate an analysis of economic activity and differences between industries among the companies studied (García-Pérez-de-Lema et al., 2022; Sarkodie, Owusu, 2021). In this vein, crises and unforeseen disasters have asymmetric impacts on companies, which can vary depending on factors such as the sector, size and age of the companies involved. According to Saleh (Saleh, 2020), the impact of COVID-19 varied between different economic sectors. The author conducted a comparison between the food and entertainment sectors, revealing the distinct effects of the pandemic on sales and profits within these industries. Similarly, Sarkodie and Owusu (Sarkodie, Owusu, 2021) provided examples of the differential impact of the global crisis caused by the pandemic across economic sectors. They identified a decline in logistic activities, such as transportation, aviation, and related industries, while primary and health-related sectors experienced a rebound, contributing to the sustenance of the economy. Furthermore, in the context of the European Union, Juergensen et al. (2020) confirmed similar findings to those in other countries around the world, as most of the companies in various economic sectors have been affected by the pandemic to varying degrees. In particular, companies operating in the agro-food and medical equipment industries have seen an increase in revenues. Similarly, Goodell & Huynh (2020), find abnormal returns in several industries. Specifically, the medical and pharmaceutical industries demonstrated positive abnormal returns, indicating a relatively positive impact. On the other hand, the service sector, which includes restaurants, hotels, and motels, experienced negative abnormal returns, suggesting a more adverse effect of the pandemic on these industries.

The varying impact of the pandemic is observed in retail. Essential goods retailers, including groceries, food and healthcare products, witnessed a surge in demand as consumers engaged in stockpiling behavior (Pantano et al., 2020). This presented both opportunities and challenges for these retailers in catering to customers at home (Naeem, 2020). In contrast, retailers of non-essential goods, such as clothing and homeware, experienced a substantial decline in sales and had to explore innovative approaches to reach and engage housebound customers (Roggeveen, Sethuraman, 2020). The textile and apparel industry, in particular, experienced a significant decline in firm performance (Cho, Saki, 2022). This decline can be attributed to two primary factors. First, concerns about COVID-19 led to a decrease in investor confidence, resulting in reduced investments and a negative impact on the financial performance of companies in the industry. Second, global supply chain disruptions caused by the pandemic affected textile and apparel production and distribution, leading to delays and increased costs as concerns about COVID-19 continued to decrease investor confidence.

In practice, the response strategies of companies to the COVID-19 pandemic exhibited significant variation. While some enterprises chose a retreat strategy, such as selling assets or acquiring additional debt, others embraced agile approaches by leveraging digital technologies (Papadopoulos et al., 2020) and transitioning to online sales channels (Papadopoulos et al., 2020; Thukral, 2021). Choi & Sethi (2021) explored two strategies 'Bring service to your home' and 'WhatsApp shopping' as a panacea for restrictions on direct sales during the pandemic. These agile responses are considered a demonstration of organizational resilience that has allowed companies to take advantage of the opportunities that digital transformation presents (Klein, Todesco, 2021).

Forson et al. (2022) conducted a study that investigated the impact of the expansion of online sales on the financial resilience of enterprises in sub-Saharan Africa during an economic downturn. The primary focus of the research was to assess the level of financial resilience by examining the magnitude of sales and cash flow reduction experienced by these enterprises throughout the pandemic period. They indicate that increasing the share of online sales to at least 40% has a diminishing effect on sales declines and cash flow reductions, thus improving financial resilience. In such a situation, the direct result of the pandemic was a change in the activities of businesses to an e-Commerce model (Mishrif, Khan, 2022; Shahzad et al., 2020), although the business-to-consumer (B2C) e-Commerce model has become more developed and widely used than the business-to-business (B2B) model (Hayakawa et al., 2023).

In the case of certain goods, shifting sales to online channels did not prove to be a panacea for the limitations associated with the pandemic. The findings of the study by Pang et al. (2021) indicate that there has been a decrease (increase) in offline (online) clothing consumption in mass markets since the onset of the pandemic. However, sales of luxury fashion brands in offline department stores have shown growth. Furthermore, a detailed analysis revealed a notable decrease (increase) in sales for luxury brands with a focus on clothing (leather goods). These conclusions confirm general observations that the period of isolation caused by

COVID-19 has increased consumer interest in luxury brands (Thapa et al., 2022). Bahl et al. (2022) highlight the percentage increase in sales for Amazon and Sephora US during the pandemic, specifically in the beauty and personal care categories, and contrasting it with their respective sales performance prior to the pandemic.

## Data and methods

We conducted the survey on an original sample of 12,081 medium-sized Polish nonfinancial enterprises. We took into account only capital companies. The source of the data was the BvD Orbis database. Due to data gaps, the final survey sample was 10,950 companies, that is, 75% of all medium-sized companies in Poland.

We built a logit model in which the explained variable takes a value of 1 if sales in 2020 were greater than or equal to sales in 2019 and 0 if there was a decrease in sales. We considered that the sales response of companies to the lockdown caused by COVID-19 is explained not only by the sector in which the company operates, but also, above all, by the company profile taking into account characteristics such as: type of business (production or services), type of business relationship with customers (B2B or B2C), position in relation to suppliers (ease of financing the business with liabilities to suppliers), type of product (mass or luxury), and stability of sales. To quantify these characteristics, we used variables based on financial indicators.

The first of the explanatory variables is the stock turnover in days, whose value reflects the profile of the companies' operations. A turnover value close to or equal to zero may indicate that a company is engaged in service operations. The higher the value of this indicator, the more likely it is that the company has manufacturing operations. We realize that the value of the inventory turnover ratio will not always indicate the business profile, so we have also included other variables in the model, such as asset turnover and the ratio of fixed assets to total assets. Both indicators should be higher for companies with a manufacturing profile. We expect both inventory turnover, asset turnover, and the ratio of fixed assets to total assets to be positively related to the explained variable. This is because manufacturing companies were likely to have lower lockdown losses than service companies, as their business does not require much personal contact with customers, as is the case with service companies.

The second explanatory variable, receivables turnover, largely reflects the business model. Companies with B2C operations generally have a short or zero receivables cycle, while companies selling to other companies generally have higher levels of receivables. As a result, we expect that mainly companies selling to final retail customers have lost less on lockdown due to greater opportunities to shift sales to the Internet. Therefore, we expect the receivables cycle to be negatively related to the explained variable. Another explanatory variable is the



payables turnover in days. In this case, we expect the relationship with the explained variable to be positive, as companies with a longer payables turnover generally have a stronger position towards their suppliers and may therefore be more resilient to the disruption of supply chains. Another variable, the gross margin, characterizes the level of sales margins. We assume that the value of this indicator is higher in industries selling luxury goods and lower for companies supplying basic goods. Assuming, based on the literature review, that consumers did not reduce their consumption of luxury goods during the pandemic but reduced their consumption of many other goods, this indicator should be positively related to the explained variable. In addition, we expected that companies that have higher revenue volatility (and therefore higher business risk) should be more sensitive to a lockdown-induced economic downturn, so we predicted a negative association of this variable with the explained variable. We also included binary variables (dummies) representing 19 sections of the economy in our model. In the model specifications presented, we included only those sectors whose membership had a statistically significant impact on changes in sales revenue during the pandemic period.

## Results

We have prepared four model specifications so that we can assess the stability of the results. For each of these specifications, the values of the model coefficients have similar values. We observe a statistically significant positive effect of inventory turnover and receivables turnover on changes in sales (H1). Similarly, the relationship between revenue variability in the years preceding the pandemic (2015-2019) and changes in revenue as a result of the pandemic (H2) is significant. We also saw that a specific industry affiliation of a company significantly influenced revenue changes as a result of COVID-19. In the case of enterprises in Section E (water supply, sewerage, waste management, and remediation activities), the positive impact of lockdown on the revenues of enterprises in this section is evident. There is a statistically significant negative impact of lockdown on revenue for companies in sections I (accommodation and food service activities) and H (transport and storage).

**Table 1.**  
*Determinants of change in revenues*

VARIABLES	(1) c1 Ldsale	(2) c2 Ldsale	(3) c3 Ldsale	(4) c4 Ldsale
stock_rot	0.00376*** (0.00114)	0.00347*** (0.00117)	0.00371*** (0.00126)	0.00348*** (0.00128)
receiv_rot	0.00398*** (0.00139)	0.00379*** (0.00140)	0.00357** (0.00152)	0.00343** (0.00153)
credit_rot	0.000801 (0.00184)	0.000980 (0.00188)	0.000758 (0.00190)	0.000833 (0.00191)

Cont. table 1.

gross_margin		0.00168 (0.00342)	0.00176 (0.00346)	0.00143 (0.00348)
assets_rot		0.0648 (0.0517)	0.0657 (0.191)	0.00762 (0.194)
fix_ass_ratio			0.00813 (0.214)	0.0722 (0.218)
rev_var			0.562*** (0.200)	0.572*** (0.201)
total_assets	1.44e-08 (1.35e-08)	1.20e-08 (1.34e-08)	1.38e-08 (1.35e-08)	1.38e-08 (1.36e-08)
Section E				1.789*** (0.638)
Section I				-1.219* (0.644)
Section H				-0.617** (0.253)
Constant	-0.535*** (0.104)	-0.611*** (0.128)	-0.763*** (0.139)	-0.710*** (0.141)
Observations	2,398	2,398	2,373	2,373
Adj R^2	0.0164	0.0164	0.0164	0.0164

Standard errors in parentheses, \*\*\*  $p < 0.01$ , \*\*  $p < 0.05$ , \*  $p < 0.1$ . Variables: stock\_rot – stock rotation in days, receiv\_rot – receivables rotation in days, credit\_rot – creditors rotation in days, gross\_margin – gross profit / operating revenues, assets\_rot – operating revenue / (shareholder funds + non current liabilities), fix\_ass\_ratio – fixed assets / total assets, rev\_var – variability of revenues = standard deviation of operating revenues / mean of operating revenues, total\_assets – natural logarithm of total assets, Section E – dummy variable indicating section “water supply, sewerage, waste management, and remediation activities”, Section I – dummy variable indicating section “accommodation and food service activities”, Section H – dummy variable indicating section “transport and storage”.

Source: Own elaboration.

The results of our model confirm that service companies were exposed to a higher risk of revenue loss. For all models' specifications, companies with a higher stock rotation ratio have a higher probability of revenue growth. This relation is statistically significant. We interpret that high stock rotation ratios are typical for service companies. However, the negative impact was particularly strong and statistically significant in accommodation and food service activities and transportation. We divided the companies into sectors based on NACE codes. In the results, we present only those model specifications in which the companies' sector affiliation had a significant impact on the likelihood of revenue growth. Furthermore, it was not possible to confirm that companies operating in the B2C model experienced an increase in sales; therefore, our hypothesis H3 cannot be confirmed. In the study, we assumed that a short receivables turnover period denotes the company's operations in the B2C model. The results of the verification of the H4 hypothesis indicate that there is a positive relationship between the profit margin ratio and the growth of revenue. Anyhow, this relationship is not statistically significant.

## Discussion

The COVID-19 epidemic significantly impacted the capacity of enterprises to sustain financial stability. Based on existing scholarly research, it is evident that a company's reaction to the lockdown measures imposed due to the COVID-19 pandemic is predominantly shaped by many dimensions of the company's profile, rather than solely being determined by the industry in which it operates. Several factors influence a company's operations, such as the type of industry it operates in (manufacturing or services), the nature of its customer relationships (business-to-business or business-to-consumer), its position in relation to suppliers (including its ability to finance operations through supplier liabilities), the type of products it offers (mass-market or luxury), and the stability of its sales. Consequently, our research endeavors to consider these issues in the context of Polish medium-sized enterprises.

The findings of our study indicate that service-oriented organizations had a higher likelihood to experience a decline in revenue compared to manufacturing-oriented companies. This implies that the service sectors experienced a greater impact due to the implementation of lockdown measures and the subsequent decrease in customer mobility. Hence, the outcomes of our model are consistent with the extant body of research, so supporting the notion that service-oriented enterprises exhibited greater vulnerability to revenue decline amidst the COVID-19 pandemic (Goodell, Huynh, 2020; Fairlie, Fossen, 2022). The observed pattern was not exclusive to Poland, as it was also seen in other countries.

The impact of the pandemic varied across sectors, with accommodation and food service activities and transportation being particularly affected (Saleh, 2020; Sarkodie, Owusu, 2021; Liu et al., 2020; Qiu et al., 2021). These sectors faced both supply and demand shocks due to restrictions and reduced travel activities of customers. The findings of our study indicate a comparable response among aforementioned sectors within the context of Poland.

Contrary to the literature that highlights the advantage of the B2C model during the pandemic (Hayakawa et al., 2023), this article did not find strong evidence that Polish companies operating in the B2C model experienced an increase in sales. This may suggest that Polish companies have benefited less from the shift to online sales compared to their counterparts in more developed markets.

The article also did not find support for the hypothesis that the lockdown period contributed to the increase in sales of luxury goods, as indicated by studies from other markets (Bahl et al., 2022; Thapa et al., 2022). Although there was a positive relationship between the profit margin ratio and revenue growth, it was not statistically significant. This observation suggests that Polish consumers refrained from participating in compensating consumption or engaging in trading up behavior within the pandemic.

## Conclusions

The analysis carried out made it possible to identify the factors that determined the drop in sales during the pandemic period, which were, on the one hand, the result of sector specificity and, on the other, reflected the company's profile based on the type of business relationship with customers, position towards suppliers, type of products offered, and sales stability. In doing so, we should pay attention to the low fit of our model. This means that the sole identification of risk factors, while useful in determining the impact of a pandemic shock on companies' sales, is not sufficient to accurately forecast a decline in sales. Our study attempts to verify 4 hypotheses: H1: asset turnover ratios are positively related to the direction of sales volume during a pandemic; H2: companies with higher revenue volatility are more sensitive to the negative effects of a pandemic; H3: companies selling to ultimate retail customers (B2C) performed relatively better during a pandemic; H4: the gross margin ratio is positively related to the direction of sales volume changes during a pandemic.

Although we were able to unambiguously verify hypotheses H1 and H2, we were unable to confirm that Polish companies operating in the B2C model experienced an increase in sales during the pandemic period (H3), despite the literature pointing out the advantage of the B2C model. Such results indicate that, unlike in developed markets, Polish companies benefited less from the shift of sales to the online environment. Similarly, our research does not provide clear evidence that the COVID-19 pandemic period contributed to an increase in luxury goods sales (H4), as studies in other markets have indicated.

We are aware of some limitations in our study. Research relies on financial indicators to quantify characteristics of the company profile, such as type of business, type of business relationship with customers, position in relation to suppliers, type of product, and stability of sales. These indicators may not fully reflect the complexity and diversity of these characteristics. Future research could use more qualitative or multidimensional measures to capture the nuances and variations of the company profile. The research is based on a survey of medium-sized Polish nonfinancial enterprises, which may not be representative of other types of enterprise or other countries. Future study has the potential to broaden the sample by incorporating both small and large organizations, as well as companies from other industries and geographies, such as Central and Eastern Europe. It is hypothesized that the implementation of the lockdown measures may have exerted a disproportionately significant influence on smaller enterprises, owing to their inherent susceptibility to fluctuations in demand and limited financial reserves or creditworthiness. The study lacks control over other external variables that could potentially influence fluctuations in sales within the pandemic, including but not limited to governmental regulations, consumer behavior, market competition, and innovations in technology. Potential areas for future research may involve the incorporation of additional explanatory variables or the adoption of other methodological approaches to effectively address and accommodate these aspects.

This study adds to the existing body of research on the effects of COVID-19 on company performance by presenting findings from the Polish market, which has received limited attention in previous studies. The paper provides recommendations for policymakers and managers regarding the design and implementation of support measures and strategies for businesses during and after the pandemic. This study benefitted from a substantial sample size of 10,950 medium-sized enterprises in Poland, enabling broader conclusions to be drawn regarding the behavior of this particular type of enterprise and its reaction to lockdown measures.

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## PREFERENCE MEASUREMENT AND SEGMENTATION OF TOURIST TRIPS CONSUMERS USING CONJOINT ANALYSIS METHOD AND CONJOINT R PACKAGE

Andrzej BAŁK<sup>1</sup>, Tomasz BARTŁOMOWICZ<sup>2\*</sup>

<sup>1</sup> Wrocław University of Economics and Business, Faculty of Economics and Finance, Department of Econometrics and Computer Science; andrzej.bak@ue.wroc.pl, ORCID: 0000-0002-5980-9694

<sup>2</sup> Wrocław University of Economics and Business, Faculty of Economics and Finance, Department of Econometrics and Computer Science; tomasz.bartlomowicz@ue.wroc.pl, ORCID: 0000-0001-9986-0841

\*Correspondence author

**Purpose:** The paper presents the application of conjoint method and functionality of conjoint R package in measurement and analysis of preferences of tourists choosing tourist trips. The main aim of the study was to identify the key factors motivating people to make decisions regarding tourist offers. Additional aims of the research were segmentation of tourists with similar choice preferences, as well as market share simulation of trip offers not previously included in the study.

**Design/methodology/approach:** Traditional conjoint analysis method was used for the measurement and analysis of stated consumers' preferences. All calculations were carried out using R program and conjoint R package.

**Findings:** The obtained results made it possible to calculate the importance of the factors included in the study, as well as to determine the most and least preferred profile of a tourist trip at the individual level as well as for all respondents. Also, estimation of market share of the so-called simulation profiles not ranked by the respondents before and segmentation of tourists with similar choice preferences has been made.

**Practical implications:** Presented in the paper authoring conjoint R package is universal tool enabling the measurement and analysis of consumers' preferences of products and services, as well as political opinions and other attitudes.

**Social implications:** The conjoint R package implements the traditional conjoint analysis method similarly to the module Conjoint IBM SPSS program. The statistics (about half a million of downloads by RStudio users) indicate that the non-commercial conjoint package is popular among users.

**Originality/value:** The results of the research, as well as conjoint R package can interest of students and researchers in the field of microeconomics and marketing research in the practical application of the traditional conjoint method in analysis of stated preferences.

**Keywords:** behavioral economics, stated consumers preferences, conjoint analysis, R program.

**JEL Classification:** C6, C8, D1.

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

## 1. Introduction

Research on the rationality of market choices, considering psychological factors, has led to the emergence of new branches of research in the areas of economics and psychology. Based on economics, it is behavioral economics, and based on psychology, it is economic psychology. The co-founders of behavioral economics include D. Kahneman (Nobel Prize in 2002), A. Tversky, R. Thaler (Nobel Prize in 2017). In the research trend of behavioral economics D. Kahneman and A. Tversky formulated the prospect theory, within which utility (experienced utility or post-choice satisfaction, referring to heuristics) is analyzed, considering psychological factors (Kahneman, Tversky, 1979, 2000). R. Thaler indicated the importance of impulses and incentives addressed to consumers to induce them to make rational decisions and economic choices (Thaler, Sunstein, 2008). Direct measurement of utility is an arduous task, and the utility measurement problem has not yet been unequivocally resolved in economic theory. This results, among others, from because the utility of the good is subjective, not objective. The utility of the same goods varies across consumers. To measure utility for the purposes of empirical research in a subjective (individual) dimension, methods and models based on the concept of preferences (preference relations) are used to quantify utility across the surveyed group of consumers.

In microeconomics, a distinction is made between revealed and stated preferences. Conjoint analysis and choice-based methods are used in stated preferences research (declared at the time of conducting research).

The measurement and analysis of consumers' stated preferences uses e.g., the so-called decompositional approach (Green, Srinivasan, 1990; Zwerina, 1997; Bąk, 2004; Gustafsson, Herrmann, Huber, 2007; Aizaki, Nakatani, Sato, 2015). The basic assumption in the decompositional approach is to present the set of objects (products or services, real or hypothetical) to the respondents (e.g., in the form of a questionnaire), described using predictor variables (attributes), each of which takes certain values (levels). The main purpose of the research is to measure consumer preferences in relation to the ranked objects (profiles), which requires trade-offs. The measurement result takes the form of the set of response (outcome) variable values (empirical stated preferences measured on ordinal or interval scale). The decompositional approach uses two main groups of methods correlated with the methods and models which are different in many dimensions, however, remain similar in terms of research objectives and the obtained results' application. Conjoint analysis methods and its applications are presented e.g., in the following studies (Green, Rao, 1971; Green, Wind, 1975; Green, Srinivasan, 1978; Louviere, 1988, 1994; Green, Srinivasan, 1990; Walesiak, Bąk, 2000; Poortinga, Steg, Vlek, Wiersma, 2003; Wind, Green, 2004; Bąk, 2004, 2009; Gustafsson et al., 2007; Bąk, 2013; Rao, 2014; Bartłomowicz, Bąk, 2021; Lu, Zhang, 2020; Kim, Lee, 2023; Shim, Lee, Oh, 2022). Discrete choice methods are discussed in e.g. (Ben-Akiva, Lerman,

1985; Zwerina, 1997; Louviere, Hensher, Swait, 2000; Hensher, Rose, Greene, 2005; Garrow, 2010; Aizaki et al., 2015). The similarities and differences of conjoint analysis and discrete choice methods are demonstrated in the following studies: (Lawson, Glowa, 2000; Louviere, 2000; Louviere, Flynn, Carson, 2010; Rao, 2014). Among these methods can be distinguished traditional conjoint analysis methods (TCA) and choice-based conjoint analysis methods (CBC). Other approaches (e.g., compositional and hybrid) additionally use Adaptive Conjoint Analysis (ACA), Adaptive Choice-Based Conjoint (ACBC), Menu-Based Choice (MBC), hybrid conjoint models, as well as many other proprietary solutions.

The computer software used at the stage of factorial design, the estimation of multiple regression model with dummy variables (in the cross-section of respondents and at the entire sample level), simulation of market shares, segmentation of the respondents and visualization of the research results is required in the professional applications of conjoint methods.

The implementation of the traditional conjoint analysis method can be found primarily among commercial products in the form of either modules of popular statistical software (e.g., IBM SPSS Statistics – IBM SPSS Conjoint module, Sawtooth Software – Conjoint/Choice Software, SAS Software, XLSTAT MARKETING – XLSTAT-Conjoint module) or websites, specifically dedicated to the conjoint method in order to conduct online research.

In the case of non-commercial The R Project for Statistical Computing (R Development Core Team, 2023), the vast majority of available modules support methods other than the traditional conjoint analysis method – predominantly CBC, ACA/ACBC, MBC and other. Among the most popular packages for the analysis methods of consumer stated preference the following are listed, e.g.: *mlogit* (Croissant, 2022), *bayesm* (Rossi, 2022), *DCchoice* (Aizaki, Nakatani, Sato, 2022), *support.CEs* (Aizaki, 2022), *survival* (Therneau, 2023), *poLCA* (Linzer, Lewis, 2022). In the case of the traditional conjoint method, the following R packages are available for analyzing stated consumer preferences: *conjoint* (Bąk, Bartłomowicz, 2018a) and *radiant.multivariate* (Nijs, 2023).

The conjoint R package covers the implementation of the traditional conjoint analysis method based on the full profile method used at the stage of collecting data on the respondents' stated preference and represents a non-commercial alternative to the commercial IBM SPSS Conjoint module (SPSS, 1994; IBM, SPSS, 2023), as well as other commercial software which supports the conjoint analysis (SAS, 2023; Sawtooth Software, Inc., 2023; TIBCO, 2023). The package functions support all the research procedure stages carried out using the conjoint analysis method.

The purpose of the article is to discuss the basic assumptions of the traditional conjoint analysis method and to present the non-commercial conjoint R package (Bąk, Bartłomowicz, 2012, 2018a) for R project (R Development Core Team, 2023) supporting empirical research of stated preferences of consumers using this method.

The article also presents the results of an empirical study of the preferences of tourists coming for a holiday to a town located in the mountains (Karpacz<sup>1</sup>). The aim of the study is to identify important factors motivating to make a decision, such as the purpose of arrival, form of organization of the trip, winter or summer season and place of accommodation.

## 2. Conjoint analysis method

The traditional conjoint analysis method has over forty years of history and a well-established position among other methods measuring and analyzing stated preference of consumers representing a decompositional approach. The first publications discussing conjoint analysis were based on the theoretical research presenting conjoint measurement in psychometry. In the 1960s and 1970s the ground-breaking articles on conjoint measurement and conjoint analysis were published, e.g. (Luce, Tukey, 1964; Green, Rao, 1971; Green, Wind, 1973; Green, Srinivasan, 1978). To date, many publications have been published on the issue of conjoint analysis, presenting various methods and models of data analysis based on stated preferences, and many computer programs and websites supporting empirical research have been developed.

Conjoint analysis method is based on the axiomatic theory of measurement, originally developed at the background of psychometric studies by R.D. Luce and J. Tukey (Luce, Tukey, 1964)<sup>2</sup>. This theory, known in the subject literature as conjoint measurement, determines the conditions of variable measurement scales (response and predictor), in which predictor variables jointly generate the response variable values, in accordance with the specified rule of the measurement model composition (an additive rule in the traditional conjoint measurement model). This model examines the overall impact of many predictor variables on the values adopted by the response variable. It also takes into account the ordering of the response variable value at various combinations of predictor variable values. A simultaneous and additive effect of predictor variables is assumed on the response variable. Due to the response variable value measurement, considering the simultaneous impact of all predictor variables (their main effects), this measurement model is referred to as additive conjoint measurement (Coombs, Dawes, Tversky, 1970; Green, Srinivasan, 1978; Wilkinson, 1998). Therefore, conjoint measurement represents the measurement theory assuming the existence of a response variable measurement scale and measurement scales of such predictor variables allowing the quantification of joint predictor variables' impact on the response variable, according to the specific rules of model composition (cf. (Green, Srinivasan, 1978)).

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<sup>1</sup> Karpacz town is situated in the Karkonosze Mountains. It is a spa town and ski resort in Jelenia Góra County, Lower Silesian Voivodeship, south-western Poland.

<sup>2</sup> The idea of nonmetric conjoint measurement was also introduced in the field of economics by G. Debreu in the work (Debreu, 1960) (Nobel Prize in 1983).

The theoretical background of conjoint measurement was developed by a psychologist and mathematician R.D. Luce and a statistician J. Tukey (Luce, Tukey, 1964; Wind, Green, 2004). An important contribution to the development of conjoint measurement was also made by the studies of J.B. Kruskal discussing the monotonic transformation of nonmetric data (Kruskal, 1964a, 1964b, 1965) and a computer program (MONANOVA), which allowed conducting experiments related to nonmetric models of additive conjoint measurement, which also significantly contributed to the development of other conjoint measurement models (Green, Wind, 1973; Wind, Green, 2004).

The first applications of conjoint analysis in the studies of stated preferences of consumers were presented in the publication by (Green, Rao, 1971) (cf. also (Green, Srinivasan, 1978; Fenwick, 1978; Hooley, Lynch, 1981)). Since then, many studies discussing methodological problems of conjoint analysis were published, including these methods' applications in marketing research. The synthetic review of the existing conjoint analysis achievements and the development perspectives of these research methods are presented in the publication dedicated to P.E. Green (Wind, Green, 2004).

Currently conjoint analysis is a commonly used method to study consumer stated preferences of products and services, as well as political opinions and denominational (religious) attitudes. The basic information on conjoint analysis and software tools used in empirical research are also available on the Internet (e.g., Bąk, Bartłomowicz, 2023a, 2023b).

In accordance with the terminology used in the subject literature referring to the conjoint analysis method, predictor variables describing goods or services are called attributes<sup>3</sup> or factors, whereas their realizations are referred to as levels. Attributes and their levels generate different variants of goods or services, called profiles (stimuli, treatments, runs). The number of all possible profiles to be generated depends on the number of attributes and the number of levels (it is the product of level numbers of all attributes).

The respondents rank product or service profiles, stating their preferences in this way. Profile ranking are referred to as total utilities and constitute the basis for further analysis. Such analysis consists in the profile decomposition of total utilities into part-worths utilities of attribute levels and in estimating the attributes' shares in the total utility development of each profile (cf. Green, Wind, 1975).

Among the most important features of traditional conjoint analysis the following are listed in the subject literature (e.g., Vriens, Wittink, 1994; Bąk, 2013):

- the number of attributes included in the study is usually limited to 6,
- the profiles presented to respondents for ranking are described using all attributes,
- the profiles are generated based on orthogonal factorial designs,

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<sup>3</sup> The term attribute is used in statistics in relation to nonmetric variables, predominantly the nominal ones (cf. (Kendall, Buckland, 1986)).

- the profiles generated based on orthogonal designs are mutually maximally differentiated,
- the conjoint analysis model considers, apart from the main effects, also the effects of
- attributes' interactions,
- all respondents rank the same set of profiles,
- the conjoint analysis model represents the so-called decompositional approach, i.e., based on empirical total utilities profiles part-worths utilities of attribute levels are estimated.

The studies of consumer stated preferences using traditional conjoint analysis are carried out in line with the procedure presented in Table 1.

**Table 1.**  
*Conjoint analysis research procedure*

Procedure stage	Procedure step
Research task specification	– response variable (empirical preferences) – predictor variables (attributes)
Model form identification	– model of predictor variables dependency (main effects or with interactions) – preference model (linear, square, part-worths utilities)
Data collection	– data collection methods (full profiles, paired comparisons, two attributes at a time approach, simulation data) – profile generation methods (factorial designs, random sample)
Profile presentation	– presentation form (verbal description, drawing, model, physical product) – research form (direct interview, traditional mail, phone, computer, Internet)
Preference measurement scale	– nonmetric scale – ranking – metric scale – rating
Model estimation	– nonmetric models (MONANOVA) – metric models (OLS)
Results analysis and interpretation	– preference analysis (the assessment of attributes' importance) – market share simulation – segmentation

Source: authors' compilation based on (Green, Srinivasan, 1978; Gustafsson et al., 2007; Bąk, 2004, 2013).

### 3. Data collection

The marketing data about the respondents' stated preferences, obtained predominantly as a result of surveys, constitute the research material used in the conjoint analysis methods. Collecting data is one of the main stages in the entire research procedure. The selection of data collection method determines the computational complexity of the parameter estimation task in the conjoint analysis model, and thus influences the nature of techniques possible to apply in estimating the value of part-worths utilities. Moreover, the method of data collection has a decisive impact on the credibility level of the rankings made by the respondents (cf. Vriens, Wittink, 1994; Bąk, 2004).

In the subject literature on conjoint analysis the following data collection methods are most often listed:

- full-profile method (the method refers to a traditional conjoint analysis),
- method of paired comparisons,
- two-attributes-at-a-time-approach (the method using the compromise matrix, the method of presenting two attributes simultaneously),
- full-profiles choice experiments (the method refers to a choice-based approach).

In a traditional conjoint analysis, the full-profile method or full-concept method are used to cover the set of all possible variants, being the combination of attributes and their levels.

In the full profile method the respondent ranks the presented variants, according to his/her own preferences stated based on the presented attributes and their levels, in terms of determining the rank order of profiles (on the ordinal scale – ranking) or determining the relative attractiveness of profiles (e.g., on the positional scale – rating).

The positive features of this method mainly include presenting the respondents with the profiles of products or services to be ranked, characterized by all the selected attributes at the same time. It is actually the situation encountered by the consumer in real life while making the specific choices among products (services) available on the market. If all the attributes are presented simultaneously, one can also take into account all the interactions occurring between them, which can generate certain synergistic effects, invisible in a different situation. The advantages of this method also include the possibility of choosing the scale of response variable value, because the preference measurement can be carried out on an ordinal, interval, or quotient scale (cf. Vriens, Wittink, 1994).

The most serious shortcoming of the method is the limited number of attributes and levels, which can be included in the designed experiment. The number of profiles ( $P$ ) presented to the respondent equals the product of levels of individual attributes, i.e.:  $P = \prod_{j=1}^m L_j$  (where:  $L_j$  – number of levels of  $j$ -th attribute;  $m$  – number of attributes describing profiles evaluated by consumers). This number can take on large values, i.e., exceeding the possibility of making a precise and reliable assessment. Therefore, in addition to the criteria for substantive selection of the attributes and levels, the statistical experiment planning systems are used in this method, which allow the reduction of the potential number of profiles.

In practice, the full factorial design can only be considered with a very small number of attributes and levels. The number of all profiles in the full factorial design results from the product of the number of attributes' levels and generally takes large values. For example, in case of  $4^1 3^2 2^3$  design<sup>4</sup> the relevant number amounts 288 profiles. It is not possible for the respondents to rank reliably enough such a large number of profiles; therefore, it is necessary to reduce the complete set of profiles to a reasonable size using a fractional factorial design. Then, the so-called incomplete (partial, reduced, fractional factorial design) factorial

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<sup>4</sup> The notation  $4^1 3^2 2^3$  means 1 attribute with 4 levels, 2 attributes with 3 levels and 3 attributes with 2 levels.

experiment is designed, which considers only a representative subset of profiles. Using the fractional factorial design scheme, the size of the full design consisting of 288 profiles can be reduced, e.g., to 16 profiles.

The problems of designing factorial experiments have been discussed in e.g., the following studies: (Louviere, 1988; Vriens, Wittink, 1994; Kuhfeld, Tobias, Garratt, 1994; Rasch, Herrendörfer, 1991; Huber, Zwerina, 1996; Zwerina, 1997; Ott, 1984; Zwerina, Huber, Kuhfeld, 2000).

The review of current achievements in planning factorial experiments for conjoint analysis models and discrete choice models is presented in the study (Großmann, Holling, Schwabe, 2002).

In conjoint R package both full and fractional design (orthogonal and effective) can be generated using AlgDesign R package functions (Wheeler, 2022).

#### 4. Conjoint model estimation

The purpose of estimating the parameters of conjoint analysis model is to assess the values of attribute levels interpreted here as the so-called part-worth utilities of attribute levels. Part-worths utilities are estimated for each respondent individually and as average values for the studied sample. Determining part-worths utilities allows, in turn, to carry out the analysis regarding (cf. Table 1):

- theoretical total utilities of profiles in the cross-section of respondents,
- theoretical total utilities of profiles in the analyzed sample,
- theoretical total utilities of profiles in the separated groups (segments) of respondents,
- the assessment of relative „importance” of individual attributes in the cross-section of respondents in the analyzed sample,
- the segmentation of respondents (Wedel, Kamakura, 2000).

In the traditional conjoint analysis, the linear multiple regression model is developed, the parameters of which (part-worths of levels attributes) are estimated using the classical Ordinary Least Squares (OLS) method.

In the multiple regression analysis, the response variable takes values (e.g., points or ranks) assigned by a given respondent to individual profiles submitted for assessment. The influence of each level of individual predictor variables (nonmetric attributes) on the rating assigned to profiles by a given respondent is taken into account by introducing dummy predictor variables to the regression model.

The linear additive multiple regression model of conjoint analysis model is presented, in general (taking into account the actual attributes of products or services), by the following formula:



$$Y = \beta_0 + \sum_{k=1}^p \beta_k Z_k + \varepsilon \quad (1)$$

where:

$Y$  – response variable, taking the values representing the respondents empirical preferences,

$\beta_0$  – model intercept;

$\beta_1, \dots, \beta_p$  – model parameters;

$Z_1, \dots, Z_p$  – predictor variables (the attributes describing profiles of products or services);

$k = 1, \dots, p$  – predictor variable (attribute) number;

$\varepsilon$  – model random component.

Next the nonmetric attributes  $Z_1, \dots, Z_p$  are encoded using dummy variables, which indicate the occurrence of particular attribute levels in individual profiles. For this purpose, indicator (dummy) coding, effects coding, deviations from means coding or orthogonal coding are used (cf. (Zwerina, 1997; Walesiak, Bąk, 2000; Bąk, 2004)). The coding results in substituting  $p$  attributes ( $Z_1, \dots, Z_p$ ) with dummy variables ( $X_1, \dots, X_m$ )<sup>5</sup>, the number of which is  $m = \sum_{k=1}^p L_k - p$ , where:  $L_k$  – number of levels of  $k$ -th attribute. Thus, it results that in order to encode all levels of a given attribute, the number of dummy variables by 1 less than the number of this attribute levels is sufficient, as shown in Tab. 2. Variable  $X_3$  in both encoding methods is redundant (gray cells in Table 2), because every level of  $Z$  attribute is clearly indicated using  $X_1$  and  $X_2$  dummy variables.

**Table 2.**

*Coding attributes using dummy variables*

Attribute	Dummy variables					
	indicator coding			effects coding		
$Z_1$	$X_1$	$X_2$	$X_3$	$X_1$	$X_2$	$X_3$
level 1	1	0	0	1	0	0
level 2	0	1	0	0	1	0
level 3	0	0	0	-1	-1	-1

Source: authors' compilation.

Including the redundant variables in the model increases the phenomenon of collinearity, which affects the quality of the estimated regression model. Therefore 2 dummy variables are used in the conjoint analysis model in the case of 3-level attribute, whereas the third level serves as the so-called reference level. After transcoding the attributes, the conjoint analysis model with dummy variables can be presented in the following form:

$$\hat{Y} = b_0 + \sum_{j=1}^m b_j X_j \quad (2)$$

<sup>5</sup> The values of dummy variables depend on the coding method, e.g. in the case of indicator (dummy) coding the respective values are 0 and 1, and in the case of effect coding, deviations from means coding they are 0, 1 and -1.

where:

$\hat{Y}$  – theoretical values of the response variable,

$b_0$  – model intercept;

$b_1, \dots, b_m$  – model parameters;

$X_1, \dots, X_m$  – dummy variables representing nonmetric attribute levels;

$j = 1, \dots, m$  – dummy variable number.

Model (2) is estimated at an aggregated level *jest* (in the cross-section of all respondents constituting the analyzed sample). Conjoint analysis models are also estimated at an individual level (for each respondent individually).

The linear regression model for the selected respondent can be presented in the following form:

$$\hat{Y}_s = b_{0s} + b_{1s}X_{1s} + \dots + b_{ms}X_{ms} = b_{0s} + \sum_{j=1}^m b_{js}X_j \quad (3)$$

where:

$s = 1, \dots, S$  – respondent's number;

$S$  – number of respondents.

As a result of model estimation (2) the values of  $b_1, \dots, b_m$  parameters are obtained and interpreted as part-worths utilities of attribute levels. Part-worths utilities of reference levels (related to dummy variables skipped in the coding process) are calculated depending on the adopted coding method. Table 3 presents the method for calculating part-worths utilities for the 3-level attribute in the case of indicator (dummy) coding and effects coding, deviations from means coding taking into account the reference level (level 3,  $b_3X_3, U_3$ ) in gray cells.

**Table 3.**

*The method for calculating part-worths utilities for the 3-level attribute*

Attribute	Dummy variables					
	indicator coding			effects coding		
$Z_1$	$b_1X_1$	$b_2X_2$	$b_3X_3$	$b_1X_1$	$b_2X_2$	$b_3X_3$
level 1	$b_1$	0	$U_1 = b_1$	$b_1$	0	$U_1 = b_1$
level 2	0	$b_2$	$U_2 = b_2$	0	$b_2$	$U_2 = b_2$
level 3	0	0	$U_3 = 0$	$-b_1$	$-b_2$	$U_3 = -(b_1 + b_2)$

$U_1, U_2, U_3$  – part-worths utilities of levels of attribute  $Z_1$ ;  $X_1, X_2, X_3$  – dummy variables;  $b_1, b_2, b_3$  – part-worths utilities.

Source: authors' compilation.

Part-worths utilities are calculated at an aggregated level (one model is estimated for the whole sample) and at an individual one (the number of estimated models equals the number of respondents). The knowledge of part-worths utilities allows estimating theoretical total utilities of the profiles being the subject of research. The total utility of  $i$ -th profile for  $s$ -th respondent ( $U_i^s$ ) is calculated based on the following formula (Walesiak, 1996):

$$U_i^s = \sum_{j=1}^m b_{0s} + U_{l_j^i}^s, \quad (4)$$

where:

$b_{0s}$  – the intercept for s-th respondent;

$U_{l_j^i}^s$  – part-worths utility of l-th level of j-th attribute of i-th profile for s-th respondent;

$l_j^i$  – level number of j-th attribute in i-th profile.

The average theoretical total utility (at an aggregated level, i.e., for the whole sample covering  $S$  respondents) of i-th profile ( $U_i$ ) is calculated based on the following formula (cf. (Walesiak, 1996)):

$$U_i = \frac{1}{S} \sum_{s=1}^S \left( \sum_{j=1}^m b_{0s} + U_{l_j^i}^s \right). \quad (5)$$

The knowledge of part-worths utilities also allows estimating the so-called attribute „importance” for every attribute in the assessment of profiles, which are the subject of research. The relative importance of j-th attribute for s-th respondent ( $W_j^s$ ) is calculated using the formula (6) (cf. (Hair, Anderson, Tatham, Black, 1995)):

$$W_j^s = \frac{\max\{U_{l_j^i}^s\} - \min\{U_{l_j^i}^s\}}{\sum_{j=1}^m \left( \max\{U_{l_j^i}^s\} - \min\{U_{l_j^i}^s\} \right)} \times 100\%. \quad (6)$$

The average „importance” of particular attributes in the cross-section of the whole sample covering  $S$  respondents ( $W_j$ ) is calculated based on the formula:

$$W_j = \frac{1}{S} \sum_{s=1}^S W_j^s, \quad (7)$$

where:  $W_j^s$  – defined by a formula (6).

The results in the form of estimated partial utilities obtained in the conjoint analysis procedure can be used in simulation models of market events, the so-called choice simulators, which enable the analysis of what-if scenarios. The simulation analysis of market shares allows estimating the total utility of additional profiles, which were not ranked by the respondents in the questionnaire. The anticipated market share of the selected profiles is estimated based on the following models (cf. (Hair et al., 1995; Walesiak, 1996)):

- maximum utility model, used in calculating the percentage of respondents for which a particular product received the highest total utility score, among the products covered by the simulation:

$$P_i^s = \begin{cases} 1, & \text{if } \hat{U}_i^s = \max(\hat{U}_i^s), \\ 0, & \text{otherwise} \end{cases}, \quad (8)$$

where:  $P_i^s$  – the probability of i-th profile selection by s-th respondent,

- probabilistic BTL (Bradley-Terry-Luce Model), following which the total utility, corresponding to a given profile, is divided by the sum of total utilities of profiles covered by the simulation (the calculations are carried out separately for each respondent and next their average value is computed):

$$P_i^s = \frac{\hat{U}_i^s}{\sum_{i=1}^n \hat{U}_i^s}, \quad (9)$$

where:  $n$  – number of profiles;

- logit model, in which the calculations, as opposed to the probabilistic BTL model, use natural logarithms of total utilities' values rather than the utilities themselves:

$$P_i^s = \frac{e^{\hat{U}_i^s}}{\sum_{i=1}^n e^{\hat{U}_i^s}} = \frac{\exp(\hat{U}_i^s)}{\exp(\sum_{i=1}^n \hat{U}_i^s)}. \quad (10)$$

The parameter values of the estimated conjoint analysis model (estimated part-worths and total utilities) can constitute the basis for consumers' segmentation, as they reflect the respondents' preferences presented in the study regarding the specific profiles of products and services (real or hypothetical).

In the practice of segmentation studies, using conjoint analysis methods, the post hoc approach is most frequently used, which applies data classification methods (cluster analysis) in the division of respondent's set into classes (segments), based on individual part-worths utilities, representing the heterogeneity of preferences. Due to certain specific features (unequivocal qualification of objects into groups, effective processing of large data sets) the  $k$ -means method is frequently used, which belongs to the group of iterative optimization methods.

## 5. Overview of the functions in the conjoint package

The conjoint R package (Bąk, Bartłomowicz, 2018a) is an implementation of the traditional conjoint analysis method. The source code of the package was written in R language and represents an extension of the computational tools offer in microeconometrics and consumers' preference studies available under the terms of GNU license („free and open software”)<sup>6</sup>, thus free of charge and providing access to the source code. The correct functioning of the package requires installing the base GNU R program (R Development Core Team, 2023) and a dozen additional packages which, starting from 3.3.2 version of R base program, are downloaded, and installed along with the conjoint package. The package can be downloaded and installed from the CRAN R project repository website (<https://cran.r-project.org/package=conjoint>) or from the GitHub website <https://github.com/packagesR/conjoint>. The conjoint package has been available on the CRAN R repository website (R Development Core Team, 2023) since October 2011.

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<sup>6</sup> The GNU General Public License is intended to guarantee your freedom to share and change all versions of a program – to make sure it remains free software for all its users, <https://www.gnu.org>.

The current version of conjoint (1.41) package offers 16 functions which allow for: model parameters estimation of conjoint analysis model and the segmentation of respondents (functions: `caModel`, `caSegmentation`), estimation of part-worths utilities and theoretical total utilities in the cross-section of respondents (functions: `caPartUtilities`, `caTotalUtilities`), measurement of attributes' importance and part-worths utilities of attributes' levels at an aggregated level (functions: `caImportance`, `caUtilities`), and also - within the framework of simulation analysis – market share estimations of simulation profiles (functions: `caBTL`, `caLogit` and `caMaxUtility`). The special purpose functions include the function converting the empirical preference data set (function `caRankToScore`) and the functions which allow obtaining the aggregate results of conjoint analysis and simulations (functions: `Conjoint`, `ShowAllUtilities` and `ShowAllSimulations`).

In addition, the package offers tools supporting the design of a questionnaire survey. The package includes functions creating the appropriate factorial designs, allowing the reduction of the complete set of profiles in the form of fractional designs (orthogonal and effective). For this purpose, the conjoint package uses `AlgDesign` package (Wheeler, 2022) provided in CRAN R (R Development Core Team, 2023) repository. The application of the selected `AlgDesign` package functions in conjoint package is carried out in the form of functions which allow e.g., obtaining orthogonal or effective fractional factorial designs (functions: `caFactorialDesign`, `caEncodedDesign` and `caRecreatedDesign`) and their coding using dummy variables (effects coding, deviations from means coding is applied). It means the possibility of designing an experiment to be implemented in the form of a questionnaire survey (using indirect and direct methods of collecting data from primary sources, e.g., direct, or online surveys). In order to generate the relevant fractional factorial design, the data on the number of attributes (factors) taken into account and their levels, including names, are sufficient. Fractional designs are presented in two versions: with the names of levels (questionnaire version) and with the numbers of levels (version for further calculations).

The Table 4 presents the concise description of the purpose of conjoint package function and Table 5 meaning of function arguments. The detailed features of all available functions, data sets and practical examples of the package application in measuring consumers' stated preferences is included in the documentation of conjoint R package.

**Table 4.**

*The functions of conjoint R package (version 1.41)*

<b>Functions of the conjoint package</b>
<code>caFactorialDesign(data, type="null", cards=NA, seed=123)</code> – the function generates full or fractional factorial design maintaining the names of variables and levels
<code>caEncodedDesign(design)</code> – the function encodes the experiment design obtained using <code>caFactorialDesign</code> function for the needs of conjoint package functioning
<code>caRecreatedDesign(attr.names, lev.numbers, z, prof.numbers)</code> – the function recreates the fractional factorial design based on the number of profiles from the full factorial design
<code>caRankToScore(y.rank)</code> – the function transforms the empirical preference data measured on a rank scale into a data set in the form of point grades (on a positional scale)

Cont. table 4.

caPartUtilities(y, x, z) – the function calculates the part-worths utility matrix of attribute levels in the cross-section of respondents (including an intercept)
caTotalUtilities(y, x) – the function calculates the theoretical total utilities matrix of profiles in the cross-section of respondents
caImportance(y, x) – the function calculates an average relative „importance” of all attributes (as %) at an aggregated level
caUtilities(y, x, z) – the function calculates part-worths utilities of attribute levels at an aggregated level
caBTL(sym, y, x) – the function estimates market shares of simulation profiles based on the BLT probability model (Bradley-Terry-Luce Model)
caLogit(sym, y, x) – the function estimates market shares of simulation profiles based on logit model
caMaxUtility(sym, y, x) – the function estimates market shares of simulation profiles based on the maximum utility model
caSegmentation(y, x, c=2) – the function carries out respondents’ segmentation using <i>k</i> -means method based on kmeans function
caModel(y, x) – the function estimates conjoint analysis model parameters
Conjoint(y, x, z, y.type="score") – the function calculates basic results of conjoint analysis at an aggregated level
ShowAllUtilities(y, x, z) – the function calculates all utilities available in the conjoint package (part-worths and total)
ShowAllSimulations(sym, y, x) – the function estimates market shares of simulation profiles based on all simulation models available in conjoint package

Source: authors’ compilation.

**Table 5.**

*The functions arguments of conjoint R package (version 1.41)*

Argument name	Argument meaning
data	data describing the object of an experiment (product, service) – the set of attributes (factors) and their levels in the form of expand.grid function
type	optional parameter describing the type of generated factorial design (default type="null" – fractional design is generated with no specific criteria)
cards	optional parameter describing the number of generated profiles (default cards=NA – the number of profiles results from the type of generated factorial design)
seed	optional parameter describing the seed value of the random number generator (default seed = 123)
design	factorial (fractional or full) experiment design
attr.names	vector representing names of attributes (factors)
lev.numbers	vector representing numbers of attributes’ (factors) levels
prof.numbers	vector representing numbers of reconstructed profiles
z	vector representing names of attributes’ (factors) levels
y.rank	matrix (or vector) of empirical preferences in the ranking form (the ranking data require transformation to rating data using caRankToScore function)
y	matrix (or vector) of empirical preferences (in the form of importance assessments on a rating or ranking scale)
x	matrix representing profiles (including names of attributes)
y.type	type of data about preferences – data in the form of profile importance assessments on a rating or ranking scale (default type is rating)
sym	matrix representing simulation profiles (including attributes’ names)
c	optional parameter specifying the number of segments (default c = 2 – division into 2 segments)

Source: authors’ compilation.

## 6. Application of the conjoint R package

The conjoint package was used in an empirical study of the stated preferences of tourists choosing a place and form of recreation. The main aim of the research was to identify the factors (attributes) that guide tourists when choosing a trip from among many offered on the market. Additional aims of the research were segmentation of tourists with similar choice preferences, as well as forecasting the market share of trip offers not previously included in the study. The following features, along with the respective levels, were listed in the set of variables describing the examined product – tourism trips: purpose (cognitive, vacation, health, business), form (organized, own), season (summer, winter), accommodation (1-2-3 star hotel, 4-5 star hotel, guesthouse, hostel). Due to too many profiles resulting from the combination of levels of all features (in this case the so-called full factorial design consists of 64 profiles<sup>7</sup>), the following fractional factorial design of 14 profiles was used:

```
> library(conjoint)
> data(journey)
> journey<-expand.grid(
+ purpose=c("cognitive","vacation","health","business"),
+ form=c("organized","own"),
+ season=c("summer","winter"),
+ accommodation=c("1-2-3 star hotel","4-5 star hotel","guesthouse","hostel"))
> jprof<-caFactorialDesign(data=journey,type="fractional")
> print(jprof)
purpose form season accommodation
1 cognitive organized summer 1-2-3 star hotel
8 business own summer 1-2-3 star hotel
10 vacation organized winter 1-2-3 star hotel
15 health own winter 1-2-3 star hotel
19 health organized summer 4-5 star hotel
21 cognitive own summer 4-5 star hotel
30 vacation own winter 4-5 star hotel
34 vacation organized summer guesthouse
39 health own summer guesthouse
41 cognitive organized winter guesthouse
48 business own winter guesthouse
54 vacation own summer hostel
60 business organized winter hostel
61 cognitive own winter hostel
```

Respondents rated profiles according to their preferences. Data in the form of ratings on an interval scale<sup>8</sup> were collected using questionnaires sent electronically<sup>9</sup>. Of all the surveys, in the research 306 responses were included – 166 from women and 140 from men. Ratings of all 14 profiles by 6 first respondents are as follows:

<sup>7</sup> The number of profiles is the product of the number of all attribute levels ( $4^2 \cdot 2^2 = 64$ ).

<sup>8</sup> Rating on an interval scale means the valuation of profiles within the adopted interval (in the research the scale takes [0 – 10] interval).

<sup>9</sup> The empirical data were collected using a questionnaire presented on the website <https://www.webankieta.pl/>. The study was carried out by Mateusz Gordzicz for the needs of his Master's thesis. The respondents' age: less than 20 years of age – 10%, 20-40 – 85%, more than 40 – 5%.

```

> head(jpref)
profile01 profile02 profile03 profile04 profile05 profile06 profile07
1 0 10 0 10 10 8 4
2 10 0 10 3 7 9 2
3 8 2 6 9 7 9 0
4 8 10 1 6 3 0 3
5 3 4 8 10 10 1 10
6 5 1 8 3 10 0 9
profile08 profile09 profile10 profile11 profile12 profile13 profile14
1 5 10 2 4 0 0 6
2 7 4 0 8 10 3 7
3 1 8 5 0 0 0 5
4 1 8 4 7 4 1 10
5 4 9 4 10 0 7 10
6 5 3 10 10 4 1 8

```

Having the set of data about empirical preferences (jpref), the study design (jprof), the names of variables and their levels (jlevn) it is possible to estimate part-worths utilities using conjoint package. The part-worths utilities determine the relative importance, which the particular levels of attributes have in total utilities. The estimation of part-worths utilities is carried out by decomposing total utilities stated by the respondents. For this purpose a linear regression model with dummy variables is estimated for each respondent using formula (3), in which the response variable is the empirical total utility allocated by  $s$ -th ( $s = 1, 2, 3, \dots, 306$ ) respondent to the particular profiles. The aggregate model for the whole sample is also estimated based on formula (2).

Model (3) is estimated using the least squares method and the values of parameters  $b_{is}$  ( $i = 1, 2, \dots, 12; s = 1, 2, \dots, 306$ ) are obtained, which allows calculating all part-worths utilities in the cross-section of respondents using caPartUtilities function:

```

> print(head(caPartUtilities(jpref,jprof,jlevn)))
intercept cognitive vacation health business organized own
[1,] 4.938 -0.937 -2.687 3.639 -0.014 -1.563 1.563
[2,] 5.625 0.875 1.625 -0.827 -1.673 0.250 -0.250
[3,] 4.188 2.562 -2.438 3.341 -3.466 0.063 -0.063
[4,] 4.375 1.125 -2.125 0.788 0.212 -1.625 1.625
[5,] 6.688 -2.187 -1.188 3.534 -0.159 -0.062 0.062
[6,] 5.500 0.250 1.000 0.202 -1.452 0.750 -0.750
summer winter 1-2-3 star_hotel 4-5 star_hotel guesthouse hostel
[1,] 0.692 -0.692 0.063 1.639 0.313 -2.014
[2,] 1.058 -1.058 0.125 -0.452 -0.875 1.202
[3,] 0.135 -0.135 2.062 -0.034 -0.688 -1.341
[4,] 0.346 -0.346 1.875 -2.962 0.625 0.462
[5,] -2.385 2.385 -0.437 1.034 0.062 -0.659
[6,] -1.808 1.808 -1.250 1.202 1.500 -1.452

```

Part-worths utilities determine the relative contribution of individual attribute levels to the total profile utility. This contribution is interpreted in accordance with the value preference principle, i.e., the higher the part-worths utility, the more the given attribute level is appreciated by the respondent. For example, in case of the respondent no. 1 the estimations of part-worths utilities are as follows:



- for purpose attribute:  $b_1 = -0.937$  (cognitive),  $b_2 = -2.687$  (vacation),  $b_3 = 3.639$  (health),  $b_4 = -(b_1 + b_2 + b_3) = -0.014$  (business),
- for form attribute:  $b_5 = -1.562$  (organized),  $b_6 = -(b_5) = 1.562$  (own),
- for season attribute:  $b_7 = 0.692$  (summer),  $b_8 = -(b_7) = -0.692$  (winter),
- for accommodation attribute:  $b_9 = 0.063$  (1-2-3 star hotel),  $b_{10} = 1.639$  (4-5 star hotel),  $b_{11} = 0.312$  (guesthouse),  $b_{12} = -(b_9 + b_{10} + b_{11}) = -2.014$  (hostel).

It means that first respondent prefers the most health purpose and own trip, at summer in 4-5 star hotel. It should be noted that there is a differentiation between the respondents in part-worths utilities ranking of individual attributes. It means that not all respondents value equally the individual levels of features, which manifests the heterogeneity of preferences.

The estimation of model (2) parameters in the cross-section of whole sample (all respondents) can be carried out using Conjoint function:

```
> Conjoint(jpref,jprof,jlevn)
Call:
lm(formula = frml)
Residuals:
  Min 1Q Median 3Q Max
-5,4460 -3,0144 -0,0949  2,7758  5,9051

Coefficients:
Estimate Std. Error t value Pr(>|t|)
(Intercept) 4,979371 0,052578  94,704 < 2e-16 ***
factor(x$purpose)1 0,139093 0,084780  1,641 0,1009
factor(x$purpose)2 0,146446 0,084780  1,727 0,0842 .
factor(x$purpose)3 0,437924 0,097823  4,477 7,78e-06 ***
factor(x$form)1 -0,070057 0,052578 -1,332 0,1828
factor(x$season)1 -0,094834 0,052172 -1,818 0,0692 .
factor(x$accommodation)1 -0,136234 0,084780 -1,607 0,1081
factor(x$accommodation)2 -0,028171 0,097823 -0,288 0,7734
factor(x$accommodation)3 0,005923 0,084780  0,070 0,9443
---
Signif. codes: 0 '***' 0,001 '**' 0,01 '*' 0,05 '.' 0,1 ' ' 1

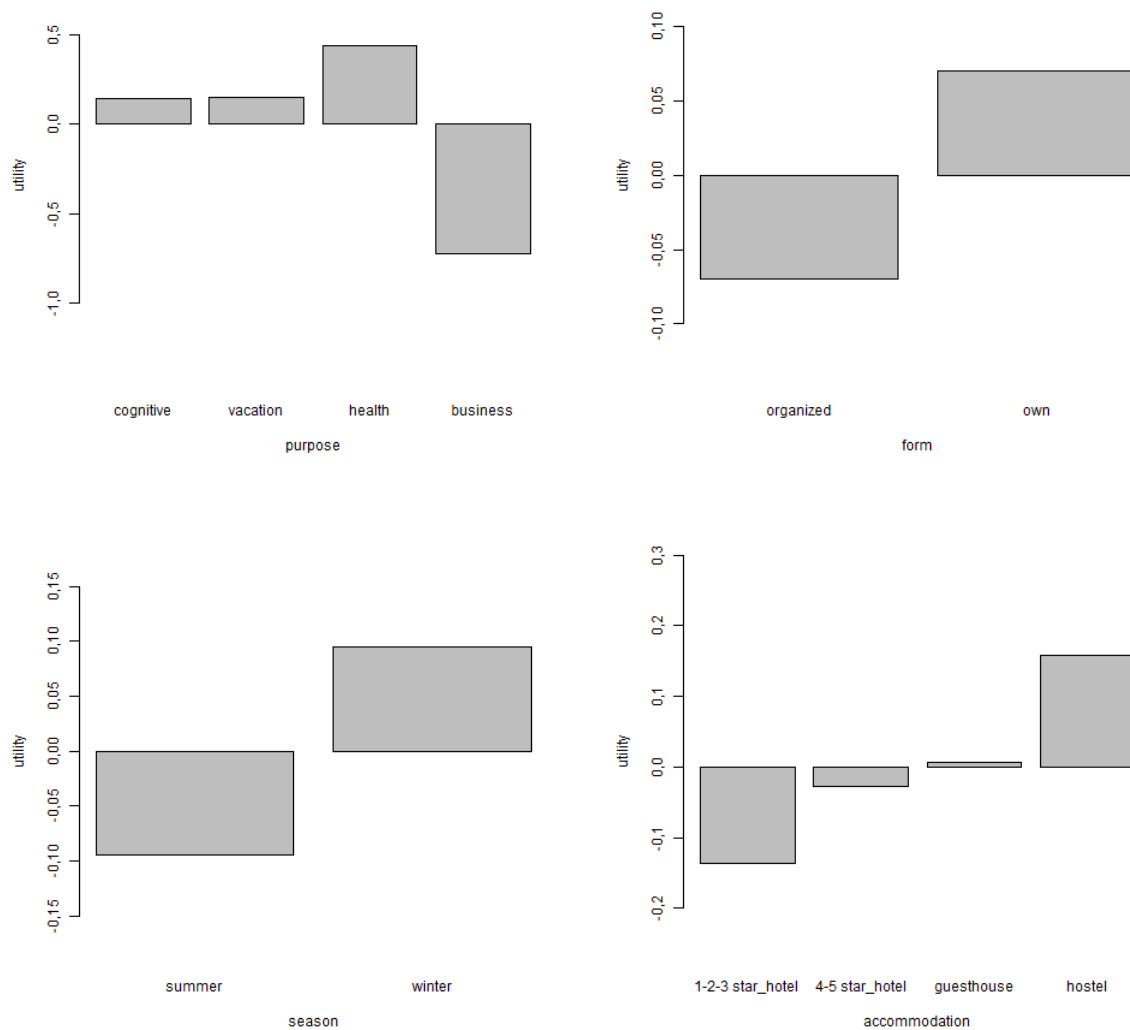
Residual standard error: 3,291 on 4275 degrees of freedom
Multiple R-squared: 0,01474, Adjusted R-squared: 0,0129
F-statistic: 7,994 on 8 and 4275 DF, p-value: 9,444e-11
```

[1] "Part worths (utilities) of levels (model parameters for whole sample):"

```
levnms utls
1 intercept 4,9794
2 cognitive 0,1391
3 vacation 0,1464
4 health 0,4379
5 business -0,7235
6 organized -0,0701
7 own 0,0701
8 summer -0,0948
9 winter 0,0948
10 1-2-3 star_hotel -0,1362
11 4-5 star_hotel -0,0282
12 guesthouse 0,0059
13 hostel 0,1585
```

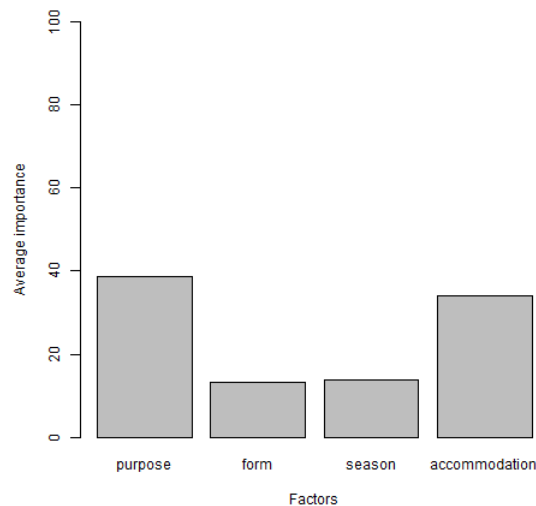
[1] "Average importance of factors (attributes):"  
 [1] 38,62 13,30 13,97 34,11  
 [1] Sum of average importance: 100  
 [1] "Chart of average factors importance"

The obtained results indicate that at an aggregate level (for all respondents), the most popular are health purpose trips focused on regenerating physical or mental condition of tourists, formed on their own trip and in winter, with hostel as an accommodation (Figure 1). At the same time, trip purpose and accommodation type seem to be the most important among the attributes used in the example, followed by the season of the year, whereas the form (organized, own) of the trip seems to be the least important. These results are illustrated by the chart of attributes' importance (Figure 2).



**Figure 1.** The chart of attributes' part-worths utilities.

Source: authors' compilation using conjoint R package.



**Figure 2.** The chart of attributes' importance.

Source: authors' compilation using conjoint R package.

The conjoint package allows estimating market shares of the so-called simulation profiles, i.e., the profiles which were not ranked by the respondents before. Based on the analysis of the conjoint model estimation results for the whole analyzed sample (306 respondents ranking 14 tourist product profiles), 5 trip variants were chosen for simulation analysis, which were not included in the survey questionnaire. The selection of variants was carried out taking into account the average importance of features and their levels, following the trade-off principle. Profile no. 3 offers the majority of the desired features (health oriented purpose of the trip, own organization form and winter season) combined with accommodation in a 4-5-star hotel. Profile no. 2 does not offer any of the preferred features, and the other profiles one each – profile no. 1 own trip organization form, profile no. 4 – hostel as the form of accommodation, whereas profile no. 5 – trip in winter season:

```
> print(jsimp)
purpose form season accommodation
1 2 2 1 1
2 2 1 1 2
3 3 2 2 2
4 1 1 1 4
5 4 1 2 3
```

The total utility (attractiveness) of the simulation variants for all respondents was calculated using maximum utility models, the probabilistic BTL (Bradley-Terry-Luce Model) model and the logit model:

```
> ShowAllSimulations(sym=jsimp,y=jpref,x=jprof)
TotalUtility MaxUtility BTLmodel LogitModel
1 4,96 20,26 19,31 17,51
2 4,93 11,44 20,01 15,72
3 5,55 31,05 22,32 29,02
4 5,11 24,84 20,77 23,07
5 4,29 12,42 17,59 14,68
```

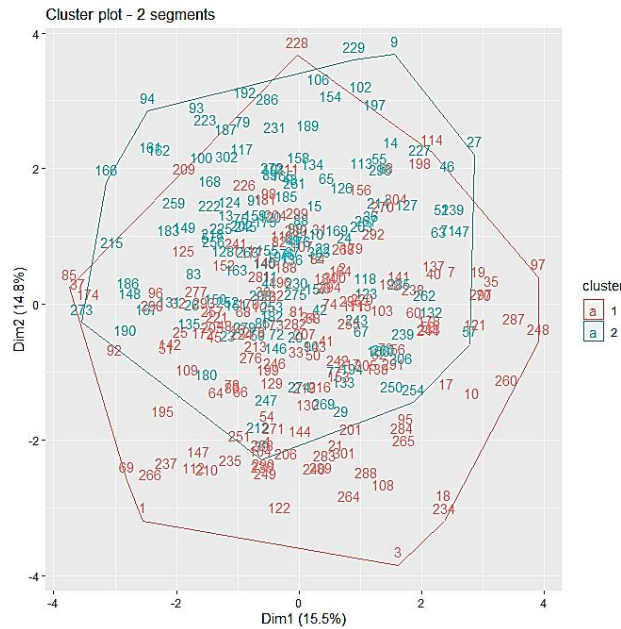
From among the selected trip variants subject to simulation analysis, the largest market share (according to all models – maximum utility, BTL and logit) is expected for profile no. 3. The smallest market share (according to the BTL and logit model) is expected for profile no. 5 and (according to the maximum utility model) – for the model no. 2. The comparison of relevant profiles confirms the respondents' preferences regarding the desirable features and indicates that respondents are able to accept the levels of some features (e.g., a 4-5-star hotel) in exchange for the other preferred attributes (profile no. 3).

In order to perform respondents' segmentation on the basis of estimated part-worths utilities using `caPartUtilities` function (individual models – one model for each respondent), the conjoint package offers `caSegmentation` function using k-means method, which allows the division of respondents into the indicated number of segments (this number must take the value of 2 or higher).

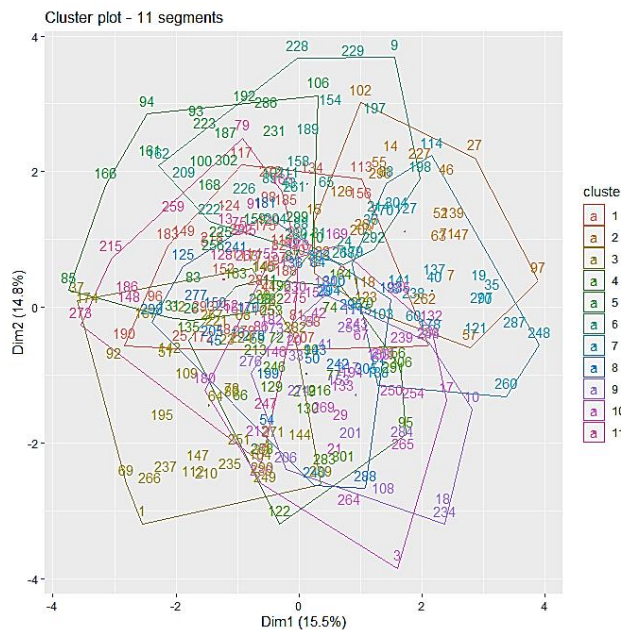
Determining the relevant number of segments was carried out using a `NbClust` package (Charrad, Ghazzali, Boiteau, Niknafs, 2014). The `NbClust` package allows you to estimate 30 indexes indicating the optimal number of clusters for various methods of partitioning a data set, including the k-means method. In the procedure of selecting the optimal number of clusters, 17 indices were estimated. Clustering validity indices indicate the division of respondents into 2 (6 indices) or 11 segments (5 indices).

Figures 3 and 4 present the visualizations of segments (division of 306 respondents appropriately into 2 and 11 clusters) using the `factoextra` package (Kassambara, Mundt, 2020) obtained with the script:

```
library(conjoint)
library(factoextra)
data(journey)
segments<-caSegmentation(jpref,jprof,2)
print(segments$segm)
fviz_cluster(segments$segm,segments$util,
geom=c("text"),ellipse.type="convex",ellipse.alpha=0.0,
main="Cluster plot - 2 segments")
segments<-caSegmentation(jpref,jprof,11)
print(segments$segm)
fviz_cluster(segments$segm,segments$util,
geom=c("text"),ellipse.type="convex",ellipse.alpha=0.0,
main="Cluster plot - 11 segments")
```



**Figure 3.** The visualisation of respondents' segmentation into 2 clusters.  
 Source: authors' compilation using conjoint and factoextra R packages.



**Figure 4.** The visualisation of respondents' segmentation into 11 clusters.  
 Source: authors' compilation using conjoint and factoextra R packages.

In case of the division 306 respondents into 2 segments, the following segment sizes were obtained: 1 – 163, 2 – 143. The respondents' inclusion in the following segments is as follows:

K-means clustering with 2 clusters of sizes 163, 143

Cluster means:

[,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]

1 5.501558 4.550515 3.716233 4.385067 4.571755 6.404399 4.618963 4.723951

2 4.037385 3.575552 6.494084 6.655217 5.967993 3.539399 5.996126 5.243678

[,9] [,10] [,11] [,12] [,13] [,14]

1 5.392896 5.070528 4.119374 5.364166 3.323951 5.710632

2 5.404783 5.238839 4.777035 5.140238 5.710329 5.135427

Clustering vector:

```
[1] 1 1 1 1 2 2 1 1 2 1 2 2 2 2 2 1 1 1 1 2 1 2 2 2 1 2 2 1 2 1 1 1 1 1 1 2
[37] 1 1 2 1 1 2 2 2 1 2 2 1 2 1 1 2 1 1 2 1 2 1 2 1 2 1 2 1 2 1 1 1 2 2
[73] 1 1 2 2 2 1 2 1 1 1 2 1 1 2 2 2 2 2 2 1 2 2 1 1 1 1 2 2 2 2 1 1 1 2 1 1
[109] 1 2 1 1 2 1 1 1 2 2 1 2 1 1 2 2 1 2 2 2 2 1 1 2 2 2 2 2 1 1 2 2 1 1 1 1
[145] 1 2 1 2 2 2 2 1 1 2 2 1 2 2 2 2 2 2 2 1 2 2 2 2 2 1 1 1 1 1 2 2 1 1 1 2
[181] 1 2 2 1 2 2 2 1 2 2 2 2 1 2 1 1 2 1 1 2 1 2 2 1 1 1 1 2 1 1 1 2 1 2 2 1
[217] 1 2 1 1 1 2 2 1 2 1 2 1 2 2 2 1 1 1 1 1 1 2 1 1 1 2 1 2 1 2 1 2 1 2 1 2
[253] 2 2 1 2 1 1 2 1 2 2 2 1 1 1 2 1 2 1 1 2 2 2 2 1 1 1 2 1 1 1 1 1 2 2 1 1
[289] 1 1 1 1 1 1 1 1 2 1 1 1 1 1 2 2 1 1 2
```

Within cluster sum of squares by cluster:

```
[1] 13619.73 11304.09
```

(between\_SS / total\_SS = 9.6 %)

In case of the division 306 respondents into 11 segments, the following segment sizes were obtained: 1 – 40, 2 – 25, 3 – 36, 4 – 29, 5 – 26, 6 – 25, 7 – 24, 8 – 30, 9 – 20, 10 – 29, 11 – 22.

The respondents' inclusion in the following segments is as follows:

K-means clustering with 11 clusters of sizes 40, 25, 36, 29, 26, 25, 24, 30, 20, 29, 22

Cluster means:

```
[,1] [,2] [,3] [,4] [,5] [,6] [,7] [,8]
1 4.147575 3.276725 5.921175 6.304525 4.526950 5.887350 7.660775 5.210075
2 5.911520 3.236920 7.848480 4.643080 5.290720 3.786160 5.723080 5.751520
3 4.190861 6.034694 2.003583 6.493083 5.569500 6.434083 4.246556 3.308917
4 4.827966 2.637276 3.758241 5.742034 5.713517 7.402103 6.332552 2.043483
5 3.548500 5.258846 6.701500 5.606538 5.065115 4.256231 7.409423 4.538885
6 3.021480 3.911920 6.008520 2.898080 3.770840 4.821120 7.808080 7.881480
7 7.715917 3.453458 6.554917 3.775708 1.589667 4.848167 3.687167 6.580500
8 5.225300 4.470300 2.749700 2.588033 5.823133 5.409633 2.933867 6.350300
9 6.698050 6.228800 3.701950 3.821200 5.161500 6.817400 3.821200 4.048050
10 5.763241 2.611448 5.305724 9.043724 6.644552 2.872069 2.414414 5.090828
11 2.667864 4.340364 5.820773 7.852818 8.379409 2.006455 5.159636 4.417864
[,9] [,10] [,11] [,12] [,13] [,14]
1 5.593600 4.021175 3.150150 8.082975 2.798050 6.893900
2 2.546160 7.968480 5.293840 2.116920 6.509280 4.333840
3 7.798667 3.302194 5.145778 5.996500 3.569389 5.989528
4 4.027103 6.611690 4.421172 2.762276 4.286483 7.330655
5 3.443731 3.441885 5.152423 7.850192 8.242577 6.753385
6 4.771120 5.128520 6.018880 5.701920 3.029160 2.948880
7 3.801292 6.982000 2.719542 5.885750 2.327000 6.287250
8 6.188800 5.008033 4.252867 7.066133 6.110200 5.723700
9 4.167400 4.851950 4.382600 1.278800 1.738500 2.082600
10 8.828966 6.874690 3.722759 4.085586 3.872690 5.869310
11 6.449636 3.320773 4.993545 4.238091 7.029682 3.141273
```

Clustering vector:

```
[1] 3 1 10 3 11 2 2 7 6 9 5 2 11 2 2 8 10 9 7 10 10 2 3 6
[25] 1 5 2 8 10 3 6 3 9 9 7 7 3 7 11 7 9 10 6 1 8 2 2 1
[49] 8 8 3 2 9 8 2 4 2 1 4 7 1 8 2 3 6 4 10 3 3 7 2 4
[73] 4 4 11 11 4 3 11 3 1 1 5 8 5 11 5 6 6 4 11 3 5 5 4 1
[97] 2 1 1 5 5 2 7 3 1 5 1 9 3 5 1 3 1 7 8 1 1 2 1 1
[121] 7 4 2 1 8 2 7 11 4 4 5 10 10 1 4 8 7 7 2 4 7 3 8 3
[145] 1 10 3 11 1 8 11 1 9 6 10 1 10 6 5 10 5 6 4 4 11 5 3 5
[169] 10 8 9 1 9 3 1 11 3 7 7 10 8 10 1 9 1 11 5 1 6 1 1 5
[193] 8 10 3 4 6 6 8 10 9 1 2 6 8 9 1 5 6 3 6 10 4 6 11 4
[217] 9 1 4 4 3 6 5 3 5 6 2 6 6 10 5 4 1 9 3 10 3 7 10 8
[241] 8 8 10 9 11 4 11 7 3 10 3 11 4 10 9 5 3 4 11 7 6 2 11 10
```

[265] 10 3 2 6 10 7 3 1 11 9 11 9 8 8 1 6 1 3 4 9 10 5 7 8  
[289] 3 3 4 6 1 8 8 2 7 8 5 8 4 5 8 7 8 4

Within cluster sum of squares by cluster:

[1] 1907.956 1257.565 1865.649 1432.238 1223.052 1265.228 1134.321 1540.495

[9] 1214.192 1713.851 1205.163

(between\_SS / total\_SS = 42.9 %)

All results of this research and others illustrating the application of conjoint package in the analysis of stated preferences (using ranking and rating measurement scale), including simulation analysis and consumer segmentation are available on the following websites: (Bąk, Bartłomowicz, 2018b) (in Polish) and (Bąk, Bartłomowicz, 2023a) (in English).

## 7. Conclusions

From all conjoint methods, currently the Choice-Based Conjoint is the most popular method of stated preference analysis (Garrow, 2010; Aizaki et al., 2015). Nevertheless, the Traditional Conjoint Analysis is still highly popular with many practical applications. According to the research, the Traditional Conjoint Analysis is the third most popular and, in practice, most commonly used conjoint method, just after Choice-Based Conjoint and adaptive methods (ACA/ACBC).

One implementation of the traditional conjoint analysis method for R environment is the conjoint R package. A feature which characterizes the conjoint package is the high statistics of conjoint package downloads by RStudio users (RStudio, 2023). Until May 2023 total number of conjoint package installations exceeded 475,000. The most similar to the conjoint package in terms of the implemented conjoint method – the radiant.multivariate package has been downloaded a little more than 90,000 times (May 2023). Both results confirm the growing interest of students and researchers in the field of microeconomics and marketing research in the practical application of the traditional conjoint method in analysis of stated preferences. We can say that although the traditional conjoint analysis method has been known and used in marketing research for over forty years, it is still one of the most commonly used methods of measurement consumers' stated preferences.

Figure 5 illustrates the number of daily downloads of conjoint and radiant.multivariate R packages prepared using `cran_downloads` function from `cranlogs` package (Csárdi, 2022) and `ggplot` function from `ggplot2` package (Wickham, 2023) – script<sup>10</sup>:

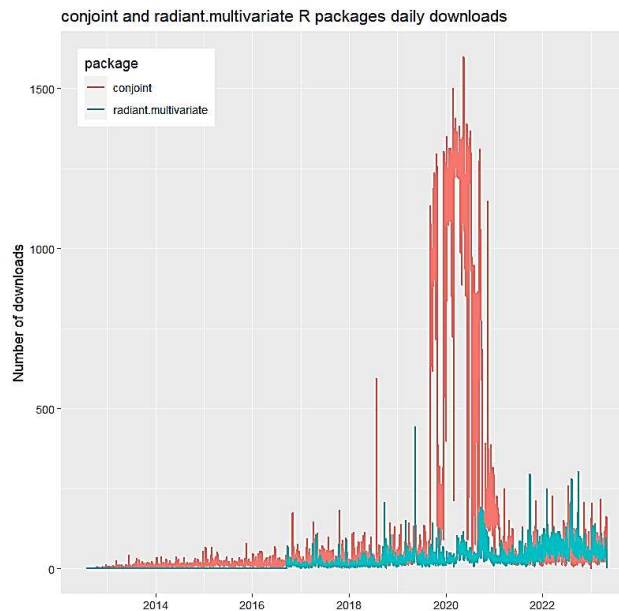
---

<sup>10</sup> It should be noted that the download statistics do not additionally cover the users of other R package versions, including primarily the original version of R environment, as well as the users of Microsoft R Application Network.

```

library(cranlogs)
library(ggplot2)
c<-cran_downloads("conjoint",from="2012-08-01",to=Sys.Date())
r<-cran_downloads("radiant.multivariate",from="2012-08-01",to=Sys.Date())
df<-data.frame(x=c$date,val=c(c$count,r$count),
package=c(rep("conjoint",nrow(c)),rep("radiant.multivariate",nrow(r))))
g<-ggplot(df,aes(x,val,col=package))+geom_line(linewidth=.6)
g+xlab("")+ylab("Number of downloads")+
labs(title="conjoint and radiant.multivariate R packages daily downloads")+
theme(legend.position=c(.15,.90))
sum(c$count);sum(r$count)

```



**Figure 5.** The number of conjoint and radiant.multivariate packages downloads by RStudio (RStudio, 2023) users.

Source: authors' compilation using cranlogs and ggplot2 R packages.

High popularity and proper functionality of the conjoint package is confirmed by the publications which recommended or at least described and cited the package: (Fiedler, Kaltenborn, Melles, 2017; Ben-Akiva, McFadden, Train, 2019; Aizaki et al., 2015; Mair, 2018; Koeser, Klein, Hasing, Northrop, 2015; Makkar, Williamson, Turner, Redman, Louviere, 2015; Le, Le, Nguyen, 2014). The users of social media channels also express their positive opinions about the conjoint package. Since 2018, websites (Bąk, Bartłomowicz, 2018b) and (Bąk, Bartłomowicz, 2023a) have also been available, which present detailed information about the conjoint package and examples of the use of the traditional conjoint analysis method and the conjoint package in empirical research on consumer preferences.

The article also presents the results of a survey of preferences of tourists choosing a place for a holiday trip. Using the data about the stated respondents' preferences and R program with conjoint package, the partial utilities of levels of attributes were estimated with OLS method. The obtained results made it possible to achieve the main aim of the study – to calculate the importance of the attributes included in the study, as well as to determine the most and least preferred profile of a tourist trip at the individual level as well as for all respondents. Additional



objectives of the study were also achieved. With total and maximum utility and BTL models also implemented in the package, estimation of market share of the so-called simulation profiles not ranked by the respondents before was possible. At the end, using conjoint and some other packages the segmentation of tourists with similar choice preferences has been also made.

The obtained results of preference analysis indicate that at an aggregate level (for all respondents) the most important among all attributes used in the research trip purpose and accommodation type seem to be the most important among the attributes used in the example, followed by the season of the year, whereas the form (organized, own) of the trip seems to be the least important. At the attribute level the most popular are health trips focused on regenerating condition of tourists, organized on their own and in winter, with hostel as an accommodation. Organized business trips in the summer to a 1-2-3 star hotel turned out to be the least preferred by the respondents. At the same time, an analysis of the market share of simulation profiles revealed that respondents are able to accept the levels of some features in exchange for the other preferred attributes. Information on choice preferences made it possible to divide respondents into the segments. The results obtained in the study indicated the division of respondents into 2 or 11 segments.

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## KNOWLEDGE MANAGEMENT IN ORGANISATION ON THE BASE OF USING THE HYBRID METHODS OF UNSERTAINTY ANALYSIS

Bogusław BIEDA<sup>1</sup>, Dariusz SALA<sup>2</sup>, Alla POLYANSKA<sup>3\*</sup>, Dmytro BABETS<sup>4</sup>,  
Roman DYCHKOVSKYI<sup>5</sup>

<sup>1</sup> AGH University of Krakow; bbieda@zarz.agh.edu.pl, ORCID: 0000-0003-0416-1859

<sup>2</sup> AGH University of Krakow; sala@agh.edu.pl, ORCID: 0000-0003-1246-2045

<sup>3</sup> AGH University of Krakow; polyanska@agh.edu.pl, ORCID: 0000-0001-5169-1866

<sup>4</sup> Dnipro University of Technology; Babets.d.v@nmu.one, ORCID: 0000-0002-5486-9268

<sup>5</sup> AGH University of Krakow; dychkovskiyi.r.o@nmu.one, ORCID: 0000-0002-3143-8940

\* Correspondence author

**Purpose:** The purpose of this study is to formalize knowledge management based on the use of methods of uncertainty analysis in the organization, which will allow collecting missing or incomplete information, as well as finding appropriate management solutions.

**Design/methodology/approach:** The methodology consists of three stages: (1) analysis and evaluation of description of uncertainty in LCA; (2) recommendation of the most appropriate measures of uncertainty; (3) construction of a new hybrid method for LCA based on the fuzzy theory.

**Findings:** Alternative ways of modeling of uncertainty, such as Monte Carlo (MC) and fuzzy sets (FS) (possibility distributions) are discussed. Based on literature data on hybrid LCA and uncertainty in LCA an overview has been developed. It is concluded that given possibility to analyze different situations creates knowledge experience and its usage due to the knowledge management process.

**Research limitations/implications:** given research propose the new approach on the environment investigation that forms additional knowledge for making decision support in management process. But additional investigation must be completed and should include suggestions for future research on the implementation of knowledge management in the decision support system of organization.

**Practical implications:** the study examines the practical results of applying the proposed approach to uncertainty analysis using specific methods that reflect the impact of risk on the consequences of the commercial results of a mining company's project implementation.

**Social implications:** Proposed research could be impactful to the society by giving methods of environmental investigation with possibility of accounting the factors of uncertainty.

**Originality/value:** the new hybrid LCA method is proposed when uncertainty is due to both randomness and the lack of, or incomplete, information. The development of such methods is necessary for the appropriate uncertainty analysis in LCA. A set of such techniques are knowledge management tools that support the decision-making process through a clearer understanding of the situation and its implications.

**Keywords:** knowledge management, life cycle assessment (LCA), uncertainty, fuzzy logic, Monte Carlo (MC) method.

**Category of the paper:** conceptual paper, case study.

## 1. Introduction

Modern civilization progress is based on the application of the concept of knowledge management. Its main postulate is the formation and use of unique knowledge, which allows to transform the potential opportunities of organizations into its driving forces of development. And these opportunities are manifested not only in material assets, but are significantly dependent on their intangible component, formalized in the results of intellectual work. Thus, the study of the peculiarities of the implementation of knowledge management in enterprises is relevant. Consideration of this issue will allow us to highlight the basic elements of knowledge management, which should be given primary attention when implementing the mentioned concept in practice.

Today, issues related to the relevance of knowledge management concept in the practice of domestic enterprises are widely discussed. In literary sources, knowledge management is considered in various planes of practical application. This can be attributed to the fact that this concept quickly evolved from a theoretical discipline (the beginning of the 90s of the last century) to its versatile practical application. When considering knowledge management from interdisciplinary positions, the following basic approaches to defining its essence are distinguished: the best practical change transformer based on benchmarking; information and resource management; organizational learning and organizational memory; electronic performance support systems (EPSS); knowledge economy and knowledge as a corporate value; Internet and Web portals (Regan, 2007). In our opinion, such a wide range of definitions of this concept allows us to cover various spheres of the organization's activities that are related to knowledge management processes and allows us to develop directions for the practical implementation of accumulated knowledge. At the same time, it complicates the procedure of identifying the possibilities of implementing knowledge management in the activities of a separate enterprise and identifying practical ways of implementing this concept.



## 2. Literature review

Despite this, the use of knowledge as a unique resource that forms the competitive advantages of the enterprise within the existing approaches to defining the essence of this category requires the selection of those key provisions of the management activity of the organization that allow bringing the concept closer to real business conditions. In our opinion, knowledge management is a modern concept of enterprise development, which is based on the purposeful activity of people, which ensures the processes of generation, accumulation, storage and use of knowledge in the organization to support the processes of current functioning and long-term development, and is based on the optimal combination of it (knowledge) economic and informational context. Such a combination will allow to increase the quality and efficiency of management decisions, speed up reactions to changes in the organization's environment, and improve the quality of customer service. When studying the peculiarities of the development of the concept of knowledge management in practice, it is necessary to pay attention to the distinction between the concepts of knowledge management, under which a functional task is considered, and knowledge management as a purposeful activity of a person and a company, which determines the philosophy of the development of the ability to learn. It is also important to note that in literature, knowledge management is considered as an economic category related to the development of methods of optimal use of the organization's intellectual potential (Wing, 1997), and information technologies designed to optimize work with knowledge (Mahdi et al., 2020). The choice of the allocation method has a strong correlation with the aims of the study as defined by decision makers. This allows practitioners to both justify their choice and discuss and discuss the results with alternative scenarios for sensitivity analysis (Ijassi, 2021). Qualitative methods are growing the more and more important, because in numerous decision-making situations, uncertainty of economic and environmental parameters is not of probabilistic in nature, but it results from insufficient or vague information and is epistemologically indeterminate Mohamed and McCowan (Mohamed, McCowan, 2001). Moreover, sometimes, as pointed by Gupta (1993), it happens that uncertainty is probabilistic, but the available information is fuzzy. In practice, quite often it is not possible to determine probability distribution because of not sufficient volume of data (and there is no possibility to get enough data) facilitating execution of statistic tests. On the other hand, assumption of "no data available at all" is also not true. In general, there is always some information available, e.g., experts' estimates of unknown values. A good example is the LCA model. By the meaning of LCA or Life cycle assessment it is considered the methodology of environment assessment on all stages of product or service life cycle. The main difficulty in this case stems from the uniqueness of case and the time interval between the moment of studies on a project and its realization and exploitation. Usually, only experts' opinions and subjective probability distributions of the possible values of parameters can be used. The estimation of LCA model parameters from

historical data is much more difficult because of the specificity and uniqueness of each case. It is not possible to obtain perfectly reliable information regarding similar past cases. The lack of enough information causes that it is necessary to use subjective probability distribution. The estimation of subjective probability is based on the experience of a person that determines the probabilities of occurrence of individual events. The level of subjectivity depends on the way of estimation and on the knowledge of other similar events. In practice, an arbitrary probability distribution between minimal and maximal estimation is usually adopted. The evaluation of effectiveness of LCA projects using subjective probability distributions is related, among others, to the problem of estimating these distributions. Choobineh and Behrens (1992) and Kuchta (2001) point out these difficulties. Moreover, Kuchta says that sometimes a decision-maker does not know how to answer the question on the probability of the unique, unrepeatable event. The question about frequency has not much sense. A decision-maker can have, however, some opinion on the degree of possibility of occurrence of respective values. Moreover, the subjective probability distribution must have the same properties as any probability distribution. For example, the sum of probabilities of all elementary events must sum up to one and the probability of the simultaneous occurrences of two independent events is the product of the probabilities of each event. It is extremely difficult to maintain these properties in expert judgments about subjective probability of future values Kuchta (2001). This problem can be partially solved by modeling uncertainties using, e.g., fuzzy numbers.

Uncertainty is a pervasive topic in LCA (Heijungs, Lenzen, 2014). In fact, data uncertainty is often mentioned as a crucial limitation for a clear interpretation of LCA results (Sonnemann, 2003). However, uncertainty analysis is not commonly performed in LCAs (Huijbregts et al., 2001; Bjorklund, 2002; Ross et al., 2002), although great efforts have been made on classification, definition, and sources of uncertainty as well as on methodological aspects for expressing uncertainty (Guo, Murphy, 2012). Classification of methods for uncertainty characterization, uncertainty analysis, as well as sensitivity analysis are discussed in detail in (Igos et al., 2019).

Uncertainty is present in many forms (Yen Le, Hendriks, 2014) and shows up in many ways (Heijungs and Lenzen, 2014) in all stages of an LCA. So, it's critical for LCA that the input data is accurate and current. Unfortunately, the available data is usually burdened with uncertainty due to measurement errors, incomplete knowledge, or variability. Therefore, the key stage in the process of LCA assessment is the choice of an appropriate method for describing uncertainty.

The Table 1 present the essential approaches to uncertainness description are considered, on the base of which the methods of uncertainness assessment are variated and suggested to be used for. Currently, the researchers on uncertainty analysis mainly consist of two parts. One is to explore new two main methods to improv the uncertainty estimate: one is the qualitative assessment, and other is the quantitative assessment proposed to use data quality

indicators to describe the different magnitudes of influence on the overall uncertainty of a data (e.g., completeness, temporal correlation, etc.).

**Table 1.**  
*Methods of uncertainty description and assessment*

<b>Approaches to uncertainty description</b>	<b>Methods of uncertainty assessment</b>	<b>Authors</b>	<b>Limitations of methods</b>
Hybrid description of uncertainty	The hybrid description of uncertainty is useful and also suitable for alternative ways - the uncertainty modelling of an LCA results which can be built using the variance and entropy of fuzzy numbers.	Scope et al., 2016	Not all fuzzy numbers equally suited to address different categories of uncertainty. The validity of LCA strongly depends on the validity of the input data (Grant, Horne, 2009).
Expression of uncertainty through a probability distribution	To obtain a result, different statistical methods can be applied including well-known sampling method as Monte Carlo (MC) simulation.	Igos, 2019; Huijbregts et al., 2001; Warren-Hicks, 1998; Bieda, 2012; Sonnemann et al., 2004	High cost of data preparation and difficulties with determining probability distributions of parameters (e.g., economic) significantly limit the usage of this approach; randomness, imprecise or incomplete information is an important source of uncertainty
Risk assessment	Software for LCA based on MC simulation. Methods for propagation uncertainties, apart from MC, as Latin hypercube sampling, quasi-Monte Carlo sampling, analytical uncertainty propagation and fuzzy interval arithmetic. Alternative ways of modeling of uncertainty, such as fuzzy sets or interval numbers. MC simulation with the mathematical description of imprecise or vague information, with information visualization Science-based and practical application of uncertainty analysis integrated within risk management in accordance with ISO 3100 (2009) and IEC 62198 (2013)	The United States Environmental Protection Agency (EPA), Smith, 1994, Heijungs, Lenzen, 2014; Bisinella et al., 2016; Groen et al., 2014; Skalna et al., 2015; Baudrit et al., 2006; Scope et al., 2016	In the risk assessment (including risk identification, risk analysis, and risk evaluation), no distinction is traditionally made between types of uncertainty, both being represented by means of a single probability distribution provided guidance for a science-based and practical application of uncertainty analysis integrated within risk management in accordance with ISO 3100 (2009) and IEC 62198 (2013).
Transformation of a probability distribution into a possibility distribution	The methods which allow different representations of uncertainty (e.g., by probability distributions, fuzzy numbers of interval numbers) to be processed according to their nature and only finally combine them into a synthetic easy-to-interpret measure of environmental impact; sampling method	Groen et al., 2014	Causes the loss of information, whereas the opposite one requires additional information to be introduced. This eventually leads to systematic errors in risk assessment, i.e., overestimation or underestimation of the risk

Cont. table 1.

Random variability, referred to as „objective uncertainty”. Imprecision referred to as “subjective uncertainty”	Deterministic, probabilistic, possibilistic, and simple methods	Ferson, Ginzburg, 1996	Weaknesses or limitations of the semi-quantitative approach are discussed (one being that uncertainty is always considered as following a lognormal distribution) implemented in Eco invent v2, based on the use of a pedigree matrix which considers two types of uncertainties
The basic uncertainty as the epistemic error	New methodology developed to apply the semi-quantitative approach to distributions other than the lognormal	Ciroth et al., 2016; Muller et al., 2016	
The additional uncertainty as the uncertainty due to using imperfect data	Procedure geometric standard deviation, used as the uncertainty measure, is essential to overcome scaling effects; it should therefore also be used if the analyzed data do not follow a lognormal distribution	Zhang et al., 2016; Weidema, Wesnaes, 1996	

Source: worked on the base of literature review.

Most of the real decision-making problems contain a mixture of quantitative and qualitative data. Due to the above, conventional probabilistic approach appeared to be insufficient for modelling of numerous decision-making problems, in particular problems related to LCA. Many authors have applied the alternative description of the uncertainty. The investigations performed for the purposes of this article indicate that fuzzy numbers are the mostly used.

So, the complexity and variety of uncertainness cause the demand on Hybrid LCA enhancing for the better integration between the different methods of uncertainness assessment. Hybrid LCA in this article is proposed to be considered through the combining Monte Carlo (MC) simulation and fuzzy set theory (FST) while taking advantage of its process specificity.

### 3. Article purpose

The purpose of this study is to show the background of knowledge management functioning at an organization on the base of investigation the theoretical and practical aspects of getting substantiated information on uncertain conditions of organization’s activity with help of the expanding the view of the hybrid LCA method, which is based on the application of uncertainty analysis to the LCA method. This will allow the description and processing of uncertain data in a situation where uncertainty arises from randomness and lack of or incomplete information, using a broad overview of scientists’ views on uncertainty assessment problems regarding new combinations of different methods. Alternative methods for modeling uncertainty, such as Monte Carlo (MC) and fuzzy sets (FS) (probability distributions), are discussed. The process of knowledge management at mining organization is considered with proper recommendation according to the uncertainness analysis results implementation.

#### 4. Methods description

Fuzzy sets were introduced by Lofti Zadeh in 1965. They generalize classical set theory by replacing the binary membership function with a real function taking values in the interval  $[0, 1]$ .

The fuzzy set theory can be used in a wide range of domains in which information is incomplete or imprecise and are recommended in the case of intangible data (but not limited to) (Scope et al., 2016). A fuzzy subset  $\tilde{A}$  of universe  $\mathcal{X}$  is a set of pairs  $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) : x \in \mathcal{X}\}$  where  $\mu_{\tilde{A}} : \mathcal{X} \rightarrow [0, 1]$  is any function defined in  $\mathcal{X}$  and is called a membership function of the fuzzy subset (Zadeh 1965). Fuzzy subset can be unambiguously determined by a sequence of ordinary subset of set  $\mathcal{X}$  called  $\alpha$ -levels of subset  $\tilde{A}$  (Zadeh). These are classic subsets of  $\mathcal{X}$  given by  $A_{\alpha} = \{x \in \mathcal{X} : \mu_{\tilde{A}}(x) \geq \alpha\}$ , where  $\alpha \in (0, 1]$ . The fuzzy set can be treated as a family of  $\alpha$ -levels. The closed subset  $A_0 = \{x \in \mathcal{X} : \mu_{\tilde{A}}(x) \geq 0\}$  is called the support of the fuzzy set  $\tilde{A}$  and is denoted by  $\text{sup}(\tilde{A})$ .

The fuzzy subset  $\tilde{A}$  can be identified with the approximate value of element  $x_0$ . This can occur when  $x_0$  is any element of universe  $\mathcal{X}$  and  $\tilde{A}$  such a fuzzy set, that  $\mu_{\tilde{A}}(x_0) = 1$ . In general, fuzzy numbers are used for modeling values which are approximate, imprecise, or not clearly defined. The membership function of the fuzzy number is then given by Jorba and Adillon (2017):

$$\mu_{\tilde{A}}(x) = \begin{cases} f(x), & x \in [a_1, a_2] \\ 1, & x \in [a_2, a_3] \\ g(x), & x \in [a_3, a_4] \\ 0, & \text{otherwise.} \end{cases} \quad (1)$$

where  $a_1, a_2, a_3$  and  $a_4$  are real numbers such that  $a_1 < a_2 \leq a_3 < a_4$ ;  $f(x)$  is a real-valued strictly increasing and right-continuous function; and  $g(x)$  is a real-valued strictly decreasing and left-continuous function (Jorba, Adillon, 2017). Moreover, researchers detailed discuss and propose a generalization of trapezoidal fuzzy numbers based on modal interval theory, which named *modal interval trapezoidal fuzzy numbers*. Trapezoidal fuzzy numbers are a special class of fuzzy numbers.

Possibility distribution was first introduced by Zadeh (1965). The fuzzy set  $\tilde{A}$  generates two functions defined on a family of subsets of some space  $\mathcal{X}$  : a measure of possibility *Pos* and a measure of necessity *Nec*. These measures are defined for every classic set  $X \subset \mathcal{X}$  by the formulae:

$$\begin{aligned} Pos(X) &= \sup \{ \mu_{\tilde{A}}(x) : x \in X \}, \\ Nec(X) &= \inf \{ 1 - \mu_{\tilde{A}}(x) : x \notin X \} \end{aligned} \quad (2)$$

Their definitions are associated with a well-known interpretation of a fuzzy set given by Zadeh. It assumes that the fuzzy set  $\tilde{A}$  is a fuzzy restriction of a certain variable  $X$ , which takes values in space  $\mathcal{X}$ . It is assumed that the only information about the variable is that „ $X$  is  $\tilde{A}$ ”. In this case, the variable  $X$  is characterized by a fuzzy set membership function which describes the possibility of  $X$  taking values of  $x \in \mathcal{X}$ , i.e., it induces a possibility distribution in space  $\mathcal{X}$ . Such a defined variable  $X$  is called a fuzzy variable with a possibility distribution of  $\pi_X(x) = \mu_{\tilde{A}}(x)$ . It can be determined how possible is the event that the value of variable  $X$  belongs to set  $X$  using the possibility distribution (González et al., 2002):

$$\pi(\mathbf{X} \in X) = \sup\{\pi_X(x) : x \in X\} = \sup\{\mu_{\tilde{A}}(x) : x \in X\} = \pi(X). \quad (3)$$

Such a defined quantity does not have complementary characteristics, i.e.  $\pi(\mathbf{X} \in X)$  is not necessarily equal to  $1 - \pi(\mathbf{X} \in X^c)$ , where  $X^c$  is the absolute complement of  $X$ . Liu (2006) introduces the concept of credibility measure. The degree of credibility that the value of variable  $X$  belongs to the set  $X$  can be defined as follows:

$$Cr(\mathbf{X} \in X) = \frac{1}{2}(\pi(\mathbf{X} \in X) + (1 - \pi(\mathbf{X} \in X^c))). \quad (4)$$

The quantity defined in this way has complementary characteristics (Cravleuret et al., 2013; Liu, 2006; Cruze et al., 2013; de Figueiredo, Stolfi, 1996). Moreover, when the grade of credibility reaches a value of 1, there is confidence that the fuzzy event will occur. On the other hand, when the degree of possibility reaches a value of 1, such confidence does not exist.

Liu (2006, 2014) define the concept of credibility distribution  $\Phi(x)$ . The distribution function  $\Phi(x)$  determines the grade of credibility, that the fuzzy variable  $X$  will have a value equal to or less than  $x$ . If  $\mu$  is a membership function of fuzzy variable  $X$  then the credibility distribution function  $\Phi(x)$  is expressed by:

$$\Phi(x) = \frac{1}{2} \left( \sup_{y \leq x} \mu(y) + 1 - \sup_{y > x} \mu(y) \right) \quad \forall x \in \mathfrak{R}, \quad (5)$$

where  $\mathfrak{R}$  denotes real numbers.

Effective processing of data expressed in the form of fuzzy numbers requires the properly defined arithmetic operations on such numbers. Operations on arbitrary fuzzy numbers can be defined, in line with Zadeh's extension principle (Klir, 1990; Zadeh, 1965), by performing operations on  $\alpha$ -levels using interval arithmetic. If  $\tilde{A}$  and  $\tilde{B}$  are two fuzzy numbers,  $A_\alpha$ ,  $B_\alpha$  their  $\alpha$ -levels and  $\circ$  any arithmetic operator ( $+$ ,  $-$ ,  $*$ ,  $/$ ), then operations on these numbers can be defined as:

$$\tilde{A} \circ \tilde{B} = \bigcup_{\alpha \in [0,1]} \alpha(\tilde{A} \circ \tilde{B})_\alpha, \quad (6)$$

where  $(\tilde{A} \circ \tilde{B})_\alpha = \{A_\alpha \circ B_\alpha\}$ ,  $\alpha \in [0, 1]$  and  $\circ$  is the respective operation on intervals (Kuchta, 2001).

This definition allows all combinations of values belonging to the respective intervals ( $\alpha$ -levels) (Klir, Yuan, 1995; Klir, 1990; Rębiasz, 2011). However, this is not always true. Let, for example, one number represents the price of hot rolled sheets and the second, the price of cold rolled sheets. These quantities are dependent since high prices of hot rolled sheets will generally result in high prices of cold rolled sheets and combinations of low prices of one product and high prices of the other will probably never occur. Thus, the main stress is put on modeling the dependencies between parameters. Interval regression and affine forms will be used to handle these dependencies. However, other methods, identified during the literature study, will be considered as well.

Fuzzy regression is identified when parameters of regression equation are expressed in form of fuzzy numbers. Interval regression is a specific case of fuzzy regression. Tanaka and Lee (Tanaka et al., 1982; Tanaka, Lee, 1998) were among the first authors reported that parameters of regression equation are in this case expressed in form of bounded interval. Interval and fuzzy regression are used in solution of numerous practical problems (Hladík, Černý, 2012). Several methods are used for estimation of the parameters of interval regression equations. The best-known method uses linear programming for this purpose (Tanaka, Watada, 1988). However, these methods are criticized because of many faults (Tran, Duckstein, 2002). Many authors present alternative solutions, e.g. (1) quadratic programming methods in combination with the least squares method (Tanaka, 1987; Tanaka, Watada, 1988), (2) use of Minkowski distance (Fuller, Majlender, 2003) or (3) multi-criteria programming (Tran and Duckstein, 2002). Those modified methods provide more balanced intervals representing the coefficients of interval regression equations. Nevertheless, these require longer computation time and estimation of weigh coefficients by experts, thus they become heuristic methods (Hladík, Černý, 2012).

The major drawback of these methods is that often some of the estimated regression parameters tend to be crisp; it even happens that the method produces only a few unexpectedly wide interval parameters while all the remaining regression parameters are crisp. This drawback is called unbalancedness.

The second drawback is non-centrality property, i.e., the method might produce interval regression parameters, the center of which only poorly fits the data with respect to traditional non-parametric goodness-of-fit tests (such as R-squared, Chi-squared and/or Kolmogorov-Smirnov tests).

The third drawback relates to high sensitiveness to outliers. One of the most promising methods for determining parameters of interval regression equations was developed by Hladik and Černý (2012). They proposed a method based on sensitivity analysis of linear systems. The most appropriate approach will be selected and used to model dependencies between fuzzy numbers. As it was mentioned above, arithmetic operations on fuzzy numbers implicitly assume independence of the operands, thus it is necessary to define new arithmetic on fuzzy numbers which will enable the dependencies to be considered. To reach this goal, nonlinear

programming and affine forms will be used. The latter being rarely used in problems of assessing risk in a company.

Affine arithmetic (AA) was first introduced by Comba and Stolfi in 1993 as a new self-validated model for numerical computation. It was designed to eliminate the main weakness of standard interval arithmetic (Moore, 1996), that is the tendency to produce intervals which are often much wider than the true range of the corresponding quantities, especially in long computation chains. AA is like standard interval arithmetic in that it keeps track of input, truncation, and rounding errors. In addition, it considers correlations between computed and input quantities, and is, therefore, able to provide much tighter bounds on computed quantities than standard interval arithmetic.

In affine arithmetic (De Figueiredo, Stolfi, 1997; 2003) an unknown ideal quantity  $x$  is represented by an affine form:

$$\hat{x} = x_0 + x_1\varepsilon_1 + \dots + x_n\varepsilon_n, \quad (7)$$

which is a degree 1 polynomial.

The *central value*  $x_0$  and the *partial deviations*  $x_i$  are finite floating-point numbers; the *noise symbols*  $\varepsilon_i$  are unknown but assumed to vary within their domains, i.e., intervals  $[-1, 1]$ . Affine forms sharing the same noise symbols are partially correlated through them (de Figueiredo, Stolfi, 1997). All possible pairs  $(\hat{x}, \hat{y})$  (if each  $\varepsilon_i$  vary independently within the interval  $[-1, 1]$ ) lie in a convex polygon (*zonotope*) which is called a *joint range* and is denoted by  $\langle \hat{x}, \hat{y} \rangle$ .

Every affine form  $\hat{x}$  implies the range  $[\hat{x}] = [x_0 - r_x, x_0 + r_x]$  for an unknown ideal quantity  $x$ , which is the smallest interval that contains all possible values of  $\hat{x}$ , if each  $\varepsilon_i$  varies independently within the interval  $[-1, 1]$ . The radius  $r_x = \sum_{i=1}^n |x_i|$  is called the *total deviation* of  $\hat{x}$  (Comba, Stolfi, 1993). Conversely, if an ideal quantity  $x$  belongs to an interval  $x = [\underline{x}, \bar{x}]$ , then  $x$  can be represented by an affine form  $\hat{x} = \check{x} + r(x)\varepsilon_i$ , where  $\check{x} = (\underline{x} + \bar{x})/2$  is a midpoint of  $x$ ,  $r(x) = (\bar{x} - \underline{x})/2$  is a radius of  $x$ , and  $\varepsilon_i$  is a noise symbol not occurring in any previous computations (de Figueiredo, Stolfi, 1996; 2003).

Affine-linear operations on affine forms result straightforwardly in affine forms. Non-affine operations must be approximated by affine forms. An extra term must then be added to bound the error of this approximation (this extra term usually also includes round-off errors). Selecting appropriate affine approximation might reduce this error.

Given a non-affine function of two variables  $z = f(x, y)$  and two affine forms  $\hat{x}$  and  $\hat{y}$  representing  $x$  and  $y$ , an affine form  $\hat{z}$  representing  $z$  must be computed. It is desirable that  $\hat{z}$



is consistent with  $\hat{x}$  and  $\hat{y}$ , and that it preserves the information provided by them as much as possible. It can be easily seen that  $z = f(\hat{x}, \hat{y})$  is a function of the noise symbols  $\varepsilon_i$ :

$$z = f(x_0 + x_1\varepsilon_1 + \dots + x_n\varepsilon_n, y_0 + y_1\varepsilon_1 + \dots + y_n\varepsilon_n) = f^*(\varepsilon_1, \dots, \varepsilon_n), \quad (8)$$

where  $f^*: [-1, 1]^n \rightarrow R$  is generally a non-affine function. An affine approximation  $f^a$  of  $f^*$  can be then written in the form:

$$f^a = z_0 + z_1\varepsilon_1 + \dots + z_n\varepsilon_n + z_k\varepsilon_k, \quad (9)$$

where the last term  $z_k\varepsilon_k$  represents the *residual* or *approximation error*.

It is assumed that  $\varepsilon_k$  is a new noise symbol independent from  $\varepsilon_1, \dots, \varepsilon_n$  (de Figueiredo, Stolfi, 1996; 1997; 2003).

The quality of the approximation depends on the selection of a central value  $z_0$  and partial deviations  $z_i$ . This means that there is  $n+1$  degrees of freedom for the choice of an affine approximation  $f^a$ . In fact, two basic approaches to compute affine approximation are used the most frequently (Figueiredo, Stolfi, 2004). The first one is to minimize the approximation error  $z_k$  (*Chebyshev approximation*), the second one is to minimize the range  $[\hat{x}, \hat{y}]$  (*minimum range* or shortly *min-range approximation*).

## 5. Research results

The transformation of the organization's knowledge into its asset is based on the consistent execution of processes related to their formalization, creation of conditions for access to users, distribution, storage, and application. Key characteristics of knowledge are concepts that significantly distinguish it from data and information. Knowledge is inseparable from the subject who possesses it, has a holistic nature and a dynamic character. This characteristic complicates knowledge management procedures, since knowledge management is directly related to the presence of people, and therefore is accompanied by the appearance of a subjective factor. At the same time, we can generalize that knowledge management at the enterprise requires the organization of the following processes: creation or acquisition of knowledge; modification of knowledge in order to meet the current and future needs of consumers; using knowledge for certain purposes; archiving of knowledge for future access to it by users in an accessible form and format; transfer of knowledge; transformation of knowledge; user access; disposal. So, considering the peculiarities of the category of knowledge and its differences from such key concepts of the concept of knowledge management as data and information, it is possible to distinguish the following approaches to the formation of a knowledge management strategy at the enterprise. The first approach is based on the application of IT systems with different types of knowledge structures, which may include:

document structures (forms, templates, reports, graphs, charts); images (photos and graphic files), video (presentations and video files), sounds and signals, data, cases (case studies, best practices, lessons learned), processes (resources, specifications), models. Knowledge management strategies based on management information systems outline the possibilities of creating, storing, exchanging, and using the organization's documentary knowledge. Such strategies are accompanied by the need to codify and store knowledge with the help of information technologies and create opportunities for the reuse of knowledge.

As the example we made the analysis of the huge industrial company dealing with mining equipment. These studies were carried out as part of an investment project for one of the companies that conducts its production activities in Western Donbas in Ukraine (Dychkovskyi et al., 2013). An industrial enterprise is going to rent new high technological equipment. The cost of rent is 500 thousand euros per year. The contract must be signed for several years, therefore, even before reaching the break-even point, you will not be able to immediately return the equipment. You are going to sign a contract, hoping that modern equipment will save on labor and raw materials costs, and think that the logistics of new equipment will be cheaper. The ranges of expected savings and annual production are given in Table 2.

**Table 2.**

*Initial data for analysis*

Parameters	Value
Maintenance savings, MS	5-15 Euro per unit
Labor savings, LS	0-6 Euro per unit
Raw materials savings, RMS	4-12 Euro per unit
Production level, PL	20 000-40 000 units per year
Break-even	500 000 Euro

The mean annual saving is:

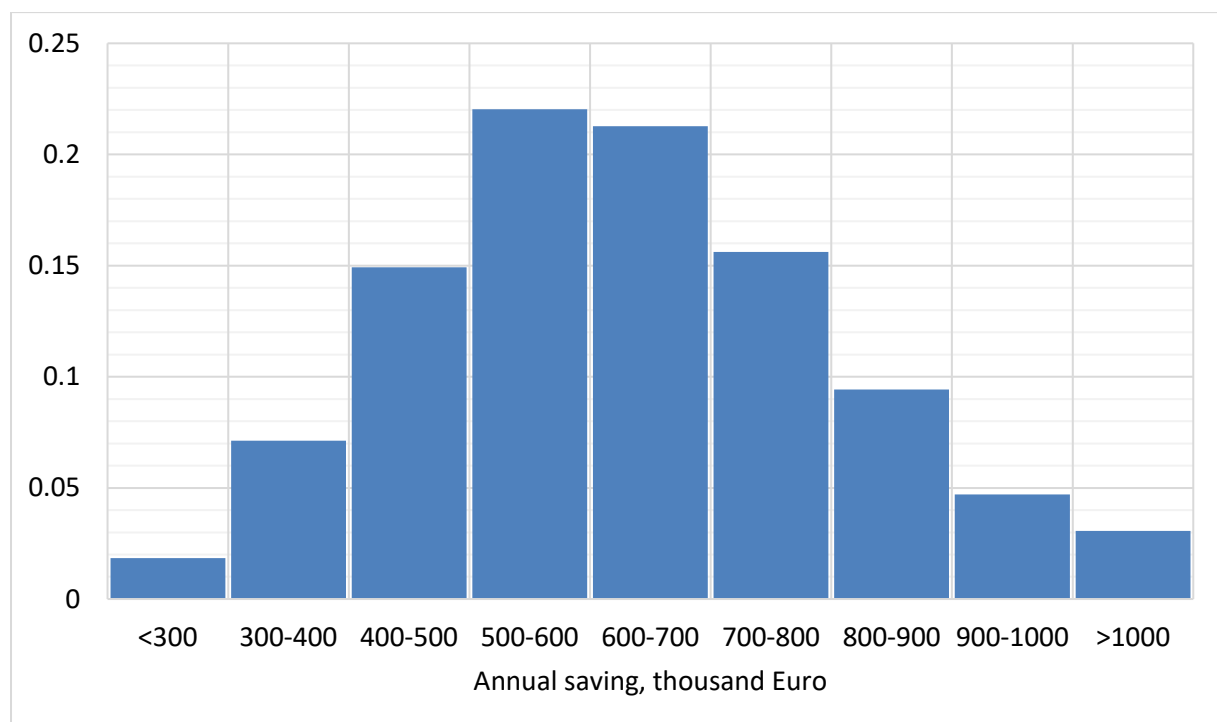
$$(MS + LS + RMS) \cdot PL = (10 + 3 + 8) \cdot 35\,000 = 630\,000 \text{ Euro.}$$

It looks like we not only broke even, but also made some profit, but remember, there are uncertainties. So, we had to provide the riskiness of these investments. Let's determine the probability that we will not break even, that is, that our savings will be less than the annual cost of renting equipment. Monte Carlo simulation is an excellent way to solve such problems. We will randomly select values in the specified intervals, substitute them into the formula for calculating the annual savings and calculate the total. Some results will exceed the calculated mean value of 630,000 euros, while others will be lower. Some will even be below the €500,000 required to break even.

In this study, we use a normal distribution with 90% confidence intervals and 10 000 scenarios. The simulation result is represented in Table 3. Distribution of annual savings by value ranges is presented in Fig. 2.

**Table 3.***The simulation result for the riskiness evaluation*

Scenario	MS	LS	RMS	PL	Annual saving	Break-even
90% CI	5-15	0-6	4-12	20 000-40 000		> €500 000
1	8,8	1,1	12,3	32 057	713 524	True
2	4,9	0,1	4,8	30 139	295 607	False
3	8,8	3,3	2,1	33 825	479 112	False
4	17,0	2,9	3,5	35 253	825 770	True
5	9,1	0,8	10,2	31 878	640 316	True
6	10,2	2,3	12,1	25 657	629 381	True
7	8,4	2,6	10,2	30 691	653 318	True
8	11,7	2,1	9,8	23 148	546 694	True
9	6,8	5,3	7,1	39 145	752 843	True
10	16,4	3,2	4,8	29 551	723 021	True
...	...	...	...	...	...	...
9995	14,3	1,5	12,4	39 051	1 101 146	True
9996	9,6	0,6	3,6	27 749	383 956	False
9997	9,4	1,4	10,1	23 574	493 253	False
9998	10,0	4,5	13,1	28 939	799 440	True
9999	13,0	0,6	6,5	36 812	741 727	True
10000	5,7	1,0	6,5	32 388	428 883	False

**Figure 2.** Distribution of annual savings by value ranges.

Of all the resulting annual savings, about 25% will be less than 500 thousand euros. This means that the probability of damage is 25%. This number represents a meaningful risk assessment.

The choice of which affine approximation to use depends on the problem to be solved. In some applications it is important to compute interval bounds which contain only positive numbers, e.g. computation of the square root. In such cases, the min-range approximation should be chosen. The range optimality is also needed in computer graphics (de Figueiredo,

Stolfi, 1997) or when the denominator of an expression is an affine form. In the latter case, the narrower interval is less likely to contain zero.

When uncertainty is described using fuzzy numbers, a decision-maker can give arbitrary values of possibility degrees according to own feelings. Fuzzy approach does not impose the form of expression of subjective opinions as much as probabilistic approach does Kuchta (2001). Mohammed and McCowan (2001) argue that for most practitioners triangular and trapezoidal fuzzy numbers are much easier to understand and to apply than probability distributions. People hardly think in probabilistic terms, fuzzy sets notation or linguistic description of uncertainty seems to be more natural and much closer to human thinking. The construction of a triangular fuzzy number based on the best, the worst and average values is closer to the possibility theory than to the probability theory (Mohammed, McCowan, 2001). Moreover, many authors question the legitimacy of modeling the absolute lack of knowledge about selected parameter using uniform probability distribution (Baudrit et al., 2006; Shafer, 1976).

The consideration of knowledge elements in mining organization activity is relevant to the operating process for the development of a company and is accompanied by defining its priorities. Focusing on the key activities of an organization will allow firm to transform available information about a risk into specific knowledge. This knowledge includes the distinctive features of a project potential consequences and gives a manager the basic idea of making decision on project applying. It is necessary to do this based on knowledge management cycle (see Table 4) (Polyanska, Malynka, 2014).

**Table 4.**

*Knowledge elements which should be considered in the context of mining company project realization*

<b>Knowledge management cycle</b>	<b>General characteristics</b>	<b>Knowledge management implication on project activity in mining company</b>
Review	Result estimate Comparison of old and new results	State of new possibilities of equipment usage that are given as result of it exploration
Conceptualize	Check (review) of knowledge and organizational context. Analysis of strengths and weaknesses	Justification of the idea of total saving of resources in the project and its advantages Determination of the impact of the environment on the implementation of the project, as well as the consequences of the implementation of the project
Reflect	Identification and necessary improvements. Improvement planning	Working out of production programs, achieving the appropriate level of product brake even point, working out the training program for people, raw material resources saving program
Act	Knowledge synthesis. Knowledge combination, information technologies.	Human resources management in conditions of changes. Knowledge about risks of project realization. Knowledge allocation among spheres of project activity

So, getting results of uncertainty analysis that indicating the risk on a project, create preconditions for working out appropriate measures of potential risk limitation or mitigation that, in turn could transform in knowledge and be used in management of organization. On the example of the mining company, it can be said that the obtained indicators gave an opportunity annual savings, about 25 % will be less than 500 thousand euros that is quite risky for project implementation.

It should be noted that the next step to the application and dissemination of methods, investigating the uncertainty impact on the enterprise's activities proposed in the article, will be the integration of the acquired knowledge into the decision support system at the enterprise. Today, research in this direction covers the issue of using the acquired knowledge through decision support systems (DSS). Moreover, today these systems are expanding their functions to support knowledge work using the so-called "knowledge work support systems" (Burstein, Carlsson, 2008).

## 6. Discussions

To examine the possibilities of knowledge management for getting necessary for company information on its activity results, the methods of uncertainty analysis were discussed. A study is based on the interval regression and affine arithmetic and could successfully be used to model dependencies between uncertain parameters. In the literature there is a lack of research that exploits these two approaches. Continuous efforts will be required to rely on using besides probability and possibility distributions also interval numbers, to represent uncertainty. This combination of uncertainty descriptions has been not yet used to solve decision problems in a company. Whereas preliminary research shows that it can be successfully applied to more accurate LCA models. Another study will be conducted on simultaneous processing of different descriptions of uncertainty, without the need for transformation between them. Finally, it must be emphasized that the research conducted in this study focuses on hybrid LCA. The resulting models and methods can be successfully used in the analyses in other areas, e.g., in financial analysis or economic problems. Considerations about relations between economic and environmental parameters are crucial for hybrid data processing. Economic and environmental problems often involve parameters that are mutually correlated. For example, there is a correlation between enterprise product prices and raw material prices or between volumes of sales of different assortments, as well as the number of shares of pollutions of the environment. The omission of these dependencies leads to systematic errors in calculations. Proposition of methods for processing hybrid data allows simultaneous consideration and processing of different types of uncertainty in LCA model. Moreover, based on this, future LCA work would benefit from the results for the evaluation of the effectiveness and risks of LCA projects.

So, results of uncertainty analysis provide new or additional knowledge for its further exploitation in organization management.

## 7. Conclusions and recommendations

This study focuses on the management of knowledge that is acquired by analyzing the uncertainties in the LCA models based on the hybrid approach combining MC simulation and fuzzy logic, as applied to fuzzy set theory, being an alternative way of modeling of uncertainty.

The methods for hybrid data processing have two main weaknesses which limit their practical usage. First, they do not account for interdependencies between parameters described by different representation of uncertainty, which causes systematic errors in the results. The second weakness is the lack of easy-to-interpret measures synthetically expressing uncertainty of the result of an LCA.

The proposed approaches to uncertainty assessment methods combination with hybrid LCA method were considered on the example of industrial company dealing with mining equipment. The obtained results allow summing up the next conclusions:

- this method combines several tools and mathematical mechanisms and is quite effective in evaluating investment projects;
- it makes the possibility to assess the riskiness of investments with a high reliability and to reduce them;
- by considering knowledge management cycle the potential of Knowledge management implication on project activity in mining company was considering.

It is hoped that the presented study will substantially increase the knowledge on processing of hybrid descriptions of uncertainty. This subject is still relatively new and the scope of applications of hybrid models is not, yet, well recognized. Presented study move the hybrid LCA one step forward. In the future, it is planned to carry out research on the implementation of knowledge management in the decision support system, which makes it easier for managers to make decisions in conditions of uncertainty with help of discussed methods.

As a result of the mentioned above, the main direction of our further research is to consider the ways of knowledge management implementation in the organizational decision support system, especially in mining enterprises. This requires a more detailed study of the organizational system of the enterprise and the level of its digitalization and the potential for continuous improvement as well as justification of possible methods of accumulation, storage and flexible use of data obtained from experience in decision support systems with the analysis and evaluation of the performance of these systems.

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## DIGITAL TRUST AND AWARENESS SECURITY OF THE NETWORK IN THE NEW ECOSYSTEM OF VALUE EXCHANGE (CONSUMER- ENTERPRISE)

Wiesława CAPUTA<sup>1\*</sup>, Izabela KRAWCZYK-SOKOŁOWSKA<sup>2</sup>, Mariola GRZEBYK<sup>3</sup>,  
Małgorzata STEC<sup>4</sup>

<sup>1</sup> Uniwersytet WSB Merito w Poznaniu; wieslawa.caputa@chorzow.merito.pl, ORCID: 0000-0002-0955-9308

<sup>2</sup> Faculty of Management, Czestochowa University of Technology; i.krawczyk-sokolowska@pcz.pl,  
ORCID: 0000-0002-2784-1577

<sup>3</sup> Institute of Economics and Finance, University of Rzeszów; mgrzebyk@ur.edu.pl,  
ORCID: 0000-0003-1107-0250

<sup>4</sup> Institute of Economics and Finance, University of Rzeszów; mstec@ur.edu.pl, ORCID: 0000-0003-0185-4510

\* Correspondence author

**Purpose:** The key aim of the article is to demonstrate that creating awareness of the network's potential is related to the need to develop and implement a digital trust model also on the client's side.

**Methodology:** The implementation of the goal is based on: a critical analysis of literature and the analysis of statistical data and reports containing the results of representative research focused on the attitudes and behaviors of enterprises and consumers in the context of their digital awareness. The research was carried out using a systemic approach and reference was made to behavioral concepts of personality.

**Findings:** We show that:

- a low level of awareness does not preclude digital trust in the provider, but the resistance to trust increases with increasing awareness of network security and translates positively into the dually defined value for the client,
- the need to build a model of trust from the customer's perspective.

**Research limitation:** Our work has limitations. Analyzing the client's awareness only through behavior, referring to a limited extent to social and specific factors determining human personality. We omit the issue of identifying the factors determining trust in the context of the duration of the relationship.

**Practical implications:** Basing the awareness of the network potential on the triad of perception, action, knowledge can point the way to establishing network awareness and digital trust in the enterprise. It can be a guideline to search for factors determining their formation and measures of effectiveness of activities undertaken in this area.

**Social implications:** The entire process of building a safety culture - not only of the enterprise, but also of the entire society - can be based on the (PAK) approach. The identified factor may be important for educational activities.

**Originality/value** The dominant part of research focuses on the search for and implementation of trust models from the perspective of bidders. However, there is a lack of research that considers digital trust from the customer's perspective and connects it with the awareness of

network security. The article is addressed to scientists and practitioners who are interested in creating digital awareness and digital trust in online relationships.

**Keywords:** awareness of network potential, digital trust, customer value, ecosystem.

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

## 1. Introduction

One of the most significant changes in the environment is the ongoing digitization process. It is commonly emphasized that the digital progress observed in recent years has translated into the creation of a wide range of systems with enormous possibilities (Wirtz et al., 2018).

With the dynamic development of the above-mentioned solutions, more and more often there is talk not only about the need to implement them or multidimensional use, but also about the need to ensure the safety of their use.

Practice confirms the growing number and cost of cyberattacks, despite the systematic implementation of new security solutions. Cybercrime research entities around the world indicate that the expanding threat landscape and new business innovations translate into an increase in the number of cyberattacks (Ninth Annual Costof Cybercrime Study, 2019). This also applies to the Polish economy, where the number of cyberattacks increased by 46% in 2022 alone.

According to PwC data, registered acts of cyber-aggression in 33 percent cases translated into financial losses, in 31 percent resulted in the disclosure or modification of data. In 16 percent contributed to the loss of the company's reputation. TNS reports that one in three large domestic companies expect a major attack in the next three months (Lobschat et al., 2021).

The process of digital transformation now applies to everything and everyone, and thus creates a new ecosystem of value exchange. This ecosystem creates new opportunities for exchange participants, but also poses new challenges and creates new threats.

From the business perspective, changing the ecosystem of establishing and developing relationships with customers is of key importance. These relations determine the capital supply to the enterprise, and thus its value. This relationship is based on a dually defined but mutually correlated customer value (Caputa et al., 2021). Research shows that the customer value defined from the perspective of both sides of the relationship is related to customer satisfaction, closeness, trust and commitment (Payne et al., 2008; Caputa, 2020; Rouhi, Geiger, 2023). Let us consider these factors as universal value-creating factors. However, we see the need for a broader and more comprehensive embedding of these factors in the new virtual exchange ecosystem, which is not immune to multidimensional threats.

The openness of this ecosystem, its network character and its software-based basis make it necessary to base it on relationships between not only the company and the client, but also network users, regardless of their intentions in using the software to make contact.

Such embedding, on the one hand, allowed us to show that in the new ecosystem of exchange, the potential of network awareness and the ability to use it is not only a factor determining the dually defined customer value, but also a factor that necessitates a new look at trust.

We pose the question whether, in a world dominated by new technologies that can be used for various purposes, it is in the interest of the client to trust the offer, or rather to be resistant to trust.

We assume that this resistance increases with the increase in network security awareness and translates positively into dually defined value for the client.

The key aim of the article is to demonstrate that creating awareness of the network's potential is related to the need to develop and implement a digital trust model also on the client's side.

We base the implementation of the indicated goals on literature studies and qualitative research based on a review of statistical data and reports containing the results of the represented research focused on the basics and behavior of customers in the digital environment. Indicating the relationships between: customer value, awareness of network security, digital trust and trust resistance, we rely on the purchasing process implemented in the e-commerce industry. It is the fastest growing industry that engages consumers in a multidimensional way, allowing them to present the entire purchasing process.

Striving to achieve the goals indicated in the following points:

1. We present a model of customer value creation and identify universal factors determining this value in a new ecosystem of customer-enterprise value exchange.
2. We define the potential of network awareness in the context of the security of both sides of the relationship.
3. Present the current concepts of defining trust, demonstrating the necessity of separating digital trust and its analysis in relation to the awareness of online security.
4. Based on empirical research, we identify the declared and actual customer awareness by relating the research results to the image of the company-customer relationship on the E-commerce market in Poland. On this basis, we indicate the relationship between trust and awareness of the network's potential.

As a result of the conducted research, we demonstrate the legitimacy of creating customer resilience.

Any use of technology that is not intended by both parties to the relationship temporarily or gradually affects the mutual relationship, changing the perceived benefits, threats and threats of the relationship. Therefore, we demonstrate the need to seek and implement trust models not only on the part of the offerer, but also the client.

## 2. The model of customer value creation in the new ecosystem of customer-enterprise value exchange

Starting from the last decade of the 20th century, we have been observing a progressing digitization process, which is directly related to the increase in the use of digital and computer technologies

Consequently, all processes of individual and collective activity are shaped by the new technological medium. The increase in the turbulence of the environment is accompanied by an increase in the number of interactions that, while setting the direction of development, are also unpredictable, which translates into an increase in risk, which increasingly concerns the security of the multidimensional use of technology and the potential of network users.

In the light of the above considerations, it is reasonable to say that the ongoing digitization process has created conditions for establishing relationships and interactions with many entities in real time to achieve multidimensional goals in open space. These conditions are conducive to the development of ecosystems. It should be emphasized, however, that this category is not uniformly defined.

**Table 1.**  
*Overview of selected concepts for defining the ecosystem*

<b>Ecosystem</b>	<b>Source</b>	<b>Source Definition</b>
<b>Business ecosystem</b>	Moore, J.F., 1993. Predators and prey. A new ecology of competition. <i>Harvard Business Review</i> , 71(3), 75-86.	Is the company's external environment.
	Eisenhardt, K.M., Galunic, D.C., 2000. Coevolving: at last, a way to make synergies. <i>Harvard Business Review</i> , 78, 91-101.	Has its roots in the idea of a value network and can be seen as a group of companies that simultaneously create value by combining their skills and assets.
<b>A sustainable entrepreneurial ecosystem</b>	Cohen, B., 2006. Sustainable valley entrepreneurial ecosystems. <i>Business Strategy and Environment</i> , 15, 1-14.	Interconnected groups of actors in a local geographic community committed to sustainable development by supporting and facilitating new sustainable ventures.
<b>Entrepreneurial ecosystem</b>	Mason, C., Brown, R., 2014. Entrepreneurial ecosystems and growth oriented entrepreneurship. <i>Final Report to OECD</i> , 30, 1. Paris, 77-102.	A collection of interconnected entrepreneurial entities, entrepreneurial organizations, institutions and entrepreneurial processes that formally and informally come together to connect, mediate and manage results in a local entrepreneurial environment.

Cont. table 1.

<b>Ecosystem entrepreneurship</b>	Malecki, E.J., 2018. Entrepreneurship and entrepreneurial ecosystems. <i>Geography Compass</i> , 12, 3, e12359.	Dynamic local social, institutional and cultural processes and actors that encourage and enhance the creation and growth of new businesses.
	Spigel, B. 2017. The relational organization of entrepreneurial ecosystems. <i>Entrepreneurship Theory and Practice</i> , 41(1), 49-72.	Combinations of social, political and cultural elements in the region that support the development and growth of innovative start-ups and encourage start-up entrepreneurs and other entities to take risks related to establishing, financing and otherwise supporting high-risk ventures.
	Cantner, U., Cunningham, J.A., Lehmann, E.E., Menter, M., 2021. Entrepreneurial ecosystems: a dynamic lifecycle model. <i>Small Business Economics</i> , 57, 1, 407-423.	Interactions between nearby entities disseminating and commercializing new ideas through intrapreneurship. The basic function of ecosystem activity is entrepreneurship, representing the diffusion of previously uncommercialized knowledge and ideas.
<b>Innovation ecosystem</b>	Adner, R., 2006. Match your innovation strategy to your innovation ecosystem. <i>Harvard Business Review</i> , 84(4), 98-107; Frenkel, A., Maital, S., 2014. Mapping national innovation ecosystems: Foundations for policy consensus. In: Mapping national innovation ecosystems: Foundations for policy consensus (edward elg).	Interactions between different industry and innovation actors or stakeholders. The most important of these actors are enterprises - large and small companies, start-ups and entrepreneurs, financial markets, universities and research-related organizations and NGOs and government institutions.
	Shaw, D.R., Allen, T., 2018. Studying innovation ecosystems using ecology theory. <i>Technological Forecasting and Social Change</i> , Vol. 136, November, 88-10.	Interconnections of business models with paths that transfer material and information resources, as well as values. Business models are similar to an organism's genome in that they describe the limits of feeling, acting, and understanding.

Source: own elaboration.

Taking into account the overview of definitions of selected concepts of defining ecosystems presented in Table 1, it is not difficult to prove that each ecosystem has its actors. Each type of ecosystem is directly geared towards value co-creation (Aarikka-Stenroos, Ritala, 2017; Kapoor, Lee, 2013). However, co-creation is driven by different processes in different types of ecosystems. Unlike networks, co-creation of value in ecosystems does not necessarily involve explicit principles of value capture (Bouncken et al., 2020). Importantly, a multi-stakeholder approach is taken in co-creation of value in ecosystems (Bacon, Williams, 2021), going beyond the classical linear, i.e. sequential approach to joint value creation. Indeed, in ecosystems, co-creation of value with customers and even communities with customers (Prahalad, Ramaswamy, 2004) goes much further, involving co-creation with other external actors and even entire networks of actors (Vargo, Lusch, 2011). This confirms the earlier statement that, regardless of the type of ecosystem, each has a purpose.

It is generally accepted that the main goal of a company is to create value. This process takes place in changing environmental conditions. The result of this process from the company's perspective should be the multiplication of the invested capital (Jonek-Kowalska, 2012). It is therefore in the interest of the company to acquire such a client who is profitable and able

to provide the capital desired by the company for the longest possible period (Alsyouf, 2007). The consequence of this is the need to establish and develop lasting and profitable relationships with customers, which are based on dually defined customer value (Caputa et al., 2021).

From the customer's perspective, this value reflects the ability of the product offered on the market to solve its subjective, multidimensional needs (Swenney, Soutar, 2001, Caputa, 2020).

The customer value assessed from the company's perspective is not only directly related to the assessment of the customer's readiness and ability to make purchases (transaction value), but also his readiness and ability to launch such an information message that can contribute to the value creation process (resource value) (Payne et al., 2008; Rouhi, Geiger, 2023).

There are correlations between the value for the customer and the value of the customer. As a result, the dually perceived customer value can be defined as a complex bundle of benefits: economic, technical, emotional and social contained in the product and accompanying services, which arises as a result of the involvement of the company's knowledge resources and related value network partners, creating the opportunity to obtain capital supply securing the implementation of the company's interests.

Maximizing the above-mentioned benefits in the long term for both sides of the relationship raises the need to transform contacts into lasting and profitable relationships.

Achieving such an effect requires not only creating a state of satisfaction, but also maintaining and developing ties, which, along with their duration, should be increasingly based on trust and commitment of the parties (cognitive-emotional phase).

This increases the likelihood of a transition from the customer's intention (cognitive loyalty) to the willingness to take action (actional loyalty). Creating such relationships requires interactions that boil down to a constant game between the subjective expectations of both parties to the relationship and the objective possibilities of satisfying them (Caputa et al., 2021).

However, the classic value creation process indicated in the figure cannot be separated from the ongoing digitization process, which, by transferring business processes to the network, creates:

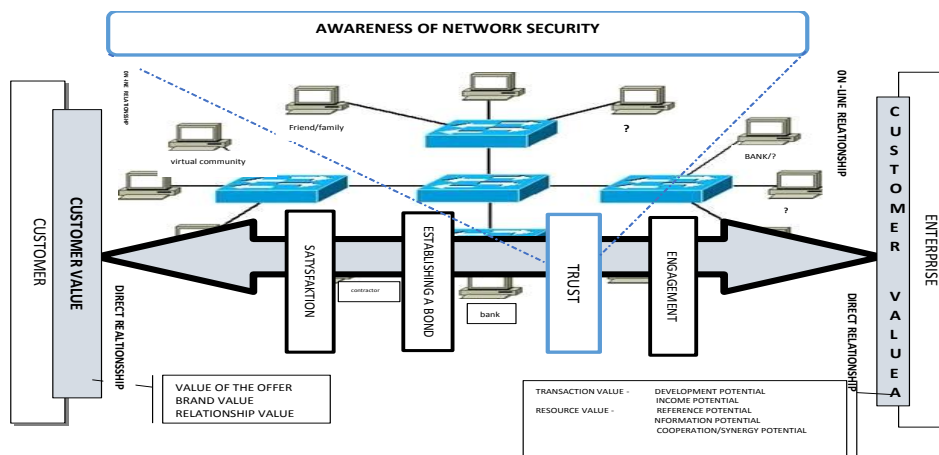
- a new relationship that is established through technology with known, unknown and invisible entities operating in the network,
- a new customer who no longer wants to be a passive participant in the exchange,
- a new environment, created with the use of information technology, which in a multimedia way creates a computer vision of objects, space and events, enables interaction and the flow and processing of information in real time.

As a result, digitization changes the purchase and sale process, opens the way to obtaining information and knowledge from many sources. Each network user may: support other users in making decisions and use their support, share experiences, create a virtual community of brands, or have a negative impact on brand perception, create communities and/or participate in virtual communities and use them for their own purposes, warn against threats, including



those related to computer use, network activity or the use of software, and to be the creator of such threats.

Therefore, we are dealing with the opening of the process of creating customer value, which, based on the network of relationships and interactions, can be used by both parties to the relationship to achieve individual and/or common goals, with the support of other entities and institutions. Therefore, we can talk about a new ecosystem of value exchange, which is evolving along with the ongoing digitization process (Figure 1).



**Figure 1.** Model of creating relations with clients.

Source: own study.

This ecosystem offers a range of opportunities, but it is based on the use of technology and networks. As a result, both sides of the relationship must be willing and able to use it to meet their own needs. As a consequence, this means that each element of the dually defined customer value and each factor determining the durability and profitability of the relationship determines the awareness of the network's potential and the ability to use it.

### 3. Awareness of the network's potential and the ability to use it

The category of consciousness has no uniform interpretation (Vimal, 2009). Consciousness is the state or ability to perceive, feel, or be aware of events, objects, or sensory patterns (Najafi, 2012). In the general sense, consciousness is identified with the intellectual state of individuals or society, which results from the degree of knowledge, understanding and rational evaluation of facts or events (Pazio, Formanowska, 2002). It is also associated with knowledge and the ability to use it rationally in the context of an emerging problem (Szumlicz, 2006). In the narrow sense, consciousness is a measure or indicator of the intellectual level of individuals and social groups.

Therefore, the concept of consciousness is associated with the ability to generate, process and use information. This ability is largely conditioned by human personality, i.e. "a set of permanent and variable psychophysical features that are associated with all human activities, experiences and needs at the physiological, characterological, intellectual and spiritual level" (Horzyk, 2012).

We assume that although consciousness remains associated with knowledge, i.e. with the intellectual level, it is in fact a mental state (a set of mental states) in which the individual is aware of his own thought processes (self-awareness) and phenomena occurring in the external environment and is able to react to them. According to P. Carruthers, the degree to which a person "is aware of an object/event is actually the degree of intensity and accuracy of the perceptions generated by that object/event, resulting from the degree of attention paid" (Carruthers, 2003). This perception of consciousness is related to the need for security.

Building a customer-enterprise relationship in the virtual space is inextricably linked to the need to meet the need for security. In general terms, security means a state in which an individual feels confident and does not identify any threats. It is a subjective state (Williams, 2008). Therefore, it can be assumed that security is a function of the two main risk factors and the probability of its occurrence.

This need, in a new environment, takes on a new dimension. The threat, as a rule, is not material. Its source is the space where data and information processing and interactions in ICT networks take place (Zhang, 2020). The source of the threat can be found at every stage of building a relationship, even before establishing a transactional contact (Caputa, 2020). These threats can have a negative impact on customer satisfaction, trust and engagement. Therefore, the risks must be important to both the customer and the seller.

Therefore, security awareness should be associated on the one hand with the customer's willingness and ability to perceive these threats, and on the other hand with the tendency to take action against their negative effects, which is related to the risk assessment of the threat and confidence in protective measures. In a virtual network, digital situational awareness is required (Tadda et al., 2006), which is a three-step process that includes recognition (or awareness of the current network situation); understanding (or awareness of malicious behavior in the current network situation); and projection (evaluation of malicious behavior in the current network situation). Awareness of the potential of the digital network means the ability of the general public to use online services and information and communication technologies effectively. Using a digital system requires clients to be computer literate, understand digital documents, and websites, and the risks involved (Tripathi, Gupta, 2020). Awareness of digital relationships plays an important role in ensuring effective digital communication as participants need to be aware of behaviors and responsibilities people with whom they interact. Awareness of potential includes the ability and knowledge necessary to use digital tools and the ability to sense, know and perceive digital developments around the individual (Karakuş, Kılıç, 2022). In an open space, technology can be used by others in a way that puts the well-being of the client or the

reputation of the company at risk (Caputa, 2020). As a result, the course of the relationship and its effects also depend on the awareness of network threats and the ability to limit them.

Threats resulting from the need to use technology and the use of network relationships require a new look at trust as a factor determining customer value. If an unknown network user, through the use of technology and the network, can interfere in the course of the relationship in a way that reduces the benefits of both parties to the relationship. Each party to the relationship must, on the one hand, build relationships based on trust, but on the other hand, demonstrate resistance to digital trust.

#### 4. Digital trust and determinants of trust

Trust is an interdisciplinary concept. In the literature, this concept is to: a kind of belief in the good will of the other subject (Seligman, 1997), created in conditions of non-transparency of his intentions and will, *a bet made on the uncertain future actions of other people* (Sztompka, 2005) the belief that the results of the actions of others will be appropriate from the perspective of the evaluator the expectation of a person or group that they can rely on the word or promise of another person or group (Rotter, 1980) the expectation of favorable behavior from someone in a socially precarious situation based on the knowledge of his inclinations (Yamagishi, 2002).

Trust means the subjective belief of the parties to the relationship regarding maintaining credibility in the context of potential risk. Due to the subjective nature of trust, it may result from relational and individual characteristics. The attributes of relational trust occur and relate to relationships with other entities, and the dimensions of the individual are derived from the individual's own characteristics.

Among the factors affecting trust, conditions should be distinguished that include internal and/or external properties, such as the mental state of the individual and the social/political relationships of the entities (Cho et al., 2015). Risk critically affects the relationship of trust, i.e. readiness to taking risks under conditions of uncertainty (Luhmann, 1979). Faith, i.e. belief based on irrational grounds (Castelfranchi, Falcone, 2010). Fear, or "perceived risk" that is unbearable or unmanageable as extreme distrust. A feeling is something that the subject "feels" in the context of the subject, a feeling formed on the basis of experiences, dispositions, intuitions, knowledge and/or implicit learning (Castelfranchi, 2009). Dunn and Schweitzer show that positive emotional well-being (e.g. happiness, hope) increases trust, while negative emotional well-being (e.g. fear, guilt) lowers trust (Dunn, Schweitzer, 2005). Belief, fear, feeling and emotional well-being are components related to individual characteristics that affect trust. On the other hand, the group of conditions affecting trust includes controls (Castelfranchi, Falcone, 2010), which can complement trust and lead to its growth or loss. In the context of trust and risk, there is also institutional trust associated with norms and regulations to protect

the parties to a relationship of threat or abuse of trust. An important element of trust is cooperation recognized as a result of the relationship, in which the foundation is the durability of the relationship based on the possibility of mutual reward and reciprocity of benefits, i.e. cooperation of behavior for others (Gambetta, 1988). Another factor is the transfer of responsibility through the process of delegating activities to other entities (Castelfranchi, 2009).

Digital trust "underlies every digital interaction" (Gartner, 2017). Trust in digital services creates a new type of relationship and addresses certain trust in people and technological processes to create a secure digital world (Joyce, 2018). Digital trust reflects the customer's belief that the organization collects, stores and uses their information responsibly and that they protect that information. (Accenture, Digital Trust..., 2017) This trust is seen as a separate but potentially co-existing mechanism to reduce the uncertainty and complexity of transactions and relationships in electronic markets. The basis for such action is the ability to communicate in an open space, which can be reduced to the ability to share oneself. According to M. Heidegger, the dynamically advancing digitization process allowed to overcome the distance, but did not create closeness (Fors, 2010). The customer can therefore trust companies, buy their products and recommend them to others, which, however, does not mean that they will be immune to the actions of competing entities. It also does not mean that he has a sense of personal security and the processes in which he participates. The company must therefore strengthen its credibility and the level of acceptability, which is facilitated by the inclusion of the customer in the value creation process, which is related to his involvement.

As a result, the customer's trust can be combined with a subjective assessment of the company's willingness and ability to solve its problem, made under conditions of risk and uncertainty. The risk decreases with the increase in the level of knowledge, which means that the customer experience and the intensity and quality of knowledge transfer between the indicated parties to the relationship positively translate into the level of trust.

This statement is confirmed by research which shows that one of the important correlates of trust are previous experience and the prospect of repeated transactions with the bidder (Williamson, 2014). The quoted studies also indicate other determinants, such as: trust or distrust as an individual feature of the client's personality, factors related to the level of service and competence of people directly serving the client, or the level of legal and institutional protection of the client.

A significant impact on trust is also exerted by current impressions (Delgado-Ballester, Manuera-Aleman, 2000), which in the "flat world" should also be combined with the possibility and consequences of establishing relationships by the client and the company in the network.

Consequently, this means that trust, remaining in the network of: suppliers, distributors, subcontractors, producers of related products and other entities that affect the creation and delivery of the company's products and are the subject of their impact, is a derivative of the ecosystem in which the exchange takes place. Therefore, when creating relationships based on trust, the company faces the need to influence the entities of the ecosystem in such a way that

it is conducive to building positive customer experiences and impressions, and such an impact on the customer that strengthens the bond between him and the company.

## 5. Research methodology

Literature studies have shown that the progressive development of digital transformation transfers relationships to the network, which enables interactions between all its users. This is conducive to the development of ecosystems, which by nature are oriented towards co-creation of value (Aarikka-Stenroos, Ritala, 2017), with the involvement of many actors (Bacon, Williams, 2021).

This blurs the boundaries of the enterprise and expands the client's space. Based on the systemic approach (Jackson, 2000) and referring to the achievements of institutional economics and relationship marketing, we assume that the company and the client are entangled in a network of relationships and interactions. This network is now being created through technology. As a result, the establishment of a relationship and its development with the participation of its users at the very beginning depends on the acceptance of the use of technology and the ability to use it in a multidimensional way to build a relationship based on dually defined customer value. Thus, the awareness of the network's potential, i.e. the readiness and ability of both parties to the relationship to use technology, create and use the network's potential, determines the value of the customer. This awareness cannot be separated from the threats resulting from the use of technology as well as relationships and interactions established on the web.

Awareness of online security in the context of creating customer value becomes the main subject of our research. We base this study on the triad: perception, action, knowledge (PAK).

Consciousness, being a set of mental states, is therefore related to personality. Referring to the behavioral concepts of personality (Pawlov, Watson, Skinner, Hull) we assume that a person throughout his entire personal and social development, as a result of the influence of positive stimuli or negative, learns various forms of behavior and reactions, also under the influence of rewards and punishments. As a result, his awareness changes through gaining experience or obtaining information. This leads to the following assumptions:

- the leading factor determining network security awareness is age (H1),
- there is a difference between the declared and real potential of network security awareness (H2).

The acceptance of technology in establishing and developing relationships is closely related to trust. In the digital world, this trust applies to the technology itself as well as to the entity that uses it. As a consequence, the trust that underpins any lasting relationship is becoming digital. Just like awareness, trust is related to a person's personality. The key objective of the study is therefore to identify the relationships between the awareness of the network's potential, digital trust and customer value.

We pose the question whether, in a world dominated by new technologies that can be used for various purposes, it is in the customer's interest to trust the offer and the way to satisfy the need, or rather to be resistant to trust.

We assume that a low level of awareness does not preclude digital trust in the provider, but the resistance to trust increases with increasing awareness of network security and translates positively into the dually defined value for the client (H3).

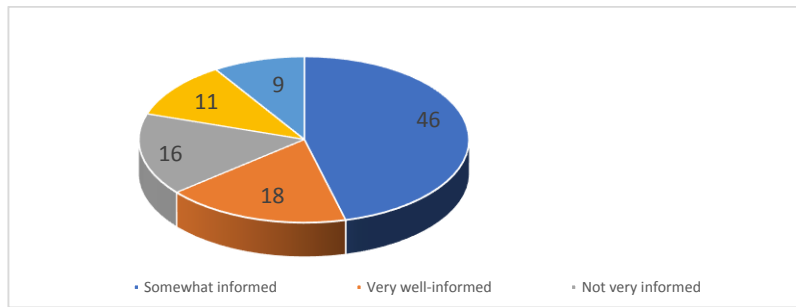
This is a new context of research, which, unlike the previous ones, does not focus on the company, but on the client as an entity who, being entangled in the network of relationships established through technology, has to take care of his own safety, and thus create his own trust model.

Striving to achieve the indicated goals and hypotheses, apart from literature studies, we rely on the analysis of statistical data and the results of representative research relating to the attitudes and behavior of consumers in the digital world, with particular emphasis on the Polish e-consumer.

## 6. Study results

### 6.1. Awareness of the network's potential and trust in the light of research – the perspective of cybersecurity

The legitimacy of the construction of the triad based on three links: perception, action and knowledge is confirmed by the research on cybersecurity awareness that was carried out in 2019 on a sample of 1005 Americans (Consumers' Awareness, 2019). This research focused on answering the question whether consumers are aware of the threats related to privacy and information security on the Internet and how they behave when it comes to protection against cyber threats. The distribution of answers to the question *how do they feel about cybersecurity* Indicated in Figure 2 clearly shows that the majority of respondents declare the existence of a knowledge gap in the field of cybersecurity. Every fourth respondent claims to be uninformed.



**Figure 2.** How do they feel about cybersecurity?

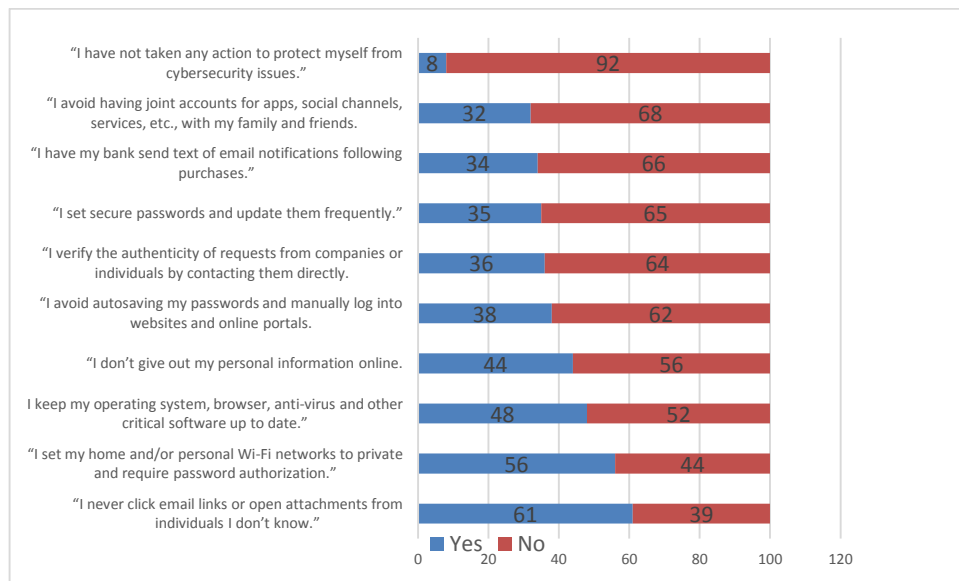
Source: Own study based on: (Consumers' Awareness, 2019).

Every fourth respondent realizes that they do not do everything to ensure their safety (25%). Most see their own activity gap (55%), indicating that they could do more to ensure security, while justifying their attitude with the inconvenience of implementing systems and applying security procedures (55%). These inconveniences, in the subjective opinion of the respondents, are so great that they effectively prevent them from taking action, even if their undertaking would be combined with perfect protection (59%). As a result, the cost-benefit ratio is not attractive to the customer, and therefore does not correlate with the customer's net worth. As a consequence, this means that the client, guided by his own criteria, estimates the level of risk acceptable to him.

According to the research, respondents feel vulnerable to cyberattacks, and therefore defenseless in three areas: community (33%), electronic banking (25%) and online shopping (23%). However, it should be noted that Although nearly one-third (32%) of this year's respondents have had a personal credit or debit card compromised, the number has dropped since 2017. At that time, nearly three-fifths (57%) of consumers reported a compromise to a credit or debit card. In the opinion of the respondents, the most valuable information for them, the acquisition of which would be particularly negative for them, is related primarily to: medical documentation (33%), photos (22%) and financial resources (17%).

It is also worth noting that in 2017, 26% of respondents declared cash payments for purchases from their preferred supplier due to the fact that they had suffered a security breach. Two years later, this share increased to 40%. As a result, it can be concluded that a breach of transaction security does not change trust in the bidder, but it results in a change in the way the transaction is performed. However, their declared behaviors differ in the case of hacking social networking sites. They are no longer tolerant and as many as 95% indicate that they would delete the media account if the platform was compromised.

In the context of the discussed issue, interesting observations are also provided by the results of research characterizing the behavior of respondents relating to security in the network (Figure 3).



**Figure 3.** Actions to secure information security.

Source: own study based on: (Consumers' Awareness, 2019).

Most respond correctly by not opening emails with links or attachments from strangers, secure their home or personal Wi-Fi with a private password, but less than half: take care of the operating system, anti-virus software and constant updates, do not disclose their personal information on the Internet, avoids automatic saving of passwords, avoids having shared accounts. Almost every tenth respondent did not take any actions related to the protection of their cyber security. Despite warnings that simple passwords, including passwords containing the names of pets, were often considered weak, as many as 25% use such passwords.

Research indicates differences between the declared and actual digital awareness of the client, ow. More than half say they are taking steps to reduce the risk of a cyberattack. However:

- few change passwords unless forced to (42%).
- they have a "basic password" which they modify slightly to meet certain password requirements (33%).
- would use a public Wi-Fi network that is not password protected, even for sensitive tasks (35%). Only 19% of respondents would never do it, and 28% declare that they would use such a network for online shopping.

The presented research results became the basis for identifying five types of consumer personality, whose characteristics can be related to the awareness of the potential of the network based on the triad: perception, action, knowledge (Table 2).



**Table 2.**  
*Personality types in the context of the PAK triad*

Personality types	% of respondents	Perception of threats	Action	Knowledge
"Rebellious Olivia"	1	He doesn't understand the importance of cyber security	He doesn't protect himself from it	He doesn't know how to protect himself
"Meticulous Maik"	6	He knows the dangers	He actively wants to protect himself	He took extra steps to gain knowledge
"Trying Terry"	38	He knows the dangers	He actively wants to protect himself	He doesn't have all the information to protect himself, but he's working on improvements
"Ambivalent Endi"	44	He knows the dangers	He will protect himself from it when it is convenient for him	He doesn't worry enough to do anything to protect his data
"Denying Dan"	11	Is somewhat aware of the risks	Does not work to protect itself	Maybe he knows how to protect himself, but he thinks, "there's no way this is going to happen to me"

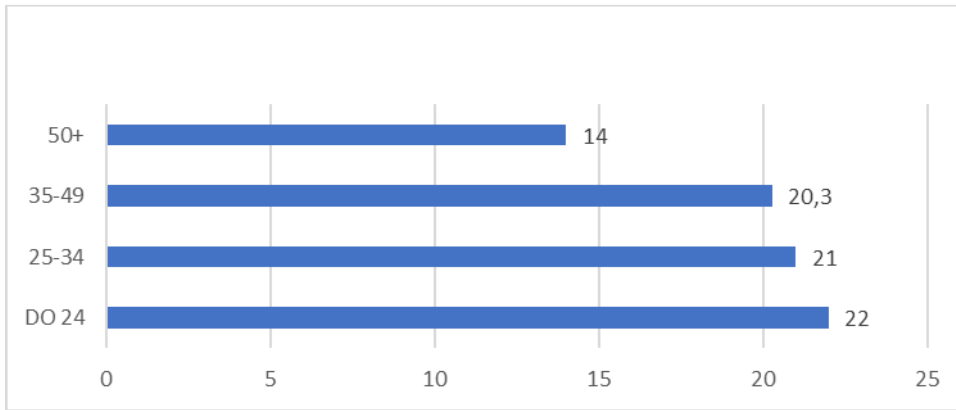
Source: own study based on: (Consumers' Awareness, 2019).

So, the dominant personality types:

- are aware of cyber security threats,
- take action to protect themselves or declare to take action when it is convenient for them,
- they recognize their knowledge gap and strive to fill it, or they are not concerned enough to take appropriate action.

It is worth noting, however, that respondents realizing the importance of cybersecurity expect tougher cybersecurity measures from companies and the government and believe that both parties could do more (44%). The results of the presented research are also confirmed in Poland (Świadomość Polaków...). It is worth noting, however, that in 2022, compared to 2020, an increase of 182% in the number of cyberattacks was recorded in Poland (Poles in cyberspace, 2022). Despite this high dynamics, in representative research by the company "Procontetnt Communication", only 20% of Poles indicated the experience of an attempted attack understood as a violation of their IT infrastructure at work, data in the home Internet network or theft of funds (Poles in cyberspace, 2022). The results of the report show a serious problem of the lack of awareness of Poles in the sphere of cyber threats.

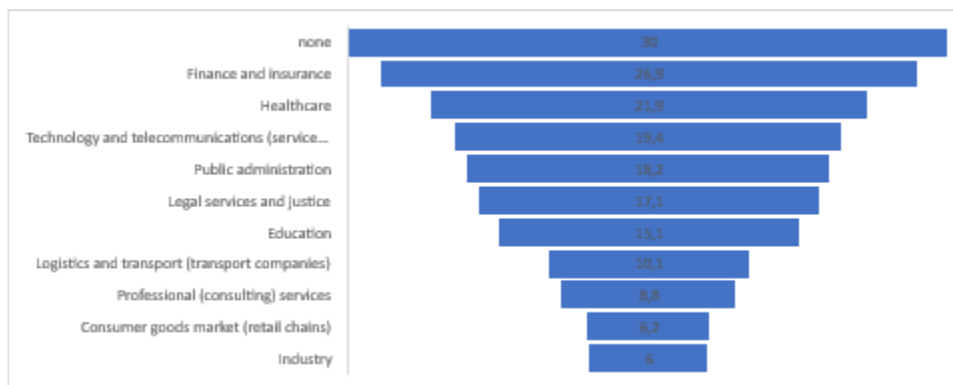
The cited studies indicate that the experience of a cyber attack is mainly differentiated by age. However, the results presented in Figure 4 do not mean greater susceptibility of young people to such practices, but a greater ability to recognize them. As a result, as the authors of the report indicate, the digital awareness of Poles decreases with age. It also changes with the level of their education. Persons with higher education than those with vocational education admitted to being victims of an attack more often.



**Figure 4.** Have you experienced an attempted cyberattack in the last year (yes).

Source: own study based on: (Poles in cyberspace, 2022).

It is also worth noting that 24.1% of respondents indicate a high level of security in the companies they work for, while 11.8% indicate that it is low. Digital trust in individual sectors also varies (Figure 5).



**Figure 5.** Which of the following sectors do you trust the most when it comes to ensuring the security of your data? (max three indications).

Source: own study based on (Poles in cyberspace, 2022).

It is worth emphasizing, however, that this trust is in contrast to the number of recorded cyberattacks.

The set of the most trusted sectors includes: the financial sector, healthcare and telecommunications, where the largest data breach took place in 2021 (Fig. 5). In the set of sectors that enjoy the least trust, there is logistics, where the smallest number of leaks occurred (Global Threat Report, 2022). These results are also confirmed by the analyzes of Check Point Research, which, taking into account all types of attacks around the world, indicates that the scale of threats in 2022 increased by 28%, and in Poland by 22%. The most frequently attacked sectors in the world are: Education and Research (weekly average of 2,148 attacks - an increase of 18%), Government and military sector (1,564, increase by 1,426), healthcare (1,426 with 60% increase), finance and banking (17% increase) and the wholesale-retail sector (4.4%) (Check Point Research..., 2022).

This may mean, as the authors of the report suggest, that effective image building, through communication with clients, protects the indicated sectors against the loss of credibility. It may also mean that the customer is not aware of the number of leaks and their consequences. Therefore, he builds trust on his own experiences. As a result, it is positive experiences that create his trust. However, the cited studies indicate that most of them cannot recognize cyberattacks and do not identify their consequences. This creates the basis for the statement that consumer's digital trust is also based on irrational premises (imagination). As a result, a low level of awareness does not preclude high trust.

## 6.2. The image of online shopping

All cited studies were based on a representative sample, and therefore their results can be confronted with research on consumer attitudes and behavior in the E-Commerce industry (E-Commerce w Polsce, 2022). In the light of the research presented so far, this market enjoyed low consumer confidence and was also vulnerable to cyber attacks. However, it is worth paying attention to the image of the relationship, which is indicated by research on consumer attitudes and behavior in the e-commerce sector (Table 3). The image of this relationship has been positive for years, with a tendency to improve.

**Table 3.**

*The image of online shopping*

Years	Rating	Compliance scale					Rating
		1	2	3	4	5	
2020	<i>is complicated/difficult</i>	2	3	11	27	57	<i>it is uncomplicated/easy</i>
2021		2	3	11	27	57	
2022		2	3	10	25	60	
2020	<i>it is more expensive than buying in traditional stores</i>	5	5	22	29	42	<i>it is cheaper than buying in traditional stores</i>
2021		3	3	21	29	44	
2022		2	4	17	28	48	
2020	<i>gives less choice of products than traditional purchase</i>	2	5	14	23	54	<i>gives you more product choices than traditional shopping</i>
2021		3	3	14	21	59	
2022		2	3	10	23	62	
2020	<i>takes more time than buying in a traditional store</i>	2	7	16	21	52	<i>takes less time than buying in a traditional store</i>
2021		4	6	16	20	54	
2022		4	5	14	20	58	
2020	<b>IT'S RISKY</b>	6	12	24	33	26	<b>IT'S SAFE</b>
2021		6	11	24	thirty	thirty	
2022		4	9	23	32	32	

Source: Own study based on: (E-Commerce w Polsce 2020-2022).

Therefore, these relationships are perceived as convenient, cheap, fast and, at the same time, safe. As a result, the increase in cybersecurity threats does not affect the perception of relationship security. In general, compared to the previous measurement, the opinion on online shopping is stable, with a slight (statistically insignificant) improvement in all dimensions, regardless of whether the respondent buys online or not. (of course, in this case, the ratings are

lower, but definitely above the middle). Of all the dimensions surveyed, the perception of e-shopping security is relatively the weakest.

These results may suggest that e-customers not so much did not come into contact with cyberattacks, but did not experience their negative consequences. As a result, their experiences have a positive impact on the perception of relationships and trust in this form of shopping. This statement is confirmed by research. Although customers of online stores, when making their choices related to a specific place of online shopping, are guided by many factors, three of them are definitely more important than the others and do not change over the years: attractive product price (47%), low shipping costs/delivery (41%) and previous positive buyer experience (35%).

On the other hand, in the set of factors determining credibility, the following are of key importance: opinions about a given store (43%), the option of cash on delivery (30%) and clear information about returns (29%). It should be emphasized that a significant number of e-consumers are resistant to trust. By using the network in many dimensions, the respondent supports his decision-making process, e.g. when choosing a supplier. 15% of respondents use various websites and portals containing rankings, descriptions and ratings for this purpose. 12% follow friends' recommendations. 12% of respondents review opinions on internet forums. The indicated forms of support for the purchasing process are particularly important for young people (aged 15-24). Opinions on: social networking sites or posted on websites influenced the first choice of the provider for over 17% of respondents in this age group. They are also much more active online.

## 7. Conclusions

As literature studies have shown, the progressing process of digitization moves business processes to the network, which results in the opening of the customer value creation process. As a result, their course may be influenced not only by the company and the client, but by any entity with access to the Internet and appropriate software.

Therefore, we can talk about a new ecosystem of value exchange, which is evolving along with the ongoing digitization process.

However, it should be emphasized that the new ecosystem of value exchange, based on relationships and interactions, is based on the acquisition, processing and transmission of information. On its basis, knowledge resources are created. The anonymity/invisibility of Internet users calls into question not only the actual knowledge of the information sender, but also his intentions.

In addition, the use of technology whose principles of operation are known and understood by a relatively small group of users may be used for purposes contrary to the user's intentions. This should encourage each user to assess the credibility of information and the safe use of technology. The intensity of information exchange, the increase in the number of users, the dynamic development of complex technologies, indicate the need to create trust resistance in the user.

The legitimacy of taking such actions is also confirmed by the growing problem of cybersecurity.

Supply side of the relationship understands this by implementing and constantly looking for new models of trust.

This side of the relationship is aware that a breach of the security of online relationships, through "data leakage" or depletion of one's own or the other party's financial resources, translates into a decline in reputation. As a result, network security awareness based on the PAK triad encourages the adoption of an attitude of limited trust.

In the light of the cited research, this cannot be said about the e-client. As research has shown, dominant personality types: are aware of cybersecurity threats, take action to protect themselves or declare to take them when it is convenient for them, see their knowledge gap and strive to fill it, or are not worried enough about it to take appropriate action (Table 2). Thus, we are dealing with a gap in the network security potential, which should be reduced, e.g. by providing information to understand the risks of using the Internet to make purchases and to show e-shoppers how they can protect themselves.

The aforementioned gap, however, does not exclude trust (H3.) It can therefore be assumed that trust is a mental state based on rational and irrational premises.

This state is connected with the subjective assessment of the willingness and ability of one party (trusting party) to solve the problem by the other party, made under conditions of risk and uncertainty.

As a consequence, this means that, unlike the company, the client recognizes that creating a state of security is the task of the other party to the relationship. It therefore expects, as research shows, enhanced cyber security measures from companies and the government.

They base their trust on positive experiences rather than actual knowledge. As a result, relationship time becomes a key correlate of trust.

The customer awareness gap is a reflection of the customer experience. So the client has the impression that he is safe. The problem, however, is that a breach of data or information security, in particular, may take place during the purchasing process (gathering information), but it is not necessarily connected with the classic customer-enterprise relationship, and its effects are usually postponed in time. As a result, the customer may experience a cyberattack, but not connect it to the purchasing process. In addition, it should be pointed out that the modern customer participates in the value creation process. So he becomes a co-creator himself. His household is a substitute for an enterprise, all this speaks for him to behave like business units, and thus seek and implement his own model of trust.

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## SUPPLY CHAIN RISK MANAGEMENT IN THE CONTENT DELIVERY NETWORK (CDN) INDUSTRY

Agnieszka CHOLEWA-WÓJCIK<sup>1\*</sup>, David M. HEROLD<sup>2</sup>, Agnieszka KAWECKA<sup>3</sup>

<sup>1</sup> Krakow University of Economics; cholewaa@uek.krakow.pl, ORCID: 0000-0001-5081-1416

<sup>2</sup> Vienna University of Economics and Business; dherold@wu.ac.at, ORCID: 0000-0002-4023-2282

<sup>3</sup> Krakow University of Economics; kaweckaa@uek.krakow.pl, ORCID: 0000-0001-6895-6613

\* Correspondence author

**Purpose:** The purpose of this study is to provide new insights into how supply chain risk management influences a company's operations in the Content Delivery Network (CDN) industry. We also provide recommendations to identify opportunities and how to mitigate and reduce risks.

**Design/methodology/approach:** We adopt a quantitative research approach involving a correlation and effect/probability matrix. This method relies on risk classification, which is determined by assessing the likelihood of occurrence and the associated impact. The probability is derived from historical data about the incidence of specific events in processes, with values ranging from 0 to 1. Conversely, the impact is evaluated by a team of experts from various company departments, and their recommendations are averaged, resulting in a scale ranging from 0 to 10.

**Findings:** We found that executing the risk management process within an enterprise requires thorough analysis and process auditing. In the context of a supply chain involving numerous globally reaching companies, the task becomes inherently more challenging as changes may be required across multiple if not all, entities. Nevertheless, the adoption of risk management contributes to the implementation of supply chain and organizational strategies by fostering resilience, thereby enhancing the stability of the organization's position.

**Research limitations/implications:** This study provides only a snapshot of the CDN industry, i.e. as we restricted our research to one company, this research provides only context-specific findings and we are cautious to generalize our results.

**Practical implications:** The conducted research and analyses took place within an actual enterprise. The analysis provided can be replicated in other enterprises using the presented procedure.

**Originality/value:** This is one of the first studies examining the CDN industry and providing concrete steps to reduce the risk along the supply chain. We thereby extend and expand the body of knowledge for supply chain risk management both in theory and practice.

**Keywords:** risk management; effect/probability matrix; risk mitigation; risk reduction.

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

## 1. Introduction

Risk management is an integral element of supply chain management and is particularly important for its value (Ho et al., 2015). In the context of a supply chain, risk management should be an integral part of its activities and a structured and holistic approach will contribute to increasing its stability and consistency. The risk management process should be appropriately adapted to the specific nature of the supply chain's activities, and its complexity and proportional to the threats that may appear in its environment (Manuj, Mentzer, 2008; Tang, 2006). One of the most challenging aspects of supply chain management is ensuring adequate product availability. Missing products can hurt customer service and reduce competitive advantage (Ghadge et al., 2012). The dynamics of changes in the IT field require agility in the supply chain area, hence the key aspect in the content delivery network industry is to take management actions in such a way that the risk of a given threat is minimized to an acceptable level, a previously determined level (Barczak et al., 2019; Ivanov et al., 2019).

The aim of the work is to a) analyze the impact of risk management on the activities using the case of the Content Delivery Network (CDN) industry, and b) identify and propose recommendations for risk mitigation and reduction.

## 2. The essence of risk in supply chain management

Risk management, functioning in synergy with management, reduces uncertainty and allows for better achievement of goals. Risk is defined as the probability of events occurring that may affect the achievement of goals or expected results. The concept of risk can be analyzed using basic risk concepts, which are classified as negative and neutral (Jajuga, 2018). The negative concept presents risk as a threat, the possibility of loss, potential damage, and inability to achieve a goal or achieve the intended effect. In turn, a neutral concept of risk treats it not only as a threat, but also as an opportunity. Risk management takes a negative approach to understanding risk because it is a risk that threatens the organization's results (Aven, 2016).

The risk is caused by a combination of many external and internal factors that influence the decisions made in the enterprise. In the context of a supply chain, risk is defined as an event that negatively affects the activities of the entire chain and the performance it achieves (Dolgui et al., 2021). In another way, it can also be defined as the probability of choosing an inappropriate strategy, making inappropriate decisions, or poor configuration of links in the supply chain system (Kilubi, 2016). It is also an external danger that negatively affects the efficiency of the chain. The risk can slow down supply chain operations and make it more difficult to achieve its goals.

Risk management is a set of activities that are coordinated to manage and control an organization in the context of risk (ISO 31000). The main goals of risk management are to identify threats, establish their acceptable level, and strive to maintain them at this level, as well as ensure safety in achieving the organization's goals (Puzyrova et al., 2020). An additional goal implied by the remaining goals is to achieve benefits related to risk minimization activities in the organization (Ziemiński, 2016). For supply chain operations, it is crucial to identify the categories of risk that may occur. Assigning risk to its category appropriately allows for measurable benefits for the entire supply chain, as it creates the opportunity to establish priorities about processes that should be taken into account when creating strategies and allocating resources (Roth et al., 2002). Thanks to this, it is possible to minimize its level and negative effects already at the stage of strategy creation. Taking into account the complexity of supply chain operations and the lack of clarity and uniformity in defining the concept of risk, there is no single common risk classification. Taking into account the most important processes carried out within the supply chain, risk groups can be distinguished, which are summarized in Table 1.

**Table 1.**

*Selected types of risks occurring in supply chain processes*

<b>Process</b>	<b>Risk groups</b>
<b>Customer relationship management</b>	<ul style="list-style-type: none"> <li>• incorrect identification of key recipients,</li> <li>• failure to properly identify needs,</li> <li>• inappropriate offer of products and services about the needs and expectations of customers,</li> <li>• lack of ability to react quickly in the event of a change in customer expectations,</li> <li>• possible loss of key customers.</li> </ul>
<b>Managing the customer service process</b>	<ul style="list-style-type: none"> <li>• lack of external and internal integration of supply chain management,</li> <li>• lack of appropriate customer orientation,</li> <li>• inability of supply chain participants to respond quickly and flexibly to new orders,</li> <li>• high customer service costs,</li> <li>• problems with the efficient flow of information.</li> </ul>
<b>Demand management</b>	<ul style="list-style-type: none"> <li>• the inappropriate flow of information about the demand for products from key customers,</li> <li>• lack of integration with clients,</li> <li>• lack of appropriate methods and tools for analyzing and forecasting demand,</li> <li>• lack of understanding of market needs and trends,</li> <li>• changing fashion,</li> <li>• the impact of promotion and advertising,</li> <li>• emergence of substitute products.</li> </ul>
<b>Order fulfillment</b>	<ul style="list-style-type: none"> <li>• no fixed order processing time,</li> <li>• reducing the number of orders fulfilled,</li> <li>• non-integrated production, distribution, and transport processes,</li> <li>• lack of reliability of product and service suppliers,</li> <li>• failure to comply with technical standards and lack of product quality control,</li> <li>• unstable delivery conditions and product prices.</li> </ul>
<b>Production</b>	<ul style="list-style-type: none"> <li>• inappropriate production planning,</li> <li>• failures of production lines, machines, and devices,</li> <li>• lack of flexibility in the production process,</li> <li>• shortage of products necessary for production,</li> <li>• technological limitations.</li> </ul>

Cont. table 1.

<b>Supplies</b>	<ul style="list-style-type: none"> <li>• inappropriate inventory structure,</li> <li>• low quality of the products obtained,</li> <li>• problems related to the exchange of information.</li> </ul>
<b>Product development and commercialization</b>	<ul style="list-style-type: none"> <li>• the long process of developing and implementing new products,</li> <li>• delay compared to the competition,</li> <li>• lack of experience,</li> <li>• half-baked solutions,</li> <li>• too high costs of new solutions,</li> <li>• lack of integration between customers and suppliers,</li> <li>• lack of analysis of market needs and customer preferences.</li> </ul>

Source: own study based on (Kulińska, 2007).

When analyzing the types of risks that may occur in supply chain processes, it should be noted that disruptions occurring in one process influence problems in subsequent processes (Ho et al., 2015). For this reason, it is important to analyze possible risks in each process and try to predict the effects on others. For this reason, it is also important to identify the risk categories occurring in the supply chain, which are summarized in Table 2.

**Table 2.**

*Risk categories occurring in the supply chain*

<b>Risk category</b>	<b>Occurrence example</b>
<b>Supply chain players</b>	<ul style="list-style-type: none"> <li>• incorrect selection of participants, including inappropriate location,</li> <li>• no possibility to negotiate prices or choose the form of payment,</li> <li>• divergent action strategies, lack of a common goal,</li> <li>• mismatch of organizational cultures,</li> <li>• mismatch of production and investment possibilities,</li> <li>• financial instability,</li> <li>• customer service differences.</li> </ul>
<b>Coordination and cooperation</b>	<ul style="list-style-type: none"> <li>• the need for a thorough analysis of potential business partners,</li> <li>• delegation of competencies and related financial outlays to another entity,</li> <li>• sharing confidential data with external entities, sometimes competitors,</li> <li>• the possible opportunistic approach of other participants, consequently acting for their benefit and not the entire chain,</li> <li>• difficulties in establishing relationships and common goals for participants,</li> <li>• reluctance to share benefits,</li> <li>• lack of established conflict management procedures,</li> <li>• lack of a clear leader in the chain.</li> </ul>
<b>Standardization</b>	<ul style="list-style-type: none"> <li>• failure to establish common standards</li> <li>• lack of a common chain management strategy,</li> <li>• inconsistent or incompatible data carriers,</li> <li>• unsecured data transfers,</li> <li>• divergent technologies and infrastructure, e.g. product identification (barcodes, RFID).</li> </ul>
<b>Information</b>	<ul style="list-style-type: none"> <li>• lack of information exchange management,</li> <li>• incorrectly designed information flow process,</li> <li>• lack of use of modern techniques and technologies for data collection and analysis,</li> <li>• „bullwhip” effect.</li> </ul>

Source: Myszak, Sowa, 2016.

Myszak and Sowa (2016) pay particular attention to the place of origin of the risk in the supply chain and its category. Each of these categories influences each other and is distinguished by the possibility of mutually reinforcing or interpenetrating each other. Moreover, the increasing complexity of supply chain management processes contributes to the

emergence of new risk categories. Risk is inherent in supply chain activities, therefore its management should be a natural activity at the levels of chain planning and management. Risk management requires a change in approach and changes in the organizational culture strategy. It is also necessary to identify and precisely define the goals of this process as well as its constant monitoring. Continuous risk analysis and efficient communication between units responsible for managing individual risk categories are also necessary (Prakash et al., 2017).

### **3. Risk analysis in supply processes carried out in a company from the Content Delivery Network industry**

One of the largest companies in the world operating in the Content Delivery Network industry was selected as the research subject. The company was founded in 1998 in the United States and currently has units in 50 countries around the world. It deals with data flow management, storage, and acceleration of work on the Internet. It also ensures network security and offers cloud computing services to clients. The company has a network of over 350,000 servers located in 3000 locations in over 130 countries around the world, and its customer portfolio consists of approximately 2900 enterprises, including clients such as Microsoft, Facebook, banking and government institutions, and leading car manufacturers. The company's annual revenue in 2022 was \$3.5 billion. The company's supply chain is a coordinated network of logistic and operational connections, and its operational efficiency is reflected in the efficiency of the network built by the company. Ensuring adequate availability of servers and complementary products allows placing further units in the network, consequently increasing its capacity and the possibility of faster and safer transmission of larger amounts of data, which may constitute a competitive advantage in the CDN industry. The company serves many global enterprises, and due to the scale of operations and the complexity of processes, the risk occurring in the enterprise is complex and has a significant impact on its operations. Therefore, risk analysis is extremely important in risk management, the results of which constitute the basis for implementing actions aimed at identifying opportunities for risk mitigation and reduction.

Risk analysis in the company was carried out in stages based on shared internal data, the research method used is correlation, effect/probability matrix. The first stage of risk analysis was to identify all possible types of risk that may hurt the supply chain activities. In the next step, the risk description was developed in more detail and the possible impact on the supply chain activities was identified. Each risk was then assigned a probability of occurrence and a weight. The next stage of the analysis was the classification of risk and its division into internal and external risk. This division was extremely helpful in further steps of the analysis and establishing a plan for improvement actions. Identified risks related to the supply chain of

servers that occur within the company are presented in Table 3. The company has a direct impact on the verification, assessment, and implementation of improvements. The risks concern both the specificity of the product, the ordering process, and difficulties related to communication between teams. Probability was assigned in values from 0-1, and risk weight was assigned in values from 0-10.

**Table 3.**

*Identification and characterization of internal risk occurring in the company's supply chain*

No.	Risk	Description of the hazard	Possible impact	Probability of risk occurrence (0-1)	Impact importance (0-10)
1. W.	Changes in long-term forecasts for needs	Forecasted server demand increases significantly above the prior period forecast due to new business, organic growth, or unforeseen errors. The seller is unable to react to changes, only part of the new demand can be fulfilled within the required time	Insufficient hardware to implement it	0,8	10
2. W.	Mistakes during the implementation of new servers	New generations and types of equipment increase the complexity of the planning schedule. Bad assumptions when implementing new equipment can lead to purchasing the wrong parts or quantities	Insufficient or inappropriate equipment for implementation	0,3	1
3. W.	Difficulties in introducing new system integrations	The internal complexity of company "X" (with multiple vendors, specialized routing guides, etc.) can make the onboarding period for new vendors long. Internal and external bureaucracy can play a role in the delay	Supply delays	0,25	2
4. W.	Order acceptance process	The order acceptance time is a minimum of 3 days before it can be sent to the seller	Supply delays	0,3	5
5. W.	Communication problems between the supply chain and "hardware" departments	Decisions made by departments responsible for production equipment (e.g., changes in the number or types of servers) without notifying the supply chain	Purchasing the wrong part; delay in obtaining the correct product	0,25	4
6. W.	Server generation changes	Major changes in the transition map from one generation to the next	Insufficient ability to obtain the old version before the new version is in full production	0,05	6
7. W.	No acceptance of the purchase of spare parts	When a company is faced with supply problems, it takes a long time to test alternative solutions	Buying the wrong part; delay in obtaining the correct product	0,6	2
8. W.	Changes to projects	Design changes affecting used parts are not always communicated in time (e.g. factory)	Buying the wrong part; delay in obtaining the correct product	0,55	10



Cont. table 3.

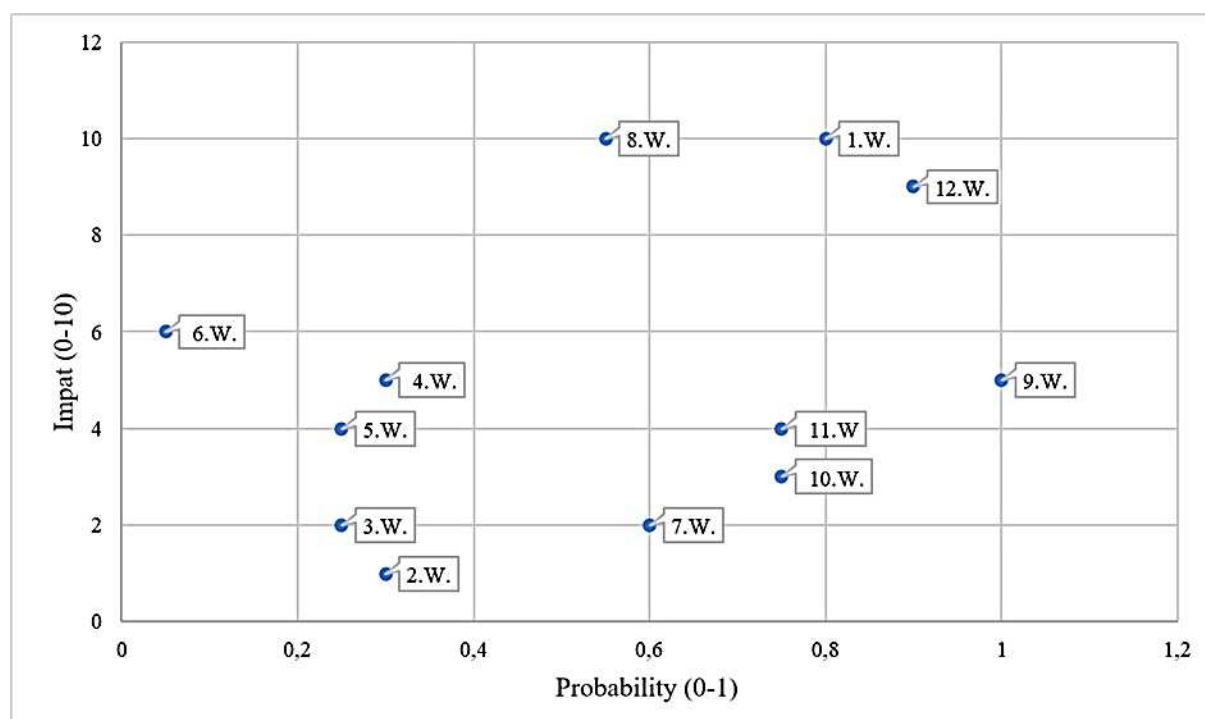
9. W.	Using only customized servers	Company "X" servers are designed by us and built to our specifications. We are unable to run "X" software on off-the-shelf servers, which makes us dependent on our specialized supply chain	Only custom servers can be deployed - if they are not available, there is no way to expand the network	1	5
10. W.	Too many server types	Different parts must be ordered for different types of servers	Buying the wrong part; delay in obtaining the correct product	0,75	3
11. W.	Failure to return unused products from data centers	Parts and servers are stored as spares in data centers, affecting the entire supply chain	Need to order more additional parts and products	0,75	4
12. W.	Components produced only by one manufacturer	Relying on a single supplier for the parts needed for implementation means we have no support if something disrupts that supplier's business	Not enough equipment to implement our actual demand	0,9	9

Source: Own study.

In the next step, a risk map was prepared (Fig. 1) allowing the development of appropriate strategies for each risk. The risk weight is marked on the vertical axis and the probability of its occurrence is on the horizontal axis. The analysis of the data included on the map allowed for the identification of the so-called "most urgent risks", which are located in the upper right corner, i.e. risks with high probability and high importance (risk of changes in long-term demand forecasts and components produced only by one manufacturer). There is also a borderline risk of using only custom servers, this is also a critical risk because the company uses 100% only such servers. This area of the map also includes the risk of changes in projects. This will result in the need to incur high costs and possibly also long-term use of storage space if the use of servers turns out to be impossible. It is essential to act very quickly to minimize the impact of these risks on supply chain operations and, if possible, make changes that could help eliminate them.

In the upper left corner, there is the risk of changing the server generation and related problems. The change in server generation means that new servers will have completely new physical, technical, and IT properties. Another threat is the order acceptance process, which in extreme cases can take up to several days. It is necessary to introduce decisive changes and take action to eliminate their impact, but this will not be as urgent as in the case of the previous quarter.

The next quarter, in the lower right corner, covers risks that are unavoidable and result from the characteristics of the company's operations, but it can be assumed that they are not urgent. Examples of such a threat could be keeping unused servers in data centers or maintaining too many server types.



**Figure 1.** Internal risk map.

Source: Own study.

The last quadrant, in the lower left corner, includes the risk group with the lowest probability and the lowest impact on supply chain operations. They are minor and it is acceptable to ignore them and take no action to minimize their effects. However, you should remember to monitor them and pay attention to whether their impact has changed.

Due to the scale and specificity of the company's supply chain activities, as well as the complexity of its processes, many risks appear outside the company. The impact of external risk usually has a greater impact on the functioning of the company. The characteristics of the external risks threatening the proper functioning of the company's server supply chain are presented in Table 4.

**Table 4.**

*Identification and characterization of internal risk occurring in the company's supply chain*

No	Risk	Description of the hazard	Possible impact	Probability of risk occurrence (0-1)	Impact importance
1. Z.	Long delivery time of parts and products	Some parts may take over 12 weeks to complete. It is not possible to provide supplies in a shorter time	Inability to quickly build additional hardware needed. Lack of adequate availability of parts for network construction	0,7	6

Cont. table 4.

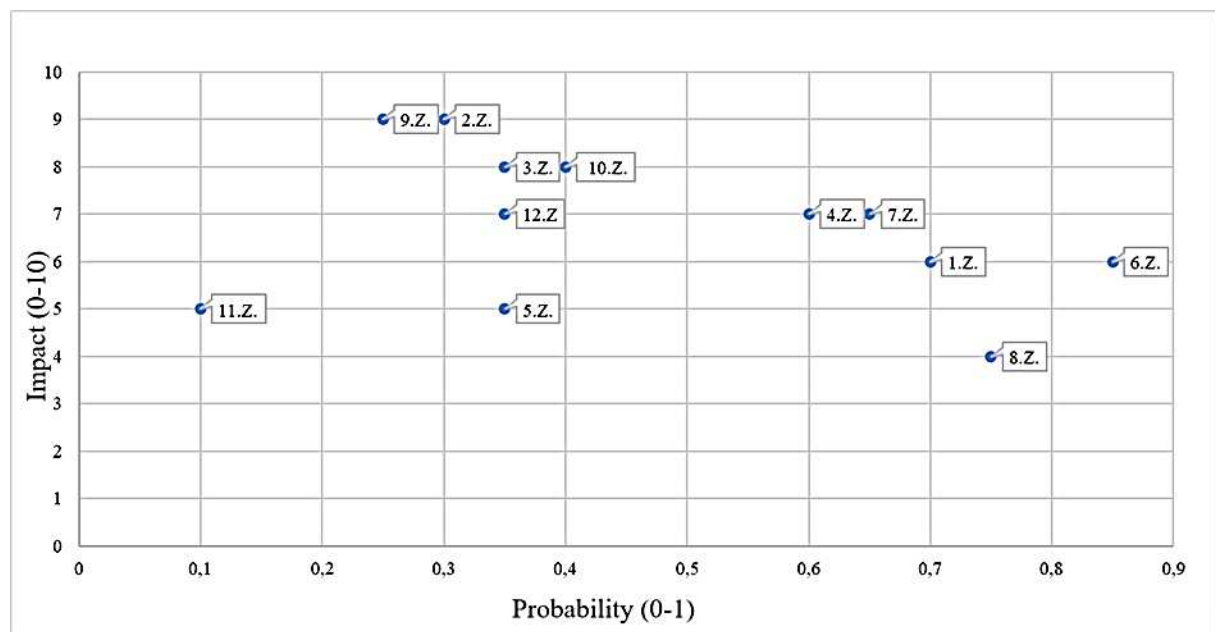
2. Z.	Seller's internal supply chain business problems	Suppliers may lose their ability to obtain necessary parts to manufacture our equipment, which may be due to mergers/acquisitions, cash flow, problems with their suppliers, or problems with their processes	The seller cannot provide servers. Insufficient hardware to deploy to actual demand	0,3	9
3. Z.	Problems with suppliers' production capacity	Sellers may not have the ability to produce to meet demand due to financial, human, space, and time constraints	Not enough equipment to implement our actual demand	0,35	8
4. Z.	No long-term contracts with suppliers who do not supply servers, e.g. spare parts for servers	Without a long-term supply agreement, forecasts provided to sellers without an order are not binding delivery commitments. Sellers may decide to ignore the company's demand and therefore deliveries will not be made	Failure to ensure the availability of parts to build the necessary servers	0,6	7
5. Z.	Devices entering the last phase of the product lifecycle without following the appropriate process	The manufacturer or supplier fails to notify the company of a product recall, which prevents the company from providing a timely replacement	Insufficient number of servers for installation. Possible downtime	0,35	5
6. Z.	Changes in market prices	A price increase from a selected supplier means that it is no longer price-competitive	The loss of an alternative supplier may reduce your negotiation options. Shopping costs will increase	0,85	6
7. Z.	Inadequate communication of delivery issues	Sellers often decide too late when to inform the company about supply or production disruptions	We cannot decide on an alternative with sufficient time; we have to wait to receive the equipment	0,65	7
8. Z.	Delays in customs clearance and shipping	The equipment was stuck at customs for a long time due to various problems. For example, strikes, documentation, or pricing problems may cause shipping and clearance delays	Difficulties in importing to a specific country	0,75	4
9. Z.	Lack of import certificates	The seller may not be able to provide regional certifications for the equipment. This may prevent equipment from being imported into specific countries	Difficulties in importing to a specific country	0,25	9
10. Z.	Force majeure / global crisis	For example, volcanoes that change air traffic routes, disrupt the flow of goods, or tsunamis that destroy manufacturing factories. Infectious diseases stopping production	Unable to obtain equipment	0,4	8

Cont. table 4.

11. Z.	Change of supplier ownership	Suppliers may merge with or be acquired by other companies. The new owners can influence production schedules, what is currently produced, escalation paths, prices, etc.	Delay in supply during the transition period, need to change and adapt processes	0,1	5
12. Z.	Product theft	Theft takes many forms, from hijacking a truck in Brazil to stealing disks from servers in a data center. Each theft reduces the availability of servers for deployment	Shortage of supplies – inability to expand the network	0,35	7

Source: own study.

External factors influencing the occurrence of risk in the company's supply chain have a significant impact on the occurrence of problems with server availability and, consequently, on the maintenance and expansion of the network. Another difficulty is import problems. Each country has its own legal and technical regulations related to the import of products. In the case of servers, this is even more complicated because they require additional certification. Due to their intended use, some countries also require additional permits issued by special state units to introduce products into the country. Large and often complicated bureaucracy slows down and, in extreme situations, prevents network expansion. The external risk map is presented in Fig. 2.



**Figure 2.** External risk map.

Source: Own study.

The figure above shows a risk map for factors affecting outside the company. As you can easily see, the vast majority are in quadrants one and two. This is because most factors have a large impact on the functioning of the supply chain and have more serious consequences. These are potential problems that may disrupt the continuity of supplies. Risk mitigation in this

case may be more difficult because it requires the involvement of more units, which the company may not influence. Often, the only way to reduce risk for a company is to "shift" it to other links, for example by forcing suppliers to maintain higher levels of inventory.

The upper right quadrant contains factors with high probability and high importance. In this case, it is necessary to take quick actions to minimize their impact. An example is the lack of long-term contracts with component suppliers or changes in market prices. It is also very important to improve communication with suppliers, especially in the event of delivery problems. And also improve the product delivery process to reduce the delivery time of parts and products.

The upper left quadrant contains factors with high importance but lower probability. An action plan must be developed and decisive steps taken to minimize their impact, but this will not be as urgent as in the previous quadrant. Most external risk factors are found here. An example is the lack of shipping certificates causing delays in customs inspection or product theft. Others include a change in supplier ownership, devices entering the final phase of the product life cycle without a proper process in place, supplier capacity issues, and the seller's internal supply chain business problems.

In the lower right quadrant, there is only the risk of delays in customs clearance and shipping. This is a relatively high probability and low severity problem. In the case of a large number of international shipments, this is unavoidable, but it is worth taking steps to minimize it. The last quarter, in the lower left corner, remained empty. This is because external risks usually have a large impact on supply chain operations, making it necessary to take action on each factor.

The identification and analysis of risk in the supply chain constitutes the basis for further risk management steps, i.e. to develop actions to improve risk management, as well as ways to reduce the impact of risk.

#### **4. Characteristics of activities improving risk management in the supply chain**

The extraction of data collected after the risk analysis of supply processes implemented in a company from the Content Delivery Network industry allowed for the development of proposals for actions to mitigate and reduce the risk.

Proposals for reducing internal risk are presented in Table 5. The table also includes the risks that may occur during this implementation. In most cases, the developed proposals are based on the need to increase the stocks held by company "X" in warehouses. This solution will certainly ensure better continuity of supply, as it will reduce the risk that servers will not be available when the actual demand for them occurs in the data center. However, this will increase

the cost of keeping servers in stock and create a risk of underutilization of inventory. Risk reduction proposals also present opportunities to improve existing processes and create new ones. These processes, of course, take place within the company and are intended to minimize the impact of risk on supply chain operations.

**Table 5.**

*Proposed improvements for internal risk occurring in the company's supply chain*

No	Risk	Possibility to reduce risk	Risks associated with this activity
1. W.	Changes in long-term demand forecasts	Consistently taking into account changes and errors in the forecast. Thorough forecast reviews and error identification. Investment in additional buffer stocks to cover likely growth	The cost of unused inventory may outweigh the benefits of covering the risk. The potential cost of revaluation if commodity prices decline
2. W.	Mistakes during the implementation of new servers	Building flexible forecasts by creating overlapping server types and a longer implementation period	High cost of stocking additional parts, risk of not using less desirable inventory before switching to new equipment
3. W.	Difficulties in introducing new system integrations	Create thorough documentation for the new supplier onboarding process, with all key stakeholders outlined	Frequently changing processes can mean that documentation may need to be updated too frequently to be useful
4. W.	Order acceptance process	Periodically review the most current sellers and add them to the exception list. Thanks to this, the acceptance process will be simplified	Possible price increases from accepted suppliers - no possibility of frequent changes and free choice of supplier
5. W.	Communication problems between the supply chain and "hardware" departments	Establish a process in which both departments must accept any design changes	Lengthening of processes and possible conflicts if changes are not consistent with the assumptions of both teams
6. W.	Server generation changes	Maintain more inventory and longer transition periods between generations	Using older, more expensive, and often more unreliable servers longer than necessary
7. W.	No acceptance of the purchase of spare parts	Introducing a requirement to have two approved dealers for certain types of parts at all times	Both vendors may use the same component supplier, which invalidates mitigation for some
8. W.	Changes to projects	Design changes must go through an approved checklist to which project managers must sign off	Delays waiting for approval of changes to be signed
9. W.	Using only customized servers	Selection and qualification of specific universal servers that can be used in case of shortage	The company's software does not work properly with an off-the-shelf system
10. W.	Too many server types	Reduction of the number of server types	Less customization may result in higher costs or poorer performance matching
11. W.	Failure to return unused products from data centers	Standardize the policy and process for what can remain in the data center as 'spare'	Increase in expenses taking into account authorized spare parts in stock (working stock)
12. W.	Components produced only by one manufacturer	The requirement to have 2 approved sellers for the product at all times	Insufficient sales capacity to meet company demand

Source: Own study.

To provide a holistic approach to risk management, a proposal for improvements aimed at reducing it has been developed for internal risk occurring in the supply chain. Introducing changes in this case will be more difficult than in the case of internal risk. All links in the supply chain must cooperate here, which will additionally require efficient communication and willingness on the part of partners. Supply chain participants will have to agree to the requested audit and implement recommended changes, which may be costly. Proposals for risk reduction and the potential additional risks these changes entail are presented in Table 6.

**Table 6.**

*Proposed improvements for internal risk occurring in the company's supply chain*

No	Risk	Possibility to reduce risk	Risks associated with this activity
1. Z.	Long delivery time of parts and products	Requiring suppliers to maintain a buffer stock for all parts with a production time greater than six weeks. Developing relationships with higher-level suppliers. Sharing forecasts or creating contracts for the supply of key parts. Demand that our suppliers provide the necessary information and give us greater visibility up the supply chain. Have them do a full supply chain audit	Providers may need financial support to maintain an additional buffer. Less flexibility to switch to new products as schedule changes. Excessive stocking of parts with expiration dates may lead to unused inventory expiring
2. Z.	Seller's internal supply chain business problems	Have vendors audit their internal processes and inventory levels. Making sure sellers are responsible for delays or shortages caused by their error	Possible costs of additional work
3. Z.	Problems with suppliers' production capacity	Quarterly/annual review to assess financial stability, capability, etc. Proper screening of new salesperson's capabilities during onboarding	Possible costs of additional work
4. Z.	No long-term contracts with suppliers who do not supply servers, e.g. spare parts for servers	Selection of strategic suppliers to implement supply contracts	The need to bear the responsibility of maintaining relationships only with selected suppliers
5. Z.	Devices entering the last phase of the product lifecycle without following the appropriate process	An alternative source or viable substitute from an existing catalog	Using a more expensive substitute before a permanent device is accepted
6. Z.	Changes in market prices	Having a minimum of two sellers approved for each product at all times. Immediately look for an alternative seller if one of the two sellers becomes too expensive	The need to allocate additional company resources. Possible additional costs
7. Z.	Inadequate communication of delivery issues	Establish a policy for sharing information and communicating any disruptions, no matter how trivial	Additionally, time is spent sifting through the noise once the policy is officially implemented. Lack of consent from the supplier
8. Z.	Delays in customs clearance and shipping	Having enough standard parts in all warehouses to cover two-quarters of the demand	Additional charges for variable price parts. Increased inventory holding costs

Cont. table 6.

9. Z.	Lack of import certificates	Start the certification process for all regions at once. Continuation of production by the existing multifunctional enterprise until the new multifunctional enterprise is certified. Documenting the certification process to make it available to future equipment manufacturers. More thorough supervision of the certification process	Certification cost
10. Z.	Force majeure / global crisis	Maintaining excess inventory of standard parts and providing equipment to quickly complete custom builds. Document and track how much a supplier's throughput can increase in a short period	The financial burden of helping the supplier with costs
11. Z.	Change of supplier ownership	Diversification of the manufacturer and supplier portfolio to adapt to changes in supply sources when switching to another supplier	A diversified portfolio may lead to higher product costs due to diluted quantities
12. Z.	Product theft	A review of the likelihood of theft and shrinkage in a market to determine whether Company "X" should be in that market. Paying additional fees for lanes that require additional security for the flow of goods. Changing lanes and vendors where theft is a problem. Purchase an insurance policy for goods in transit	The insurance premium depends on the value of the goods being moved and the number of events. Increased costs of additional security in countries where it is required

Source: Own study.

## 5. Summary

Risk is an inherent element of every business activity, especially supply chains in the content delivery network industry, the aim of which is to efficiently provide high-availability content to end users. Due to the specificity of the activity and the number of links they cover and connect, the risk has more sources. For this reason, risk management is an issue of ever-increasing importance. Risk management in the supply chain should be implemented in a way aimed at limiting its occurrence and minimizing its effects. Risk minimization is often a key activity in a functioning supply chain, especially if the chain operates in a very turbulent, unstable, and unpredictable environment, as is the case in the content delivery network industry. Building mutual trust and efficient sharing of information is also an important activity in the supply chain. Mutual trust can be strengthened by jointly sharing risk costs and equitably sharing responsibilities among all supply chain participants. Implementing the risk management process in an enterprise is a task that requires in-depth analysis and process audit. In the case of a supply chain that consists of many companies with international reach, it is reactively more difficult because changes may be necessary for many or even all



companies. However, risk management helps implement supply chain and enterprise strategy by building resilience that will make the enterprise's position more stable.

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## CREATIVITY AS A STRATEGIC ORIENTATION OF INDUSTRY 4.0 ORGANIZATIONS IN THE CONDITIONS OF SUSTAINABLE DEVELOPMENT

Aldona Małgorzata DEREN<sup>1\*</sup>, Anna Maria KAMIŃSKA<sup>2</sup>, Małgorzata RUTKOWSKA<sup>3</sup>,  
Jan SKONIECZNY<sup>4</sup>

<sup>1</sup> Wrocław University of Science and Technology, Faculty of Management, Department of Organization and Management; aldonadere@pwr.edu.pl, ORCID: 0000-0002-2377-4573

<sup>2</sup> Wrocław University of Science and Technology, Faculty of Management, Department of Organization and Management; anna.kaminska@pwr.edu.pl, ORCID: 0000-0002-6638-1155

<sup>3</sup> Wrocław University of Science and Technology, Faculty of Management, Department of Organization and Management; malgorzata.rutkowska@pwr.edu.pl, ORCID: 0000-0002-0305-5555

<sup>4</sup> Wrocław University of Science and Technology, Faculty of Management, Department of Organization and Management; jan.skonieczny@pwr.edu.pl, ORCID: 0000-0002-1027-991X

\* Correspondence author

**Purpose:** The main purpose of the article is to determine the strategic directions of Industry 4.0 organizations in the conditions of sustainable development.

**Design/methodology/approach:** Many different strategy typologies have been presented in the literature. They allow for the identification of different strategic orientations of organizations operating in a changing market environment. Taking into account the concept of Industry 4.0, the essence of which is the extensive use of the Internet, networks, and data exchange for increasingly better functioning of the organization, an in-depth analysis and review of the literature on sustainable development was carried out, which provided the basis for developing a model of strategic directions recommended to organizations implementing the idea of Industry 4.0.

**Findings:** Based on an in-depth analysis and literature review, a model of strategic orientations of Industry 4.0 organizations was developed, covering four basic activities: organizational expansion, organizational innovation, organizational entrepreneurship, and organizational creativity enabling sustainable development of the organization.

**Originality/value:** The article presents an original approach to strategic orientation as a key competence of contemporary organizations implementing the Industry 4.0 concept in conditions of sustainable development. In the proposed model, the authors emphasize the special role of organizational creativity, which stimulates the creation of new values in the organization and its strategy aimed at implementing the Industry 4.0 concept in conditions of sustainable development. These new values have a decisive impact on the organization's growth and sustainability in a turbulent and dynamic environment, focusing on maintaining the integrity of the ecosystem.

**Keywords:** Industry 4.0, sustainable development, organization, orientation, strategy, values.

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

## 1. Introduction

The fourth industrial revolution and the digital transformation that underlies it is progressing exponentially. The digital revolution is changing the way people live and the way organizations function.

The growing interest in the concept of Industry 4.0 of various stakeholders, including public authorities, entrepreneurs, R&D sector entities, and business environment institutions, is related to the process of globalization and internationalization of the world economy and the need to strengthen innovation, entrepreneurship, and competitiveness of individual national economies on a macro scale meso, and micro. In this context, these concepts are perceived both as determinants of the so-called fourth industrial revolution, as well as the evolution of information and communication technologies, business models and virtualization, and enterprise strategies (Ardito et al., 2019, pp. 323-346).

Expansion, innovation, entrepreneurship, and creativity are the key processes of organizations operating in the 4.0 industry. In light of the selected area of literature research, it was assumed that the aim of the conceptual article is to present the strategic orientations of organizations implementing the concept of Industry 4.0. in conditions of sustainable development.

## 2. The concept of sustainable development

The term sustainability development has been known in the literature since the last century (Müller, Voigt, 2019, pp. 659-670). There are many definitions of the term in the scientific literature, with no clear definition. Moreover, the concept of sustainable development is often misused as a so-called buzzword, which is currently fashionable, and thus indicative of being a cult. As J. Skorupski writes, "the idea of sustainable development has become a paradigm of environmentally friendly economic development, often serving as a buzzword disavowing the actual environmental burdens generated by various industrial, infrastructure, agricultural or service projects" (Skorupski, 2018).

The term was first defined in the World Commission on Environment and Development's 1987 Brundtland report 'Our Common Future' as 'development that meets the needs of the present without compromising the ability of future generations to meet their own needs' (Report of the World Commission on Environment and Development: Our Common Future, 1987).

The concept of sustainable development evolved and was developed, including at the 1992 United Nations Conference on Environment and Development in Rio de Janeiro (at the so-called Earth Summit) and expressed in Agenda 21, the United Nations Millennium

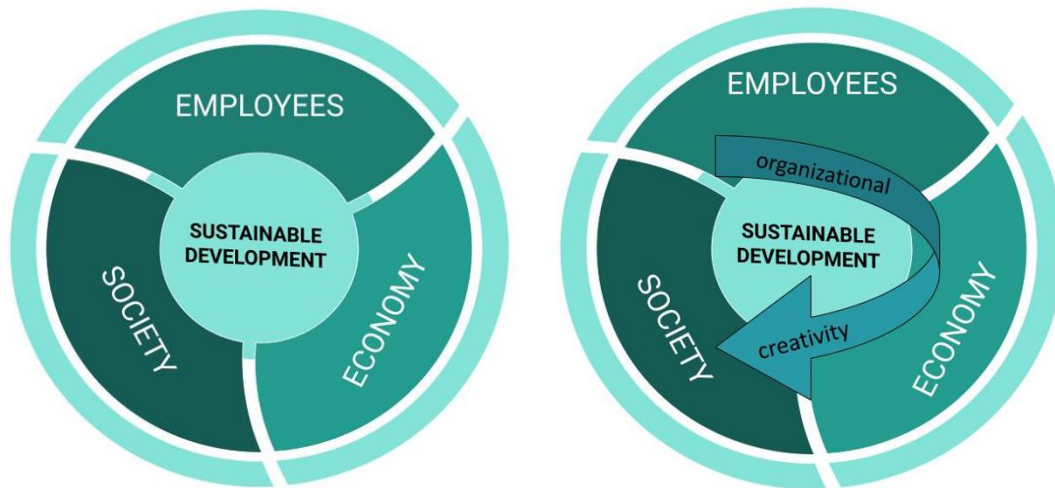
Declaration, and the declaration *The Future We Want* by the UN. It was then that the relationship between economic development and environmental protection began to be discussed. The Rio Declaration is a set of principles that address future development and environmental commitments. In 2001, meanwhile, the EU adopted a strategy for sustainable development. It was revised in 2006 and "enabled the realization of a long-term vision of sustainable development that combines mutually supportive economic growth, social cohesion, and environmental protection". Subsequently, since 2009, sustainable development has officially become one of the long-term goals of the European Union in accordance with Article 3(3) of the Treaty on the European Union (*Zrównoważony rozwój...*). In subsequent documents, namely the United Nations Millennium Declaration (Resolution adopted...), in the United Nations declaration *The Future We Want* (*The Future We Want...*) and the 2030 Development Agenda (*Transforming Our World...*), has remained essentially unchanged in its context. Sustainable development thus emphasizes the parallel development of the economy, society, and the environment.

Sustainable development can therefore be defined in two ways:

1. sustainable development can be formulated as broadly defined as the development of, among other things: countries, cities, communities, or businesses, which combines the needs of today's people and the ability to saturate the needs of future generations, but also the wants and needs of one person with another,
2. sustainable development can be defined as: "a sequence of changes in which the use of resources, the structure of investments, the orientation of technical progress, and institutional structures are to be made in such a way that there is no contradiction between future and present needs" (Sztumski, 2006, p. 73).

The key pillars of sustainable development are management by values, concern for the environment, and social commitment, which are the basis for the equalized development of organizations on the one hand and form the foundation of accountability on the other. Moreover, in sustainable, development the basis is the environment, the tool is the economy, while the goal of sustainable development is the well-being of society. Taking the above considerations into account, it is necessary to consider what is the sustainable development of an organization. Sustainable development of an organization should be understood as "such a way of management that simultaneously and equivalently respects economic, environmental and social issues that are related to their functioning. In practice, this means that in organizations following such a path of development, a new quality of management should emerge (Brzozowski, 2015, p. 138). This understanding of the sustainable development of organizations is also supported by authors of this paper, while pointing to the significant importance of human and natural resources in addition to economic, environmental, and social issues. As already indicated, there are fundamental pillars of sustainable development that focus on: workers, society, and the economy (Figure 1). In fact, it is only when we address their essence that we can confidently talk about the growth of an organization. As can easily be seen,

organizational creativity is the missing link here. That is why the authors of this publication propose to extend these pillars by combining them through the fluid creativity of organizations.



**Figure 1.** Pillars of sustainable development & organizational creativity as the key competence.

Source: own research.

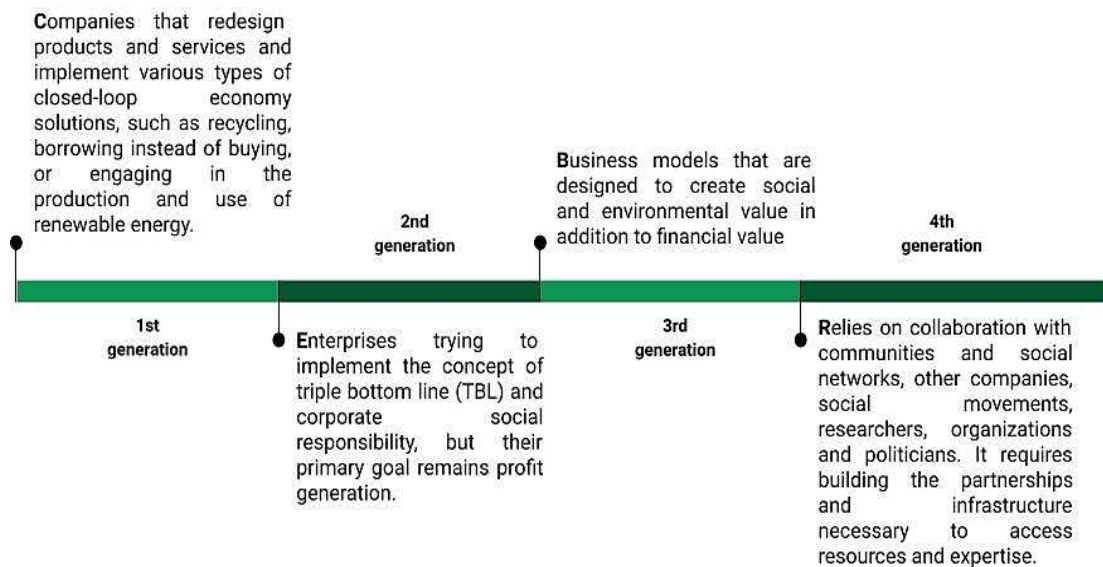
The idea of organizational sustainability is increasingly well-known and widespread. "For the business enterprise, sustainable development means adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining, and enhancing the human and natural resources that will be needed in the future". (Business Strategies for sustainable development...).

We propose to expand this traditional understanding of the idea of organizational sustainability by adding one more component, namely organizational creativity. This is a valuable, rare, and difficult-to-reproduce intangible resource. In this article, we have assumed that organizational creativity has objective implications for building innovation capacity that can result in new products, processes, and organizational innovations, it also has a subjective role. This subjective role involves improving entrepreneurial capacity, which in turn is a key problem-solving-oriented resource in organizational sustainability processes. Although the importance of organizational creativity as a resource has been exhaustively studied, to our knowledge there is still a lack of research to understand how organizational creativity supports the competencies needed by organizations to operate in a sustainable economy.

As T. Borys points out in his reflections - the concept of sustainable development is nowadays a largely operational category - with increasing concreteness at different levels of management (Borys, 2015, pp. 9-12).

In an effort to explain what sustainable business models will look like, we should refer to the genesis of the emergence of business models that integrate sustainability goals with business strategy. An interesting look at this evolution as well as the possible direction of development of this concept was presented by F. Melissen and L. Moratis (2016, pp. 8-16). According to them, four generations of sustainable business models can be distinguished (Figure 1).

Three generations of sustainable business models, by definition, do not change the rules of the game, as they operate according to existing market rules. Organizations that want to go beyond the patterns of the current system must apply business models that go beyond the solutions proposed by the first three generations. To do this, consumer acceptance and support are needed (only then can sustainable products and services have a positive impact on society).



**Figure 2.** Four generations of sustainable business models.

Source: Own research based on Szumniak-Samolej, 2022, pp. 37-45.

Thus, the concept of the fourth (current) generation of sustainable business models seems interesting and may give one direction for the development of this type of business. The premise is to integrate technology and social phenomena and new ways of organizing and collaborating. In this way, opportunities can be explored for co-creating a sustainable socio-economic system based on equality, inclusiveness, responsibility, and balanced interaction with the environment. (Szumniak-Samolej, 2022, pp. 37-45).

### 3. Strategic orientations of Industry 4.0 organizations in conditions of sustainable development

The development of the topic of models of sustainable development is the result of the search for new solutions and better ideas for implementing the postulates of sustainable development into business practice. The authors postulate a model of sustainable development for organizations based on expansiveness, entrepreneurship, innovation, and organizational creativity (Table 1).

**Table 1.**

*A model for sustainable organizational development based on expansiveness, entrepreneurship, innovation and creativity*

Environment	Stable, secure, low risk	Unstable, uncertain, high risk
<b>Management organization</b>		
By the limit value	Organizational expansion	Organizational entrepreneurship
By new value	Organizational innovation	Organizational creativity

Source: own research.

The planes that will determine the form of the aligned organizational management model are, firstly, the way in which the organization is managed (by boundary value and by new value) and, secondly, the environmental plane (Stable, secure, low risk or Unstable, secure, high risk). When these planes overlap, a suitable management model can be identified: organizational expansiveness, organizational entrepreneurship, organizational innovation and organizational creativity.

Despite the important role of creativity as a potential basis for creating intellectual capital and competitive advantage as well as a source of enterprise growth, the understanding of creativity as an important strategic factor implying the development of an organization in conditions of sustainable development has not been fully understood. There is still a cognitive gap in the scientific literature on creativity and sustainability in terms of sustainable organizational models and understanding organizational creativity in a strategic aspect. Therefore, we treat the issue of strategic orientations as a contribution to the discussion on an organization implementing the concept of Industry 4.0 in the conditions of sustainable development.

#### **4. Organizational creativity in the conditions of the sustainable development**

For the paradigm of sustainable development, creativity is increasingly important (d'Orville, 2019, pp. 65-73; Mitchell, Walinga, 2017, pp. 1872-1884). Creativity and sustainable development are two key factors influencing the development of civilization. As S. Kaufman writes, in the world of the infinitely rich creativity of nature, man is an active co-creator of it (Kauffman, 2011, pp. 60-63). Adopting such a perspective enables us to relate creativity to the study of organizational phenomena. From this perspective, creativity can be treated as an attribute of contemporary organizations (Dereń, Skonieczny, 2016). Organizational creativity is commonly believed to refer to the production by individuals or groups of new and potentially useful ideas about products, services, working methods, processes, and procedures (Amabile, 1988, pp. 123-167). In this sense, creativity is different from innovative activity (Klijn, Tomic, 2010, pp. 322-343), which focuses not so much on generating creative ideas as on putting them



into practice. If the generation of useful novelties takes place among the participants of the organization, we are talking about organizational creativity. More precisely, "organizational creativity is the creation of a valuable, useful, new product, service, idea, procedure or process by individuals working in the social system" (Woodman, 1993, p. 293). Organizational creativity is also defined as the ability to think beyond accepted ideas and conventional thinking patterns, to combine previously acquired knowledge in an unprecedented way (Kraft, 2005, pp. 16-23); new mental models (Lozano, 2014, pp. 205-216); the ability to abandon habitual ways of thinking and accumulate pieces of previously unrelated knowledge and experience (Geschka, 1983, pp. 169-183); the ability and power to develop new ideas (Wehrich, Koontz, 2005); generating innovative and adequate ideas - solutions - for open problems in any domain of human activity (Amabile, 1997, pp. 39-58); combining cognitive, affective and social domains (Runco et al., 1998, pp. 1-17), and solving problems in an unconventional way (Reiter-Palmon, Illies, 2004, pp. 55-57; Mitchell, Walinga, 2017, pp. 1872-1884). Organizational creativity arises thanks to units cooperating with each other in a complex social system, which is influenced by individual and group creativity as well as the organizational environment (Borghini, 2005, pp. 19-33; Skonieczny, 2019, pp. 113-171).

In this article, organizational creativity is conceptualized as an organizational creative process that results in ideas, thoughts, perspectives, views, and mental models characterized by novelty/originality and usefulness/value, oriented towards the sustainable development of the organization. In tab. 2. presents this conceptualization recommended for the three levels of functioning of modern organizations, the overarching goal of which is sustainable development based on the generation of new values.

**Table 2.**

*Organizational creativity in the conditions of sustainable development of the organization*

Management level	Strategic goal	New values	Result
Organization level	Sustainable development of the organization	New values in the organization	Creative organization
Business strategy level	Sustainable development of the business strategy	New values in the business strategy	Creative business strategy
Project level	Sustainable development of the project	New values in the project, e.g. new product and/or service	Creative project

Source: own study.

Assuming that organizational creativity is the key competence of an organization in the process of its sustainable development, we refer it to three levels of management: organization as a whole, business strategy, and project. These three levels of management are aimed at creating new values in the business strategy of the organization and in project activities aimed at its implementation. The harmonious combination of these new values focused on the sustainable development of the organization leads to the formation of a creative organization related to the dynamically changing natural environment.

Creative organization is a concept discussed in various contexts, but its characterization, and in particular the indication of its basic components and showing its links with the natural environment, is not an easy task. In the literature on the subject, there are not many examples that can be considered a universally applicable standard. A. Dereń and J. Skonieczny (2017, pp. 163-170). present a creative organization as a set of four factors: information technologies; creative environment; organizational creativity; and creative effects. This proposal was developed in the definition of the basic components of a creative organization, which include: creative people, creative goals and tasks, and creative means. The choice of these three basic elements refers to the classical approach to organization. The organization is created and developed by people who, working together, achieve specific goals using the available means (Dereń, Skonieczny, 2016, p. 124). In a creative organization, the human being is the most important - understood as a whole, not only as an employee but as a person. What matters is his knowledge and skills, as well as his emotions, motivations, and imagination.

The issue of creative strategies was the subject of an analysis undertaken by R.L. Kuhn, the result of which was, among others distinguishing 10 types of the so-called creative strategies: domination; pressure on the product; stand out; concentration; development of high-quality management staff; the use of opportunities by creative employees; effective innovation; agile perception of the environment; compromise; flexibility (Kuhn, 1989). J. McCrae defines a creative strategy as a set of purposeful activities aimed at business development and growth, grouped into three phases: market research, the use of creativity, and the use of strategic planning. Creative strategy understood in this way is based on five foundations: identifying market needs; setting creative, non-standard ways of achieving goals; seeking feedback on the competition sector; exceptional brand positioning and building a unique perspective for business; building networks inside and outside the organization, influencing people and attracting others to ideas (McCrae, 2013).

In the construction of the creative strategy developed by W. Dyduch (2013, pp. 115-117), four interrelated elements can be distinguished: strategic innovation; strategic entrepreneurship; strategic leadership; and strategic design of a creative organization. A.M. Dereń and J. Skonieczny are in favor of this approach to creativity in the organizational strategy and propose a model containing sixteen strategies based on intellectual resources. The dimensions of these strategies are generic strategies (cost leadership, differentiation, focus on costs, focus on differentiation), internal and external development of intellectual property (cooperation contracts, strategic alliance, acquisition), and ways of protecting intellectual property (protection, lending, sharing, acquisition) (Dereń, Skonieczny, 2016, pp. 195-204). The authors develop this theme in the work devoted to "green intellectual property" as a strategic resource of the organization in the conditions of sustainable development (Dereń, Skonieczny, 2022, pp. 1-11). The authors assume that each strategy is a creative product and arises as a result of a creative process taking place in the organization, expressed in a mental, objective, organizational, and market form. A creative strategy is characterized by a combination of the

following features: values, usefulness, and novelty, and includes four basic activities: "invent", "replace", "change", and "duplicate" (Dereń, Skonieczny, 2016).

All the social reality that surrounds us and all elements of the civilization created by man are products derived from ideas and creative ideas accumulated over millennia. That is why human creativity should be treated as any intellectual event, as a process or state in the experiences and experiences of a human being, having its effects in every sphere of social relations. A product that we define as creative may have any character; it can be a work of art, a discovery, an original machine a structure, or a specific design endeavor.

A project undertaking consists of planning, developing schedules, and controlling activities specified in the project in order to achieve the assumed level of results and costs specified within the time frame for a given scope of work, with the simultaneous effective and efficient use of available resources (Lewis, 2006, p. 135). It follows from the above definition that managing a project is not only about preparing a schedule and an action plan. It is also taking into account the parameters of time, costs, and quality of the results obtained. In addition, it is very important to use the resources at your disposal during the implementation of the project in an effective and efficient manner.

The creative design endeavor is a bit more complex than carrying out so-called standard projects. This is mainly because these are innovative activities, carried out under conditions of high risk and uncertainty. Moreover, the scope of such an undertaking is impossible to define in detail, and therefore when it is carried out, new challenges may arise constantly, and the risk is also increased as the probability of success or failure. Creative design projects carried out in the conditions of sustainable development require special monitoring and taking into account the following principles in strategic planning:

- the principle of eco-development, - the principle of environmental integrity (ecosystem integrity); its essence is the recommendation to "think globally (holistically), but act locally";
- the principle of economization, also known as the principle of economic efficiency and ecological eco-development (including environmental protection); calls for the implementation of such a policy so that the environmental goals are achieved at the minimum social cost;
- the principle of prevention, also known as the principle of active policy or, in a narrower interpretation, the principle of elimination of pollution at source;
- the principle of reacting to the existing ecological threats, also called - not always in a justified way - the principle of passive politics; a manifestation of passive politics is e.g. the formulation of declarations and subsequent programs with a clear underestimation of the implementation side;
- the principle of partnership (cooperation) and public (social) participation, also known as the principle of community participation in solving environmental problems or the principle of socialization;

- the principle of regionalization of eco-development programming (including ecological policy), is understood as a postulate to adapt protection requirements to regional and local conditions and to enable regional and local authorities to choose tools for implementing the idea of eco-development;
- the principle of the rule of law, which means that the ecological law system and the manner of its implementation must be restructured in such a way that each provision is strictly observed and it is impossible to replace the provisions with arguments so well known to the public about "higher necessity", "social interest", "we are yet to be protected the environment cannot afford" or "we are too poor to protect the environment" etc.;
- the principle of observing intergenerational (intergenerational) ecological justice, is sometimes also called the principle of intergenerational ecological egalitarianism (Berner, 2006).

C. Cucuzzella also writes about the need to respect the principles of sustainable development by organizations implementing creative design projects, emphasizes the special importance of two principles: prevention and precaution, considering them to be key and decisive in reducing the risk of a project undertaking (Cucuzzella, 2016, pp. 1548-1558). Organizational creativity conceptualized in the article in the conditions of sustainable development of the organization fits in with the concept of green creativity proposed by Chen and Chang, which concerns the development of original, innovative, and useful ideas for ecological products, services, processes, and practices (Chen, Chang, 2013; Eide et al., 2020). Green Creativity involves the ability to present novel ways to improve performance in an environmentally sustainable manner (Mittal, Dhar, 2016, pp. 118-127); it can therefore be expected to lead to innovation in services, eco-friendly practices, actions to preserve cultural heritage, and actions that add value to both customers and businesses (Bhutto et al., 2020). Shaping green creativity depends on various organizational and individual antecedents (Chen, Chang, 2013; Eide et al., 2020; Song, Yu, 2017, pp. 135-150). However, the current thinking, attitudes, and behavior of leaders and managers towards environmental problems are of key importance for its implementation in practice (Arici, Uysal, 2022). it allows you to generate and develop new values that serve the well-thought-out use of resources in such a way that they will be enough to build the prosperity of the current generation, but also be able to meet the needs of the future.

## 5. Summary

Organizational creativity is the opposite of ordinary, stereotypical, and repetitive activities. The essence of the creative process in an organization is to reorganize existing experience and create new combinations on its basis, new combinations of mental, objective, organizational, and market products. These connections create the concept of a creative product that is a finished, organized, and communicative whole.

Organizational creativity can be considered a key competence of Industry 4.0 organizations operating in conditions of sustainable development. A review of available domestic and foreign literature and research reports on creativity as a key strategic factor in the development of Industry 4.0 organizations allowed us to notice a cognitive gap. The authors treat this topic as a basis for conducting research in Industry 4.0 organizations focused on sustainable development. This research will allow for the verification of the adopted theoretical assumptions.

In the authors' opinion, creativity stimulates new values in relation to the organization as a whole, its strategy, and the projects it implements. These new values have a decisive impact on the growth and socio-economic development of Industry 4.0 organizations, whose goals and tasks should focus on maintaining the integrity of the ecosystem.

Organizational creativity in connection with the sustainable development of Industry 4.0 organizations indicates a pro-environmental approach. This usually means that the business is environmentally friendly and the technologies used are optimal.

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## IMPACT OF DYNAMICS CAPABILITIES ON COMPETITIVE ADVANTAGE IN THE CONTEXT OF STRATEGIC FIT OF ENTERPRISES

Wojciech GŁÓD

University of Economics in Katowice; wojciech.glod@uekat.pl, ORCID: 0000-0003-1343-7597

**Purpose:** The purpose of the article is to explore the relationship between dynamic capabilities and competitive advantage in the context of strategic fit taking into account the specifics of family businesses.

**Design/methodology/approach:** Validation of the set research objective and research hypotheses was done using statistical tools (factor analysis, Pearson's linear correlation analysis, structural equation modeling). The research was conducted on a sample of 422 enterprises.

**Findings:** On the basis of the empirical research conducted, it should be concluded that strategic alignment is a significant mediator of the relationship between dynamic capabilities and competitive advantage of the enterprise. In addition, both dimensions of dynamic capabilities - perceiving and seizing opportunities - are positively related to financial performance and strategic fit as dimensions of a company's competitive advantage.

**Research limitations/implications:** One significant limitation was the relatively small survey sample, and another was its non-random nature. A further limitation is that the survey included one respondent from each of the companies surveyed. As a result, the respondent may have succumbed to social desirability bias, which is counted among the most common sources of error affecting the accuracy of survey and experimental results.

**Practical implications:** The presented research results can be considered relevant for both theoreticians and practitioners because they contribute to understanding how family and non-family enterprises cope with adversities and what specifically determines their competitiveness in the conditions of the global economic crisis caused by the pandemic. The need for strategic adjustment (through formulating and implementing adequate competition strategies) in the context of strengthening the competitiveness of family and non-family businesses is a crucial factor in the functioning of these organizations in a changing environment.

**Keywords:** competitive advantage, strategic fit, dynamic capabilities, family and non-family firms.

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

## 1. Introduction

In recent years, there has been an increase in interest in family entrepreneurship. The literature often emphasizes the significant role that family enterprises – their creation process, activities, and failures – play in the domestic and global economy. In highly developed economic countries, the share of family businesses ranges from 60 to 90 percent of all operating business entities, and Poland is edging closer to these standards. Therefore, taking into account their significant share in the SME sector, the efforts of management theorists and practitioners aimed at identifying the determinants of family business competitiveness and understanding the conditions of their operations are justified. Although a growing body of research examines how family businesses achieve competitive advantage, the features that distinguish family businesses from non-family businesses are not always taken into account. However, it is worth remembering that family enterprises have certain unique characteristics that may lead to gaining a competitive advantage. This is related to the specific culture of family entrepreneurship expressed through properties, such as family nature (Pearson, Carr, Shaw, 2008; Kraśnicka, Ingram, Bratnicka-Myśliwiec, 2019), the firm's desire to survive for the next generations (Lopez-Gonzalez, Martínez-Ferrero, García-Meca, 2019), different growth models (Moreno-Menéndez, Casillas, 2021), special values shared by owners (Głód, Wronka-Pośpiech, 2018), socio-emotional wealth (Berrone, Cruz, Gomez-Mejia, 2012), or a specific leadership style (Rondoy, Dibrell, Craig, 2009). In addition to other significant differences between family and non-family businesses (Chrisman et al., 2012), researchers such as Acquaah (2013) pointed out that family businesses also achieve high efficiency in a different way than non-family businesses. Despite the justifications indicated in the literature for in-depth studies on the factors determining competitiveness in both types of enterprises, empirical research in this area is relatively rare. Little is also known about how family and non-family businesses cope with adversity. In light of the above, the COVID-19 pandemic raises the question of how both types of enterprises deal with unforeseen adversity. And what is even more interesting, is what specifically determines their competitiveness in the conditions of the global economic crisis caused by the pandemic and whether the conclusions from Acquaah's research (2013) are also confirmed in the current, highly specific conditions. Considering the above assumptions, the author decided to present the study in three parts. In the first one – based on a literature review – research hypotheses are formulated. Then, the methodology of empirical research is outlined and the obtained survey results are interpreted. The summary indicates theoretical and practical implications and formulates avenues for further research.

## 2. Dynamic capabilities

When organizations are confronted with unpredictable, changing markets, they find that their level of resources is insufficient to maintain a competitive advantage. The dynamic capabilities approach aims at understanding and explaining an organization's competitive advantage over time. Dynamic capabilities have been recognized as a firm's ability to change its resource base to respond to rapidly changing environments (Teece, 2007). In the conducted research, it was argued that dynamic capabilities include the ability to maintain constant change (Oxtoby et al., 2002). They are, therefore, challenging to observe and even more difficult for other organizations to replicate. For this reason, they have been associated with sustainable competitive advantage, especially in environments characterized by change (Ambrosini et al., 2009). Similarly, Teece (2007) found three dynamic capabilities for detecting and shaping opportunities and threats, seizing opportunities, and maintaining competitiveness by strengthening, combining, protecting, and, if necessary, reconfiguring the enterprise's intangible assets. Eisenhardt and Martin (2000) defined dynamic capabilities as "organizational and strategic routines by which firms achieve new resource configurations as markets emerge, collide, split, evolve, and die." Given the competence perspective proposed by Zahra, Sapienza, and Davidsson (2006), a dynamic capability can be interpreted as the ability to reconfigure resources and procedures. Wang and Ahmed (2007) proposed that the component factors of dynamic capabilities include adaptive, absorptive, and innovative capabilities. Some definitions of dynamic capabilities also focus on organizational routines. For example, Teece et al. (1997) emphasized that dynamic capabilities reflect how organizations develop firm-specific capabilities and competencies in a changing business environment. These capabilities and competencies are closely related to the management and organization of intra-organizational processes, market position, and the development path of the organization itself. Dynamic capabilities are characterized by their repeatable element, as noted by Helfat et al. (2007). This means that a dynamic capability results in a series of organizational changes that are undertaken in a similar way over time. However, there are ongoing debates about how dynamic capabilities should be modeled. This makes the concept of dynamic capabilities more practical and supports empirical research on such capabilities. Note that we distinguish between the introduction of a dynamic capability and the dynamic capability itself. Dynamic capability is introduced when organizational development is undertaken, while dynamic capability is the ability of the enterprise to undertake this development. In other words, a dynamic capability is the "potential for action" (Helfat et al., 2007) rather than the action itself (Easterby-Smith, Prieto, 2008). Firms need dynamic capabilities, which are "the capabilities of firms to integrate, build, and reconfigure internal and external competencies to respond to rapidly changing environments" (Teece et al., 1997, p. 516). Thus, these capabilities are firm-specific, developed over time, depending on the distinctive strengths and opportunities facing the firm, and are

a function of organizational learning (Teece et al., 1997). Given a business's market position, dynamic capabilities help companies sense and exploit opportunities by reconfiguring resources or developing new ones, thereby enabling organizations to gain a competitive advantage. Therefore, research has found more and more evidence that dynamic capabilities influence the development of companies, and thus affect their efficiency and productivity (Henderson, Cockburn, 1994; Mol, Birkinshaw, 2009), sales growth (Evangelista, Vezzani, 2010) and are responses to new market requirements (D'Este, 2002). This capability is used by companies to recognize and respond to opportunities and threats, which involves modifying and/or creating normal capabilities that enable change. It is the dynamic capabilities of the organization that are considered to be the determinant of its success or failure (Bratnicki, 2010). This is even more important because the organization's pursuit of immortality, measured by the durability of sources of competitive advantage, can be deadly because it makes it difficult to get rid of ineffective resources (Bratnicki, 2003). Although the abilities to sense, grasp, and reconfigure may not be rare (Eisenhardt, Martin, 2000), there is variation in the frequency and skill with which firms perform such activities (Winter, 2000) as they accumulate knowledge about how to change (Zott, 2003). Dynamic capabilities can, therefore, be a source of competitive advantage (Schilke, 2014b; Teece, 2014). However, dynamic capabilities also come with costs associated with committing resources to change activities (Zollo, Winter, 2002). For example, firms typically incur transaction and coordination costs when they change their resource base (Chakrabarti, Vidal, Mitchell, 2011; Karim, 2006), such as hiring external consultants and other specialists to facilitate the change. Similarly, sensing capacity relies on the allocation of managerial effort and attention to externally oriented activities (Helfat, Peteraf, 2015; Wilde, Gudergan, 2015). Furthermore, unlearning costs arise when it becomes necessary to remove existing processes to reduce the friction associated with implementing change (Lavie, 2006). The disruptive effect of changes in the resource base, especially when they are made repeatedly, can prevent a company from achieving potential competitive advantage (Schilke, 2014a). Research shows a positive relationship between dynamic capabilities and competitive advantage in dynamic environments, although this relationship may become weaker at very high levels of environmental dynamism (Schilke, 2014a). Moreover, though dynamic capabilities may be more valuable on average in dynamic settings (Karna et al., 2016), dynamic capabilities may also be useful in stable environments (Ambrosini, Bowman, 2009; Eisenhardt, Martin, 2000; Wilden, Gudergan, 2015; Zahra, Sapienza, Davidsson, 2006).

### 3. Competitive advantage

Competitiveness can be understood as a set of opportunities to compete in the market; when a company has high competitiveness, it can survive and operate in the market for a long time (Gorynia, 2002, p. 48). Therefore, competitiveness is related to the assessment of the company's performance and its ability to obtain positive results in the future, in particular, the profit from its activities in the company's changing environment (Bossak, Bieńkowski, 2004, p. 18). Competitiveness may also mean the possibilities and ways of competing in the market sector within the market mechanism in the short and long term (Pierścioneł, 2005, p. 9) It is equally often considered as a condition for the organization's survival, especially in the context of sudden, difficult, or highly unfavorable situations from the perspective of its operations – referred to as crisis (Flak, Głód, 2012). According to Filipova, the final expression of an enterprise's competitiveness is its adaptive capacity, expressing the adequacy of its responses to the impact of the environment and adapting changes to the dynamics of the environment. (Filipova, 2004). Dimitrova indicated that competitive advantages are of key importance for the process of shaping and developing the firm's competitiveness. She also noted that the emergence of the modern competitive advantage concept is related to the development of scientific and technological progress, globalization, and internationalization of competitive relations (Dimitrova, 2014, p. 38). Competitive advantages are extremely time-consuming features of an entity or factors in the external environment that provide the company with an advantage over competitors in a given market in a given period. A competitive advantage is the features or properties possessed by a product or brand that give it an advantage over its closest competitors. Kotler mentioned that competitive advantage is an advantage over competitors obtained based on offering greater value or lower prices or by having more benefits justifying higher prices (Kotler, 1996, p. 431).

### 4. Strategic fit

Strategic fit is “the degree to which the needs, demands, goals, objectives and/or structure of one component are consistent with the needs, demands, goals, objectives and/or structure of another component” (Nadler, Tushman, 1980, p. 40). It is also perceived as a link between the firm and its external environment. Strategic fit indicates how an organization adapts, changes, and reconfigures itself to achieve fit (Venkatraman, 1989). Errors in these activities may prevent the firm from adequately responding to market changes (Zajac et al., 2000; Carmeli, Sheaffer, 2008), thereby incurring risk and reducing performance. As the firm must constantly adapt to dynamic environments, adaptability becomes a resource that allows the firm to create

a competitive advantage and helps ensure long-term growth (Murray et al., 2009). The concept of strategic fit is related to strategic change because the latter involves modifying the way how companies perceive their position in terms of fit and internally change this position to achieve the best possible fit with the surrounding environment. Many studies agree that organizational success is based on the dynamic and evolutionary nature of the fit between the organization and its environment (Gabrielsson et al., 2012; Zajac et al., 2000). The term “strategic fit” is used to explain how an organization’s strategy must “fit” with its external context and how the organization must be internally aligned with the strategy. This alignment is, of course, the primary responsibility of the CEO team. Strategic fit is therefore related to the concept of building a competitive advantage, which is the situational approach, which assumes that the organization's resources should ensure its flexibility to the changing environment, which ultimately leads to strategic fit (Rybicki, Pawłowska, 2010, p. 181). Competitive advantage is revealed in the quick response of the organization in terms of continuous adaptation to market conditions dictated by the environment. Strategic fit expresses the degree to which organizations adapt their capabilities and resources to changing features in their environment and internally from a strategic perspective (Zajac, Kraatz, Bresser, 2000). In other words, it is the compliance of the organization’s external environment (requirements or demands placed on the organization by buyers or customers) with its resources and capabilities (Amoako-Gyampah, Acquah, 2008; Da Silveira, Sousa, Pieter van Donk, 2010). Strategic adjustment according to the adopted criteria should most likely also “sensitize” the organization to changes in the environment. In the context of considerations about the competitiveness of family and non-family businesses in a crisis, the element of changing the business model and competitive strategy (adjustment) seems to be crucial (Hock, Clauss, Schulz, 2016).

Based on the literature analysis, the following research hypotheses were formulated:

H1: Dynamic capabilities affect the enterprise’s competitive advantage level.

H2: Strategic alignment affects the enterprise’s competitive advantage level.

H3: Dynamic abilities affect the strategic alignment level.

H4: Strategic alignment mediates depending on the dynamic capabilities and the enterprise’s competitive advantage.

## **5. Empirical research methodology**

The discussed empirical study is one of the research strands undertaken in broader research on the competitiveness of family and non-family enterprises in Poland in the conditions of the global economic crisis, which was carried out at the Department of Entrepreneurship and Innovative Management at the University of Economics in Katowice. The research was carried out in August-October 2021 among 422 firms. According to the size criterion, 174 were micro-

enterprises (41.23%); 116 were small (27.49%); 122 were medium (28.91%), and 10 were large (2.37%). The dominant activity profile of the surveyed firms was the service profile – 187 firms (44.31%); followed by mixed – 84 firms (19.91%) and commercial – 76 firms (18.01%) and manufacturing – 75 firms (17.77%). Most businesses operate on the domestic market – 132 firms (31.28%), then 125 firms (29.62%) conduct business on the local market, while 80 firms (18.96%) operate on the regional market, and 70 firms declare international activity (16.59%) and 15 in the global market (3.55%). To verify the research hypotheses, it was decided to conduct empirical research embedded in the theory testing trend. In the first step, the examined variables were operationalized. Existing and tested in international literature scales taken from reliable sources were used for the measurement. In the next step, the size of the population was estimated using a free tool available at: <https://www.danielsoper.com/statcalc/calculator.aspx?id=89>. The minimum sample size was estimated at a minimum of 110 entities to enable at least an estimation of the model structure, taking into account the number of latent variables - 5, and two observed variables. It should be borne in mind that the recommended sample size with the anticipated effect of 0.1, the statistical power level of 0.8, and the value of the coefficient  $p = 0.05$ , amounting to 1,713 entities, was beyond the financial reach of the project. In agreement with the Center for Research and Development at the EU in Katowice, it was agreed that the Center would collect data from at least 400 economic entities randomly selected from its database containing over 10,000 records, which should allow obtaining data at least moderately representative of the population. In October and November 2021, the Center collected 422 responses from representatives of enterprises operating in Poland, which were included in the analysis. The data was collected in the following way: representatives of the center telephoned or sent links to participate in the study. If the organization agreed to it, an e-mail was sent with a link to participate in the research. The respondents were either owners or managers/representatives of senior management in the enterprise. The presented results are part of a larger study carried out as part of the funds for maintaining the capacity of the Department. Following the work carried out, the sample included 290 micro and small enterprises, 122 medium-sized enterprises, and 10 large economic entities. The structure of the research sample is presented in Tables 1, 2, and 3.

**Table 1.**

*Structure of the research sample – size and existence period/lifetime/duration of the enterprise*

	Number of observations	Mean	Standard variation	Median	Minimum	Maximum
Size of the surveyed organizations	422	83.791	431.452	14	1	8000
Organization age	422	18.085	12.534	17	2	102

Source: Own research.

**Table 2.***Market in which the organization operates*

Market	Frequencies	Percentage	Cumulative percentage
Local	125	29.62	29.62
Regional	80	18.96	48.58
Domestic	132	31.28	79.86
International	70	16.59	96.45
Global	15	3.55	100.00
Total	422	100.00	

Source: Own research.

**Table 3.***Organization's business profile*

Profile	Frequencies	Percentage	Cumulative percentage
Retailing	76	18.01	18.01
Services	187	44.31	62.32
Manufacturing	75	17.77	80.09
Mixed	84	19.91	100.00
Total	422	100.00	

Source: Own research.

## 6. Variables' characteristic

Two scales were used to measure the dependent variable – the enterprise's competitive advantage. The first one referred to the assessment of EBIT, ROI, and ROS compared to competition, in relation to the industry and three elements relating to strategic effectiveness. The Cronbach's alpha coefficient for this scale was 0.8514, and removing any of the statements caused a significant decrease in this value. Therefore, this scale can be considered reliable. The conducted factor analysis employing the method of principal components analysis (coefficient under the correlation matrix = 0.047; Bartlett's sphericity test = 1282.84, 15 degrees of freedom,  $p = 0.000$ ; Kaiser-Meyer-Olkin measure of sampling quality = 0.805) led to the identification of two dimensions, and the orthogonally the rotated factor structure is presented in Table 4. The level of explained variance for the two dimensions was 0.7628.

**Table 4.***Factor analysis results of the enterprise's competitive advantage*

Variable	Financial result	Strategic effectiveness	Uniqueness
ROS against the sector	<b>0.900</b>	0.237	0.134
EBIT against the sector	<b>0.886</b>	0.218	0.167
ROI against the sector	<b>0.849</b>	0.200	0.240
Being more successful than competitors	0.239	<b>0.840</b>	0.237
Market share size	0.208	<b>0.839</b>	0.253
Strategic advantage over competition	0.288	<b>0.724</b>	0.392

Statements significantly loading into individual dimensions have been bolded.

Source: Own research.



The tool proposed by Wilden, Gudergan, Nielsen, and Lings (2013) was used to measure the main independent variable – the organization’s dynamic capacity. The Cronbach’s alpha level for the scale was 0.7849. The analysis of the loading degree of individual statements showed that the first question, referring to the employee participation in the activities of trade associations, significantly lowers the alpha level, and after removing this statement (alpha if item deleted), the reliability level for the tool increased to 0.79. Therefore, on such an 11-item scale, factor analysis was performed (coefficient under the correlation matrix = 0.007; Bartlett’s sphericity test = 2089.37, 55 degrees of freedom,  $p = 0.000$ ; Kaiser-Meyer-Olkin measure of sampling quality = 0.856) indicated two dimensions – the first of them, consisting of 7 statements, refers jointly to the capacity to sense and seize opportunities, the second, consisting of 4 statements - to the capacity to reconfigure enterprise resources. The orthogonally rotated factor loadings explaining 61% of the cumulative variance are presented in Table 5.

**Table 5.**  
*Factor loadings of the organization’s dynamic capabilities*

Variable	Sensing and seizing opportunities	Reconfiguring resources	Uniqueness
Observing best practices in the sector	<b>0.793</b>	0.013	0.371
Implementing sector best practices	<b>0.790</b>	-0.130	0.359
Investing in finding solutions for customers	<b>0.763</b>	0.035	0.416
Changing practices based on customer feedback	<b>0.712</b>	-0.120	0.479
Collecting economic information on business activity and the environment	<b>0.638</b>	0.238	0.536
Using established processes to identify target market segments, customer needs, and their innovativeness	<b>0.602</b>	0.191	0.601
Responding to defects indicated by employees	<b>0.582</b>	0.131	0.645
Substantial renewal of business processes	-0.007	<b>0.902</b>	0.186
New or substantially changed ways to achieve goals and accomplish tasks	0.061	<b>0.896</b>	0.194
New or substantially changed marketing method or strategy	0.071	<b>0.865</b>	0.247
Implementing new types of management methods	-0.087	<b>0.862</b>	0.250

Statements significantly loading into individual dimensions have been bolded.

Source: Own research.

Finally, a 6-item tool proposed by Li, Zhou, and Shao (2009) was employed to measure strategic fit as a mediating variable. The Cronbach's alpha coefficient for this scale was 0.7504, and removing any of the items resulted in a significant decrease in the value of this coefficient. The principal component factor analysis (coefficient under the correlation matrix = 0.179; Bartlett's sphericity test = 718.51, 15 degrees of freedom,  $p = 0.000$ ; Kaiser-Meyer-Olkin measure of sampling quality = 0.742) showed that it is a two-dimensional variable. Two dimensions explain more than 68% of the cumulative variance. The factor loadings are presented in Table 6.

**Table 6.**  
*Factor loadings of strategic fit*

Variable	Marketing fit	Cost level fit	Uniqueness
Production costs lower than competitors	<b>0.856</b>	0.040	0.266
Impact of operating system efficiency on costs	<b>0.841</b>	0.176	0.261
Position of the sector cost leader	<b>0.796</b>	0.156	0.342
Building a strong, hard-to-imitate brand	0.075	<b>0.844</b>	0.283
Benefits that products and services offer to customers	0.102	<b>0.836</b>	0.291
Unique product and service offer	0.263	<b>0.692</b>	0.453

Statements significantly loading into individual dimensions have been bolded.

Source: Own research.

## 7. Variables' characteristic

The Pearson linear correlation analysis was performed in the first step to analyze the dependencies between the variables under study. The results of this analysis and the basic descriptive characteristics are presented in Table 7. Meta-variables (averages of loadings included in individual dimensions) were calculated to compute the correlation coefficients for individual variable dimensions. The size and age of the organization were included as control variables, and the standardization of these variables was adopted for the calculation employing the decimal logarithm of the number of employees and the decimal logarithm of the number of years of the enterprise's operation.

**Table 7.**  
*Correlation coefficients between variables and descriptive statistics*

Variable	Marketing fit	Cost level fit	Uniqueness
Production costs lower than competitors	<b>0.856</b>	0.040	0.266
Impact of operating system efficiency on costs	<b>0.841</b>	0.176	0.261
Position of the sector cost leader	<b>0.796</b>	0.156	0.342
Building a strong, hard-to-imitate brand	0.075	<b>0.844</b>	0.283
Benefits that products and services offer to customers	0.102	<b>0.836</b>	0.291
Unique product and service offer	0.263	<b>0.692</b>	0.453

Statements significantly loading into individual dimensions have been bolded.

Source: Own research.

The correlation analysis shows that the examined variables are relatively strongly related, and the correlation coefficients range from 0.1 to 0.5. Thus, the assessment of strategic effectiveness is strongly related to financial performance, measures of marketing and cost fit, and to a lesser extent to the reconfiguration of resources and the sensing and seizing of opportunities. Furthermore, the size and age of the organization are related to the assessment of strategic effectiveness. The financial performance is related to the marketing fit and, to a lesser extent, to the dimensions of dynamic capacity and cost fit. Sensing and seizing opportunities are positively correlated with marketing fit, and negatively with the size and age of the

organization. On the other hand, the reconfiguration of resources is correlated with both dimensions of strategic fit and the organization's size. Marketing fit is significantly correlated with cost fit and company size. Cost fit is moderately strongly related to the size and age of the enterprise. To examine the relationships between the examined variables more closely, the modeling of structural equations was carried out in the Mplus program. Three models were estimated – the first one included the main dependent variable (competitive advantage) and control variables. The second, in which the main independent variable was introduced – two dimensions of dynamic capabilities. And the third, in which a mediator/moderator was introduced to the model – two dimensions of strategic fit. The model estimation results are presented in Table 8.

**Table 7.**

*Model estimation results of the dependencies between loadings*

Variable/model	Model 1	Model 2	Model 3
CHI2	27.207	355.932	519.018
DF	16	143	252
RMSEA	0.041	0.059	0.050
CFI	0.992	0.941	0.943
TLI	0.986	0.930	0.933
Akaike Information Criteria (AIC)	7773.170	22755.026	32191.629
SRMR	0.030	0.081	0.070
<b>Dependent variable: Financial result</b>			
R-square	<b>0.097 (0.029; 0.001)</b>	<b>0.183 (0.036; 0.000)</b>	<b>0.287 (0.043; 0.000)</b>
Constant	<b>1.448 (0.133; 0.000)</b>	<b>1.275 (0.120; 0.000)</b>	<b>1.118 (0.108; 0.000)</b>
Organization size (logarithm)	<b>0.620 (0.100; 0.000)</b>	<b>0.526 (0.102; 0.000)</b>	<b>0.374 (0.102; 0.000)</b>
Organization age (logarithm)	<b>-0.872 (0.231; 0.000)</b>	<b>-0.701 (0.221; 0.002)</b>	<b>-0.634 (0.214; 0.003)</b>
Sensing and seizing opportunities	-	<b>0.376 (0.084; 0.000)</b>	0.027 (0.115; 0.813)
Reconfiguring resources	-	<b>0.191 (0.050; 0.000)</b>	0.077 (0.055; 0.161)
Marketing fit	-	-	<b>0.382 (0.095; 0.000)</b>
Cost level fit	-	-	<b>0.223 (0.082; 0.006)</b>
<b>Mediation effects (indirect influence)</b>			
Sensing and seizing opportunities – marketing fit – financial performance	-	-	<b>0.332 (0.088; 0.000)</b>
Reconfiguring resources – marketing fit – financial performance	-	-	<b>0.093 (0.028; 0.001)</b>
Sensing and seizing opportunities – cost level fit – financial performance	-	-	0.025 (0.017; 0.132)
Reconfiguring resources – cost level fit – financial performance	-	-	<b>0.062 (0.024; 0.010)</b>
<b>Dependent variable: Strategic Effectiveness</b>			
R-square	<b>0.205 (0.040; 0.000)</b>	<b>0.317 (0.044; 0.000)</b>	<b>0.577 (0.047; 0.000)</b>
Constant	<b>0.651 (0.098; 0.000)</b>	<b>0.527 (0.081; 0.000)</b>	<b>0.324 (0.056; 0.000)</b>
Organization size (logarithm)	<b>0.600 (0.080; 0.000)</b>	<b>0.481 (0.078; 0.000)</b>	<b>0.341 (0.069; 0.000)</b>
Organization age (logarithm)	-0.104 (0.167; 0.533)	0.050 (0.156; 0.748)	0.048 (0.140; 0.731)
Sensing and seizing opportunities	-	<b>0.255 (0.061; 0.000)</b>	-0.034 (0.076; 0.655)
Reconfiguring resources	-	<b>0.199 (0.037; 0.000)</b>	0.046 (0.037; 0.215)
Marketing fit	-	-	<b>0.285 (0.065; 0.000)</b>
Cost level fit	-	-	<b>0.425 (0.066; 0.000)</b>

Cont. table 7.

<i>Mediation effects (indirect influence)</i>			
Sensing and seizing opportunities – marketing fit – strategic effectiveness	-	-	<b>0.241 (0.062; 0.000)</b>
Reconfiguring resources – marketing fit – strategic effectiveness	-	-	<b>0.069 (0.020; 0.000)</b>
Sensing and seizing opportunities – cost level fit – strategic effectiveness	-	-	0.047 (0.027; 0.084)
Reconfiguring resources – cost level fit – strategic effectiveness	-	-	<b>0.119 (0.024; 0.000)</b>

Source: Own research.

The models were estimated at an acceptable fit level – the RMSEA, CFI, and TLI coefficients have values considered good, which justifies a closer look at the studied dependencies. The level of explaining financial performance increases consistently with the introduction of subsequent variables to the model, reaching the level of almost 29% for financial performance and almost 58% for strategic advantage. Model 1 analysis leads to the conclusion that the organization's size is positively correlated with both strategic effectiveness and financial performance. On the other hand, the age of an organization is negatively correlated with financial performance, which indicates that older business entities have statistically lower financial performance than their younger market competitors. Model 2 shows that both dimensions of dynamic capabilities – sensing and seizing of opportunities – are positively correlated with the enterprise's financial performance and strategic advantage. In this model, the size of the organization is strongly correlated with the dependent variables, while the age of the organization is negatively correlated with financial performance, as in the case of Model 1. This in itself confirms hypothesis H1, although in the case of this assumption it is worth considering the results of modeling shown in Model 3. Moving on to the results of modeling that takes into account, apart from competitive advantage and dynamic capabilities, as well as strategic fit, it is worth pointing out that in this model the dependencies between dynamic capabilities and financial performance and strategic effectiveness cease to be significant. This is the result of the introduction of strategic fit dimensions into the model. In this model, both marketing and cost fit are significantly correlated with financial performance and strategic advantage. These variables, therefore, take over the influence of dynamic capabilities on the dependent variables. This confirms hypothesis H2. Moreover, three of the four mediation pathways from the dimensions of the dynamic capability to financial performance and from the dynamic capability to strategic effectiveness are statistically significant, indicating complete mediation. It can therefore be assumed that strategic fit is an important mediator of the relationship between dynamic capabilities and the enterprise's competitive advantage. This confirms the assumption expressed in hypothesis H3. In light of the Model 3 analysis, there is no confirmation for the correlation indicated in hypothesis H1.

## 8. Conclusions

Based on the results of the conducted empirical research, it can be concluded that dynamic capabilities influence the competitive advantage of the studied family and non-family businesses. Adopting an appropriate competitive strategy affects the results achieved and strategic effectiveness. Thus, better strategic adjustment allows for better use of emerging opportunities in the market environment to increase the competitiveness of firms. This situation occurs primarily in the context of adapting to changing market expectations (Liu, Atuahene-Gima, 2018). The research results are consistent with those conducted in this area, which point to the role of formulating a competition strategy in strengthening competitiveness (Rahman, Rahman, 2020; Adiguzel, 2020) and the mediating role of strategic fit in this context (Musa, Nmadu, Dakung, 2019). This article is not free from limitations. One of them was a relatively small research sample, and another – its non-random nature. A further limitation is the fact that the study involved one respondent from each of the surveyed enterprises. The presented research results can be considered relevant for both theoreticians and practitioners because they contribute to understanding how family and non-family enterprises cope with adversities and what specifically determines their competitiveness in the conditions of the global economic crisis caused by the pandemic. The need for strategic adjustment (through formulating and implementing adequate competition strategies) in the context of strengthening the competitiveness of family and non-family businesses is a crucial factor in the functioning of these organizations in a changing environment. Moreover, the authors are aware that the article does not exhaust the research problem but is only a contribution to further research. In future studies, for example, other statistical analysis methods (e.g., structural equation modeling) could be used, and the analyses could be based on a larger research sample. A great added value would also be the possibility of replicating the study on the same research sample – after the pandemic has ended.

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**RESEARCH AND DEVELOPMENT vs PRODUCTION –  
RIVALRY OR COOPERATION?  
CASE STUDY OF CHEMICAL INDUSTRY ENTERPRISE**

Bolesław GORANCZEWSKI

Akademia Wojsk Lądowych im. gen. Tadeusza Kościuszki we Wrocławiu; Grupa Azoty ZAK S.A.;  
boleslaw.goranczewski@grupaazoty.com, ORCID: 0000-0001-9081-083X

**Purpose:** Purpose of research carried out described in article, is to specify problems and causes thereof that occur in relationship between research and development department and production units on example of chemical sector enterprise. It is also on purpose to indicate possibilities that such problems to be prevented.

**Design/methodology/approach:** Research used the case study method and within framework thereof: literature on the subject and internal documentation review; interviews with technologists and production unit management and laboratory and R&D staff; and self-observation.

**Findings:** Main problems occurring between employee groups, constituting rivalry and other dysfunctions background were identified, and causes thereof as well, resulting in incubating such attitudes and behaviours. Both in terms of organizational and psycho-social factors.

**Research limitations/implications:** Query revealed lack of available literature relating explicitly to the relationship between production and R&D areas. Thus, in this case, attribute of building-up, taking into account effect of previous research inquiries by the other authors, is not applicable. Therefore, it can be considered that issue undertaken in present article is of innovative nature. It was focused on literature related to intra-organizational relations in work environment. Literature in form of industry reports or reports on R&D activities of industrial enterprises was also used as auxiliary measure.

**Practical implications:** Based on research carried out, improving guidelines which can be implemented practically from now on in company constituting the study area are specified.

**Originality/value:** Nobody has undertaken dichotomy subject matter that exists between R&D and production areas until now. These two activities trigger as it were intrinsically this phenomenon in majority of organizations, regardless of industry sector or branch. Research has shown both effects and causes of this phenomenon, based on which improving conclusions have been derived. In practice, these are easy to implement in any organisation. They can take the form of evolutionary or revolutionary changes without detriment to the social potential employed in areas constituting the field of rivalry, as well as without loss to the organisation itself. Present article fills publication gap within range of R&D and production area cooperation in terms of causes and effects of problems occurring between these activities in organization.

**Keywords:** research, development and meaning thereof in organization, intra-organization relations, production vs R&D relations.

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

## 1. Introduction

Between R&D and production activities it comes to frequent dichotomies in role perception and importance of R&D function in organization. They are dependent on organizational area within framework in which employees formulate opinions or undertake defined activities. Both in terms of product development and process improvements as well, including business, technological and other processes. Rivalry is very often exemplification of these interdependencies. Thus, issue undertaken in present article has two contexts. The first one relating to awareness of R&D area importance learning among respondents employed on opposite sides of potential rivalry field. While the second context concerns the construct of organizational behaviour. It is just at level of psychosocial and organizational factors that behaving activities become to be incubated which in consequence are escalated finally to be manifested as dysfunctional and behaving attitudes, including rivalry ones. Proper coexistence and cooperation between such key areas as production and research & development constitutes organisation strength. They should be derived from appropriate organizational leadership being in accordance with contemporary conditionings (Chojnacka, 2021 p. 67). In turn, organizational strength is condition of survival in dynamically changing market environment which in case of chemical sector, besides to customer requirements, is determined by capability of:

- adaptation to changing, increasingly restrictive, environmental regulations, especially with regard to energy transformation and decarbonization (Goranczewski, Kądziałowski, 2022),
- producing new biodegradable, environmentally neutral products.

In enterprise structure which constitutes the case study area, currently there are three production units (Agro, OXO and Power Generation). They are performing production tasks and, as in case of power generation, supporting tasks for basic production. Within internal structure frames of these units, within range of process supervision and improvement, there function technology offices. Furthermore, technologists are employed in individual departments of production units. In Grupa Azoty Zakłady Azotowe Kędzierzyn SA enterprise there is also research and development department. Operation thereof includes following activities:

- quality laboratories which are testing product conformity with requirements and
- research and supporting laboratories such as (environment, HSE, power generation laboratory),
- research & development centre with research agenda dedicated mainly to OXO products,
- alternative fuel laboratory (under construction) which task will be determination of Hydrogen in purity class 5.0, for applications, among others, in automotive branch.

**The aim of research conducted, described in article, is to identify main problems that occur in relationship between research and development (R&D) and production departments in the chemical sector enterprise. It is also attempt to indicate possibilities for counteracting such problems.** Based on the objective thus formulated, the following research problems were defined:

**P.1** Perceiving by employees of role and importance of R&D department in enterprise's activities (partitive and interactional relationships) is closely associated with affiliation to organizational areas constituting rivalry field;

**P.2** Perceiving by employees of role and importance of R&D department stem from possibilities of individual potential benefits obtaining created by R&D activities. This, in turn, creates inherent/natural rivalry between job position groups such as technologists and research staff.

Nomenclature used in text in form of: research and development department, R&D area, R&D function or standalone abbreviation R&D which appears in following text, should be interpreted as identical. Also, term 'production' should be understood ambiguously. Objectively as organizational function; as business unit, according to enterprise structure in which research was conducted. Subjectively as: management staff; technologists working in individual production departments and in technology offices of production units as well.

## **2. Research Method**

To resolve problems specified above, in research carried out qualitative tools were used. Research problems presented are of practical nature. Solution thereof may constitute basis for significant improvements not only in enterprise constituting research area. Both R&D department and production understood in broadest sense also, are key areas of activity for each enterprise of this type. Explanatory dimension of research carried out is also essential, enabling generalisations to be made. Both conditions and causes of phenomenon described, context thereof, intervention conditions or preventing activities and/or techniques, will be similar in each entity similar to one under research (Konecki, 2000). In case of qualitative methods used, to describe and explain phenomena, using of hypotheses is unnecessary (Kostera, 2003). Taking into account assumptions thus defined, as leading method, case study was used (Stake, 2014). While, within research framework, research method selection is presented as follows:

1. Literature review on the subject and content analysis of available literature (Creswell, 2013). Source material selection was based on key word identification. Query was conducted in the following scientific databases: Academic Search Ultimate, including Business Source Ultimate, Education Resources Information Center, AGRICOLA, Newspaper Source and Google Scholar. In available records of individual databases, there occur trace amounts of publications that could be recognized as similar to research issue undertaken in article.
2. Internal documentation review, within range described in present article, and in particular, dispositions, instructions and procedures regulating subject matter of inventiveness, innovations and research and development projects. These are unpublished materials, available to the author due to the fact of employment in entity constituting research area (Łuczewski, Bednarz-Łuczewska, 2012).
3. Interviews conducted with the production unit employees, mainly with technologists and managers in charge of production or technology offices (Kvale, 2012). On the other hand, laboratory managers and staff in product development offices were interviewed within range for both fertilising products and OXO alcohols and plasticisers as well. In interviews the persons pursuing implementation doctorates were taken into account. It was assumed for all persons selected that they have experience adequate to issues discussed in article, including real cooperation between R&D and production departments.
4. Self-observation - the author is employee of entity under research, responsible for, among others, research and development department and production unit "power generation" (Ciesielska, Wolanik, Boström, Öhlander, 2012).

Research area was Zakłady Azotowe Kędzierzyn SA. which is part of Grupa Azoty SA - capital group structure. The plant is manufacturer of granulated nitrogenous fertilisers, aqueous urea solutions, ammonia water, among others for power generation industry, technical urea water, liquid fertilisers (nitrate-urea solution), nitric acid, and also OXO products including: alcohols, esters/plasticisers. Research was conducted in September 2023. Research population selection was quota-based and was N = 18, taking into account selection criteria described above in section 3 (interviews).

### 3. Literature review

Literature review within range of research issue discussed shows that there are no texts in available literature that directly are related to issue constituting subject of present consideration. Therefore, we focused mainly on publications which are dealing with role and importance of function itself as research and development play, and on unpublished elaborations of consulting companies and public institutions that are monitoring and/or analysing innovation and development activities of industrial enterprises as well. In this subset, publications on R&D project management itself are dominating trend (e.g. Gryzik, Knapieńska, 2012). Since, development activity is associated with broad possibilities for co-financing, implemented by various types of special purpose funds. Therefore, it is important to manage research projects properly, including intra-organizational cooperation with methodical, model solutions utilizing so that projects could be implemented effectively (Wittek, 2011).

Few of the available source materials relate to issue of expenditures on research and development activities and profitability conditions of these ventures as well (Tylman, 2013). There are also available single isolated analyses and reports within effect study range of business support in research and development activities (NCBiR, 2023; Borowczak, Dobrowolska et al., 2022). Publications available are supplemented by yearbooks of Główny Urząd Statystyczny (GUS) in sections "Research and development activity" and "Science and technology". R&D activity is indispensable element of strategy, especially in chemical sector entities where it is difficult to imagine functioning possibility without activity of research and development centres or start-ups without continuous acquisition and access to up-to-date information in order to anticipate future action directions (e.g. Chojnacka, 2023; Goranczewski, Łukaszcykiewicz, 2023). Available literature query covered also issues selected from problems of organizational behaviour, because correct relationships between two organizational functions, may be recognised to be in this scientific inquiry area. Factors contained thereof can be divided into:

- psycho-social ones, such as managers and co-workers attitudes; motivation and commitment resulting thereof; satisfaction from job done; trust and sense of justice (e.g. Matta et al., 2015; Lavanya, Kalliath, 2015; Thakre, Mayekar, 2016; Ghazi, Jalali, 2017 et al.),
- organizational ones - formalisation degree (including extent, management range, configuration and coordination); supervision degree; autonomy in decision-making, both on and off job position; entitlement and responsibility range (e.g. Kofta, 1979; Kuc, 2009; Newman et al., 2014; El-Kassar et al., 2017; Łobos, 2011, et al.),
- counter-effective and dysfunctional ones, such as (Goranczewski, 2018; Szeliga-Duchnowska, 2021): selfishness; rat race; petty political cunningness relying on diminishing of other's work importance while emphasising one's own role and importance; qualitative/quantitative work overloading and, analogically, work underloading, etc.

#### 4. Own research carried out results

To resolve issues presented in introduction, research questions were formulated and posed to respondents during interviews. Interview as tool was chosen to utilize because it allows doubts and misunderstandings among respondents to be resolved in real time. Research carried out results with utilizing interview technique for problems P1 and P2 are presented in Tables 1 and 2, respectively. In order to achieve information confidentiality and to guarantee sense of comfort and security for the employees interviewed as well, they were divided into organizationally related groups and to prevent identification by bystanders, coding was done. Coding method is presented as follows:

- A – Technologists and managers of technology offices and managers of production departments.
- B – Research and development department staff; implementation doctoral candidates, quality and research laboratory managers.
- Year range of job tenure (C – 1-8; D – 9-15; E – 16 and up).

**Table 1.**

*Research results for P1 (N = 18)*

Question number	Question content	Exemplary responses occurring most frequently, including respondent code
1.1.	What is importance of development department in chemical sector enterprise and what does it derive from? What factors and to what extent do determine the need of functioning thereof? (product, processes, business, market)?	<i>"...it is of strategic importance; it is responsible to response for current market needs...; for current and legislating branch trend tracking..." B/C</i> <i>"...nowadays, large chemical industry enterprise, without its own R&amp;D, will not develop; market is changing due to new regulations and expansion of Chinese chemical products on European market; in addition, there exists need to develop industrial and intellectual property." A/E</i> <i>"...R&amp;D centres are becoming indispensable component of chemical industry sector in particular; establishing thereof is determined by rapidly changing market and the need to be competitive through introduction of new products..." B/D</i> <i>"...in chemical industry, development department is of key importance; it is necessary constantly keep up in following customer's needs, tastes and even sometimes fashion thereof..." A/E</i> <i>"...development department that is people in it; if they have passion for learning about new trends, department can perform leading role for whole organisation..." A/D</i> <i>"...R&amp;D department provides possibility to be flexible and adapt to changes and also to improve technological processes..." A/C</i> <i>"...development department is of strategic importance; its activity is, by definition, supra-structural; it combines production, business and regulatory competences within range of: available technologies, changes in the state of the art, market realities, dynamic economic changes..." B/E</i>



Cont. table 1.

1.2.	<p>How high up in the organization structure should development department be positioned and what should relationship between R&amp;D and production look like (subordinate/supportive/rivalry/competition or maybe other, e.g. partnership)?</p> <p>With which areas in organization should the R&amp;D department primarily cooperate closely?</p>	<p><i>"...the development department should be positioned in company strategic division...; R&amp;D relationship - production should be partnership and R&amp;D department should be basic support for all company units from range of product innovations...; development department should also cooperate with sales departments..." B/C</i></p> <p><i>"...the development department should be organizationally positioned in strategic area; ...the implementation of newly developed technologies and products through R&amp;D should be ordered from above for production by managing board..." A/E</i></p> <p><i>"...R&amp;D should be unit supporting production...; ...relationships that provide opportunities for development are partnership and supporting relationships..." A/C</i></p> <p><i>"...R&amp;D should cooperate closely with production on partnership basis, know current technological problems and try to solve them together, support technologists...; ...as team of scientists, could see in practice what working on large-scale installations looks like; we would operate on symbiosis principles, thanks to which both production would know in which aspects we are able to help them and what we are currently dealing with..." B/D</i></p> <p><i>"...R&amp;D absolutely must cooperate with production and market, because research for research's sake is, in my opinion, detrimental to company..., R&amp;D, due to its competences and potential, should support production" A/C</i></p> <p><i>"...R&amp;D department tasks in close cooperation with technologists from production department who have more knowledge about large-scale production..., investigating causes of non-conforming products are tasks for R&amp;D..." A/D</i></p> <p><i>"...R&amp;D relationship – production are of two types: subordinate one – production exerts pressure on department and defines directions of development..., ...supporting one – production and R&amp;D department are in state of constant competition...; ...competition, in turn, means generating unnecessary costs through repeating expenses for similar projects..." A/E</i></p> <p><i>"...relationships between them should be partnership/supporting..., ...in both areas there are people who may cooperate by means of knowledge sharing..." B/C</i></p> <p><i>"...development department should function in enterprise strategic division...; ...close cooperation with marketing, trade and regulations is of key importance..." B/E</i></p>
1.3.	<p>What expenditures should be incurred on research and development activities, in percentage term, in the structure of enterprise costs or revenues?</p>	<p><i>"...expenditures on R+D should account for 10% of all costs; ...they should be treated as critical and have stable level of financing..." B/C</i></p> <p><i>"...I think that in typical situation, 1% of revenues in company like ours is sufficient...; ...if we want to work on new product, this level of measures is too low..." A/E</i></p> <p><i>"...we are certainly talking about cost structure of no less than 30%; ...it's a lot, but we're already working within the EU..." B/C</i></p> <p><i>"...it is assumed that expenditures on R&amp;D activities may account from 1 to 10% of operating costs; ...in my opinion, there should be no rigid guidelines; ...the most important aspect is not amount of expenditures on R&amp;D, but effectiveness of using thereof and translation into implementation..." A/C</i></p> <p><i>"...5-10% of all costs..." B/E</i></p>

Source: own elaboration based on interviews carried out.

With regard to first research problem, role and importance of R&D department are assessed similarly. Respondents point to indispensability and necessity of department functioning, especially in situation of dynamically developing market. Its basic task is to elaborate solutions and, above all, development works within range of products that meet customer requirements, ensuring competitiveness, while taking into account dynamically changing environmental conditionings. Majority of respondents, whether from R&D or production areas, recognizes strategic role thereof, pointing simultaneously to competitiveness and market as main determinant of locating this function on such high level.

Respondents' opinions as to the place in the organizational structure hierarchy thereof are less consistent. Respondents have different understandings of strategic area, especially as to interdependent and partitive relations with regard to other organizational areas. For example, representatives of production units claim that R&D department should play supporting role with regard to production, while R&D representatives claim that it should not play superior but leading role in relations associated with research and development project management. Responses of production respondents reflect view that lack of close cooperation leads to discrepancies relying on conducting research effects of which cannot be applied into large-scale production and in directions which are not market directions. Production acknowledges that technologists have better orientation within range of large-scale production and market needs than R&D employees. Respondents are in line as to that R&D should cooperate closely with units responsible for market issues. There occurs significant discrepancy in opinion regarding indication of expenditures level that should be incurred on development activities. In cost structure it is comprised within range of 1-10%. With cost level running into billions, these are high expenditures representing order of expense magnitude that, in opinion of respondents, should be allocated on research and development.

In Table 2 selected respondent responses relating to second research problem are presented.

Significant symptoms of differences between two groups of respondents begin to become apparent in dysfunction assessment during mutual cooperation. They are based on striking aspect of potential benefits resulting in from development works carried out. This, in turn, constitutes natural trigger for rivalry that is forming. In fact, case is that production units undertake standalone research, especially when quality laboratories are situated in production departments. They are motivated by rationalization inventions or patents and profits resulting thereof, rewarded with additional remuneration. It is also natural striving resulting in from specifics of technologists' work, who are analysing processes currently on regular basis without possibility of abstracting from product quality and thus improvement thereof.

**Table 2.***Research results for P2 (N = 18)*

Question number	Question content	Exemplary responses occurring most frequently, including respondent code
2.1.	Do you observe discrepancies (dysfunctions) in cooperation between production and R&D departments, and if so, what is possible cause thereof? Is it interest difference or maybe some other reasons (please provide examples)?	<p>"...in my opinion, R&amp;D department pays too little attention for finding gaps in existing processing procedures at our customers..." B/C</p> <p>"...units try to implement R&amp;D work on their own; it may be associated with conviction that if department elaborates certain solution, merit awards go to it, not to the originator..." B/D</p> <p>"...production department is not interested in implementing new products because, generally speaking, it causes troubles and confusion for them; as they claim, no one will pay them for implementing something new...; lack of additional remuneration for implementations is main obstacle: lack of financial motivation...; in addition, there take place competition between directors of production departments and directors of development department (who receives awards)...; technology offices without cooperation with R&amp;D department intensify unhealthy competition...; ...there should be defined rules and competence division as to what belongs to R&amp;D department work and what belongs to technology offices of production department..." A/E</p> <p>"...there is lack of unit specifically dealing with power generation development in connection with decarbonization..." A/C</p> <p>"...production = lack of inclination to change...; inappropriate remuneration systems, lack of process connections..." B/C</p> <p>"... dysfunctions result in from lack of proper communication or when priorities of both are completely divergent...; ....where R&amp;D unit does not work on solving problem in company, but is conducting research that is unlikely to be implemented..." it is also omission when at initial stage it seems to have something interesting, but with time the topic becomes more and more difficult - then there often lack of courage to finish it...; ...there also happens that such projects are associated, for example, with personal development of R&amp;D staff, that is I mean implementation doctorates what additionally complicates the matter..." A/D</p> <p>"...there exist many dysfunctions; they are connected to human factor, i.e. through inadequate, non-partnership relationships...; ...this is also vaguely defined activity range of individual departments; this was only since 2022 that it was formally established that research and development should be carried out exclusively in Research Department; such activities were also carried out by production area; ...in result, certain kind of rivalry between R&amp;D area and production area began; this had measurable and negative financial effect for company, because costs of R&amp;D activities on production units were not properly recorded and qualified, e.g. for tax allowance..." B/E</p>

Cont. table 2.

2.2.	How should correct cooperation between development department and production department look like, and including: how should proceed decision-making process within range of application for new research areas connected to product development, process improving etc?	<p>"... research work, whether on new product or on new technologies should be assessed at every stage in terms of their economic effects on our company...; ...analysis should be carried out on how changes introduced will affect prevailing realities on market and what these changing conditions may force on us in future...; A/D</p> <p>"...it is up to production units that should apply current needs regarding product development and technological process to development department..." A/C</p> <p>"...everyone can apply with new idea so as not to block good solutions..." B/E</p> <p>"...R&amp;D and production units should work more closely together...; ...beside of orders from production units, B&amp;R centres deal with implementation of their projects about which employees of production units often are not informed; ...there is lack of working meetings and joint implementation of projects at all stages thereof...; A/E</p> <p>"...if R&amp;D is going to support production and trade, it seems that need to solve certain problem, improve product or technology in business areas must arise first..." A/C</p> <p>"...new research areas should be discussed by both parties in order to consult on possible solutions...; results of laboratory works should be consulted on regular basis..." BR</p> <p>"...if ever comes moment when cooperation between development and production departments will be correct, it will be first symptom that organization has deviated from development and innovation paths..." A/D</p> <p>"...each employee has possibility to submit research topics...; such application is verified and decision is taken to include research topic into research work plan...; in my opinion, applications should mainly come from market environment..." B/C</p> <p>"...business units, knowing market needs best, should apply the need to carry out given research topic, and not act on their own...; Development Department, utilizing research facilities, is working on solutions within range of submitted ideas, being in constant contact with unit, and is keeping it informed currently about work progress..." B/C</p>
2.3.	Where, in your opinion, is borderline between technologist job, whose task is to improve production/operation processes and that of R&D department, and does such borderline exist at all?	<p>"...there should be cooperation between development department and technologists so that the latter can verify on regular basis whether conceptual solutions proposed by R&amp;D can be adapted to production installations..." A/C</p> <p>"...division between works of production technologists and R&amp;D area is quite fluid, so you have to draw the line (who is responsible for what) because some innovative activities can be carried out in both areas..." B/E</p> <p>"...there should be no such borderline, as technologist is developing many ideas which are consulted with his superiors, most frequently it is finished with investment application..." A/D</p> <p>"...work of technologists in production units is closely connected to work of R&amp;D staff; the difference is that technologist frequently does not have research facilities and does not have possibility to check ideas and assumptions..." B/D</p> <p>"...production technologist is working on so-called living organism and is well familiarized with installation operation specifics; production technologist should be reviewer and advisor in question of possibility of making changes, improvements or new solutions..." A/E</p> <p>"...there should be no borderline here, our commitment is to cooperate best...; sometimes main constrain is ignorance as to potential problems..." A/E</p> <p>"...there should be close cooperation between development department and technologists of production units..." BR</p>

Source: Own elaboration based on interviews carried out.

Opposite opinion represented among respondents (paradoxically also from production department) is conviction that production units are not interested in implementing innovations because this is additional problem for them. Process deregulation and instability, necessity to learn how to properly conduct modified and/or new processes, constitute additional burden that production workers are not inclined to accept, especially those who do not participate in potential benefits.

Subsequent, third category consists of dysfunctions resulting in from lack of proper communication between individual areas and subjectivity in motivation to undertake research and development work. Respondents indicate that evidence for this are, for example, 24 implementation doctorates carried out in company under research in vast majority by R&D employees. For this reason, production department is reporting doubts as to whether topics thereof, and consequently their research work, are in line with market requirements and while not with other, personal motivations.

During interviewing, respondents were asked about differences in technologists' work specifics and that of development department research staff. Is there clear borderline between work of first ones and other ones? Interviewed persons stated that such borderline is very fluid and in practice impossible to grasp. There were prevailing opinions that there was necessity to cooperate very closely between both employee groups. It was pointed out that technologists do not have research facilities, but in turn, they should have possibility to assess R&D work progress from the point of view of supervised processes and fact that they will be the ones who will be introducing necessary innovations on their installations, constituting result of these works.

## 5. Conclusions

Taking into account above contents, it can be concluded that goal of work has been achieved. Despite the scarcity of literature items, among which none which refers strictly to discussed issues, causes of dysfunctions that occur in relations between R&D and production departments have been identified. They are primarily based on factors of psychosocial and organizational nature (Goranczewski, 2018). They include:

1. Own work perceiving through prism of importance and emphasizing thereof, while depreciating the work of area constituting the rivalry field. Hence opinions expressed by respondents that production is more important than R&D and vice versa. The consensus was only to referred to R&D location in the organizational structure at the strategic level.

2. Rivalry results in from potential financial benefits that are belonging to individual groups of employees, from which, in opinion of production workers, R&D employees can benefit to greater extent. Taking into account the procedures and internal documents in force in this matter, this is unjustified view, however, it is natural that despite of widespread availability, knowledge thereof is lower in production area than among R&D employees. In addition, there are possibilities to carry out development works which by assumption are greater in R&D department. This results in suspicion emerging among respondents regarding to particularisms or subjective motivations when undertaking research work, especially relative to employees pursuing implementation doctorates. And this is despite of fact that everyone has opportunity to apply for development works, so that not to block potential solutions within range of products, technological or business processes that are good for organization.
3. Lack of communication and cooperation between technological and production offices and R&D employees. Assessment of communication low level stressed by respondents constitutes challenge for improvement in this area. Dialogue, discussion, opinion exchange and arrangements between parties, and above all, economic and technical evaluation of works carried out at every implementation stage (laboratory, piloting, serial production), constant prospect assessment for achieving success through implementation of innovations, these are foundations for improving mutual relations.
4. Author's self-observation, internal documentation analysis and interviews conducted show that technological offices of units, spontaneously, omitting R&D department, undertake research on their own. This applies mainly to product and technological processes as well, what is, as it were, natural consequence of everyday work of technologists. There would be nothing wrong with that, because improving initiatives and innovation activities are priceless for chemical industry enterprise, if it were not for fact that in this case there occur cost multiplication. Emerging of so-called hidden costs (Dahlgard, Kristensen, Kanji, 2001). Lack of possibility for correct cost accounting in favor of possibility to obtain tax allowance resulting in from innovative activity, so-called Innovative Box mechanism and in consequence thereof – measurable losses (explanations of Finance Ministry, 2015).

To recapitulate, improving activities that could effectively solve problems described in present article should be divided into two groups. The ones are of evolutionary nature, while the others are of radical nature.

1. Evolutionary actions – raising awareness among employee groups, regular meetings and joint teams, one of goals of which would be current information exchange, and building micro-communities around individual research and development projects as well.
2. Radical, organizational actions. Surely most effective, but because of social resistance and ambition particularisms, they are difficult to conduct. This is liquidation of technological offices in production units and transferring technologists employed thereof

to R&D department. Then, technologists become employees of R&D area. There can be no question of information flow lack, especially that respondents indicate that there is no visible demarcation line between work of technologists and R&D research workers. Technologists continue to work on their installations but already as employees of R&D area rather than of production unit. This way, R&D department may function as integrator of technical, product, research and regulatory competences within enterprise.

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## CONDITIONS OF THE PROCESS OF BUILDING OF AWARENESS OF CORPORATE SOCIAL RESPONSIBILITY AS AN ELEMENT NECESSARY TO INCLUDE CSR IN CUSTOMER PURCHASES

Honorata HOWANIEC<sup>1\*</sup>, Klaudia GASZCZYK<sup>2</sup>

<sup>1</sup> University of Bielsko-Biala; hhowaniec@ath.bielsko.pl, ORCID: 0000-0002-8975-3601

<sup>2</sup> University of Bielsko-Biala; kgaszczyk97@gmail.com, ORCID: 0009-0006-4379-1318

\* Correspondence author

**Purpose:** The aim of this study is to examine the relationship between the demographic characteristics of consumers, their knowledge of the concept of CSR and the awareness of CSR activities undertaken by enterprises. This paper intends to examine whether the consumer knows the CSR activities undertaken by PKN ORLEN.

**Design/methodology/approach:** The paper used a survey to assess the consumers' perception of activities undertaken by PKN ORLEN in the area of CSR. The survey was an electronic survey. The questionnaires were administered to consumers from southern Poland. In order to test the hypotheses, cross-tabulation analyzes were performed along with the chi-square test of independence and Mann-Whitney U tests.

**Findings:** The research revealed that demographic characteristics do not influence the knowledge of activities undertaken by PKN Orlen in the area of CSR or the knowledge of the Orlen Foundation run by the surveyed company. The only factor that influences the awareness of CSR activities of the examined company is knowledge of the CSR concept. The results suggest that consumers who have knowledge about CSR are more aware of the activities that companies undertake in this area. It was also identified that the factors influencing knowledge of the CSR concept are gender and level of education, with people who demonstrated higher knowledge of CSR being men and people with university education.

**Research limitations/implications:** The research was conducted on the Polish market, it concerned the activities of a large and very well-known brand in Poland (a multi-industry concern operating, among others, in the fuel and energy industry). The research can be repeated for other brands and other countries.

**Practical implications:** Research results suggest that an important aspect that increases the effectiveness of communication of CSR activities should be the educational aspect in the area of CSR.

**Originality/value:** The article obtained an interesting result that demographic characteristics do not influence customers' knowledge about companies' CSR activities, but the knowledge (understanding) of the CSR concept is such a factor.

**Keywords:** Social responsibility, Social responsibility awareness, Brand image, CSR knowledge, PKN ORLEN.

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

## 1. Introduction

CSR is seen as a company's voluntary commitment to exceed the explicit and implicit obligations imposed on the company by society's expectations regarding conventional corporate behavior, including emphasizing the increased attention of companies to environmental, social and even cultural aspects (Falck, Heblich, 2007; Hownaiec, 2019; 2023).

The social involvement of enterprises is rewarded, among others, by: increased interest of some consumers by paying attention to companies' CSR when shopping. There are studies showing who declares a greater willingness to take CSR into account when shopping (Klein, Dawar, 2004; Sen, Bhattacharya, Korschun, 2006). Unfortunately, there is still an unexplored gap in how consumers transfer knowledge about companies' CSR activities into their market decisions.

It is emphasized, among others, the need for enterprises to communicate CSR, paying attention to the numerous conditions for receiving CSR messages (Morsing, Schultz, 2006; Pomeroy, Dolnicar, 2009; Öberseder et al., 2011). The types of messages that trigger consumer reactions (at least the declared ones) as well as the types and goals of activities undertaken in the area of CSR are examined. The effects of strategic, profit-maximizing use of CSR by companies are analyzed (Kolstad, 2007). An important aspect of CSR research is also an attempt to fill the gap in the existing literature between various dimensions of CSR and brand loyalty. There is still a lack of studies examining consumer reactions in real shopping conditions with real brand practices in the area of CSR, therefore, there is a need to examine consumer attitudes and behaviors towards CSR in a real context.

This paper consists of five parts, beginning with an introduction. The second part reviews the literature on the impact of CSR on consumer behavior, communicating CSR and the impact of CSR on brand image and loyalty, and presents the adopted hypotheses. The third part describes the methodology, including data collection and characteristics of respondents, and presents the research results. In chapters four and five there is a discussion and summary.

## 2. Literature review

The literature contains more and more research results trying to determine the impact of CSR on consumer purchasing decisions (Brown, Dacin, 1997; Mohr, Webb, 2005; Sen, Bhattacharya, 2001; Castaldo et al., 2009; Öberseder et al., 2011; Howaniec, 2019; 2023). Many of them confirm that consumers choose brands/products of companies that are socially responsible and include CSR in their strategies (Sen, Bhattacharya, 2001; Salmones et al., 2005; Werther, Chandler, 2005; Pomeroy, Dolnicar, 2009). Some studies show that CSR still plays

a minor role in consumption decisions (Mohr et al., 2001; Öberseder et al., 2011; Howaniec, 2019; 2023). However, when considering the impact of CSR on customer purchasing behavior, i.e. whether this impact exists and is significant or whether it is not as important as it is attributed by some researchers (Auger, Devinney, 2007; Devinney et al., 2010), determining the relationship between CSR and consumer behavior is not easy. It has not been clearly confirmed how consumers take CSR into account in their decisions, whether knowledge about CSR influences their market behavior and how they translate knowledge about companies' CSR activities into their market choices.

The problem with most studies examining the relationship between CSR and consumer behavior is the assumed or artificially induced awareness of CSR among consumers (see Öberseder et al., 2011). However, consumers generally have a low level of awareness of what CSR is (Sen et al., 2006; Pomeroy, Dolnicar, 2009; Howaniec, 2019; 2023).

The relationship between consumers' CSR awareness or knowledge of what CSR is and their behavior on the market was demonstrated by, among others, Öberseder et al. (2011), Rodrigues and Borges (2015), Howaniec (2019, 2023). According to Öberseder et al., when companies engage in CSR activities, they must be mindful of the complex consumer evaluation process required to gain consumer recognition for CSR efforts and be mindful of communicating CSR activities. In a situation where they do not want to include CSR initiatives in their marketing activities, companies should focus on a positive image, because consumers interested in CSR associate CSR with the company's overall image (Öberseder et al., 2011). Rodrigues and Borges confirmed that knowledge about social responsibility practices and dimensions of CSR perception revealed by consumers influence the purchase of the company's products (Rodrigues, Borges, 2015). Howaniec's research has shown that the only factor that motivates people to take social responsibility into account when shopping is the knowledge of buyers themselves (Howaniec, 2019; 2023). But how does knowledge of the CSR concept or knowledge of CSR practices influence purchasing decisions?

According to many studies, the intermediary element, the link between CSR and consumers' market decisions, is the brand image.

Brand image is defined as a set of attributes that customers associate with a branded product and which give it a unique value in their consciousness and subconsciousness. These attributes include, among others: brand name, packaging, price, advertising style, but also the brand's or its owner's involvement in social responsibility (Popoli, 2011; Howaniec, 2012; Lu et al., 2020). As an attitude, brand image influences behavioral intentions such as brand loyalty (Johnson et al., 2001). Research confirms, among others, that the more favorable the image, the higher the perceived product quality, satisfaction and loyalty of consumers (Johnson et al., 2001; Herrmann et al., 2007). Socially responsible corporate behavior is a cue that helps consumers shape brand attitudes, which in turn helps determine their overall brand loyalty.

Research on the impact of CSR on brand image was conducted by, among others, Sen and Bhattacharya (2001), He and Lai (2014), Lu et al. (2020). Sen and Bhattacharya, for example, argue that high corporate credibility (positive reputation, contribution to the community and the environment) lead to more positive brand attitudes than low corporate credibility (Sen, Bhattacharya, 2001). He and Lai proved that there is a relationship between CSR, brand image and consumer loyalty, whereby brand image is an intermediate element between CSR and brand loyalty. In their research, the legal and ethical responsibility of companies has a positive impact on brand loyalty by shaping a positive functional and symbolic image of the brand (He, Lai, 2014). The results of studies Lu et al. indicate that the firm's CSR initiatives have a significant and positive impact on brand loyalty and brand image (Lu et al., 2020).

An important role in reactions to CSR activities is played by consumers' perception of the company's motives for engaging in CSR activities (Ellen et al., 2006; Vlachos et al., 2009). Ellen et al. (2006) identified different types of attribution: other-centered attribution (stakeholder- and values-oriented attribution), egocentric attribution (strategy - and self-interest-based attribution), and win-win attribution. Other-focused attributions refer to consumers' perceptions that companies feel morally committed and view helping as their duty. Egocentric attributions, meanwhile, portray companies as engaging in CSR for strategic reasons (e.g., to increase their profits). Most consumers attribute mixed motives to corporate CSR engagement and perceive it in a positive light when they attribute a combination of value-based and strategic attributions to CSR efforts (Ellen et al., 2006; Vlachos et al., 2009). Vlachos et al. (2009) show that value-based attributions have a positive effect on trust, while stakeholder-oriented, self-interested, and strategic attributions have a negative or no effect. Similarly, Becker-Olsen et al. (2006) concluded that social motivation is essential for positive consumer response, whereas profit-oriented initiatives have a negative impact.

An important aspect of the impact of CSR on consumer purchasing behavior is also the communication of CSR activities by enterprises. This problem was dealt with, among others, by: Morsing et al. (2008), Kim and Ferguson (2014), Go and Bortree (2017). Studies emphasized, among others: the importance of reliable sources of communication (Maignan, Ferrell, 2001; Schlegelmilch, Pollach, 2005; Pomeroy, Dolnicar, 2009), approvals of third parties (Morsing, Schultz, 2006; Morsing et al., 2008; Coombs, Holladay, 2011), stakeholder engagement (Schlegelmilch, Pollach 2005; Morsing, Schultz, 2006; Morsing et al., 2008), cohesion (Pomeroy, Dolnicar, 2009; Coombs, Holladay, 2011), employee engagement (Morsing et al. 2008) and good matching the company to the sponsored (supported) goal (Rifon et al., 2004).

Despite reservations and recommendations regarding CSR communication, the need for CSR communication is indicated by, among others: Öberseder et al. (2011), Howaniec and Kasiński (2021). According to Öberseder and others, companies must facilitate access to CSR information and indicate how a product or the entire company is linked to CSR initiatives.

However, they point out that companies should only communicate CSR initiatives that concern their core business, thus taking into account the peripheral credibility factor (Öberseder et al., 2011). Howaniec and Kasiński emphasize that the lack of any activity of the company in the area of CSR communication means that its stakeholders do not know the company's activity in the area of CSR and, therefore, do not take it into account in their behavior in any way (Howaniec, Kasiński, 2021).

Therefore, this study asked the following research questions:

RQ1 - How do demographic variables describing customers influence their perception of CSR at PKN Orlen?

RQ2 - How do demographic variables describing customers influence their knowledge of the CSR concept?

RQ3 - Do people with higher knowledge of CSR better perceive the activities undertaken by PKN Orlen in the area of CSR?

RQ4 - Do variables describing customers influence their perceived impact of CSR on brand image?

RQ5 - Do variables describing customers influence their perceived impact of CSR on brand loyalty?

Based on the research questions thus adopted, research hypotheses were formulated:

H1. Demographic variables describing customers influence their perception of CSR at PKN Orlen.

H2. Demographic variables describing customers influence their knowledge of the CSR concept.

H3. People with higher knowledge of CSR better perceive the activities undertaken by PKN Orlen in the area of CSR.

H4. Demographic variables describing customers influence their perceived impact of CSR on brand image.

H5. Demographic variables describing customers influence their perceived impact of CSR on brand loyalty.

### **3. Conditions of perception of CSR activities undertaken by PKN ORLEN – research results**

#### **3.1. Objectives and methodology**

The company selected for the study is PKN ORLEN. PKN ORLEN was selected for the study on purpose. PKN ORLEN and its subsidiaries (together the ORLEN Group) is one of the multi-energy concerns in Central Europe. The beginnings of the concern date back to 1944. Currently, PKN ORLEN is part of the ORLEN Group and operates on the Polish, Lithuanian,

Czech, Slovak, German and Canadian markets. The Group manages six refineries in three countries: Poland, the Czech Republic and Lithuania. In 2020, the total crude oil processed by the ORLEN Group amounted to approx. 29.5 million tones. They produce, among others gasoline, diesel fuel, heating oil and aviation fuel. They are also a leading producer of petrochemicals. They have the largest retail network in the region of over 2,850 petrol stations located in Poland, Germany, the Czech Republic, Lithuania and Slovakia. PKN OLLEN is also the largest industrial producer of electricity in Poland (Płock heat and power plant). The company and its brand are very well known in Poland.

The company is very socially involved. It undertakes a number of activities addressed to various stakeholders. PKN Orlen also runs the Orlen Foundation, which undertakes many activities. Including provides financial donations to the sick and needy, supports local communities through grant programs, grants scholarships for talented youth, donates for the purchase of equipment to fire brigades, provides support to hospitals, runs an employee volunteering program or, for example, donates to the Family Orphanages.

To conduct the study, empirical data were collected in the form of a questionnaire-based survey-CAWI (Computer Assisted Web Interview) technique. The survey was prepared in Polish. Online surveys were available at: <https://ankieta.interaktywnie.com> and information about the surveys was shared via email and on social media. The survey process lasted within a period from May 2021 to May 2022. The questionnaire-based survey had the nature of scientific intelligence and was not aimed at substantiating the representativeness of the sample. The survey covered 166 people.

The aim of the study was to determine the determinants of knowledge of CSR activities undertaken by PKN ORLEN, i.e. to determine whether demographic variables characterizing respondents have an impact on the knowledge and perception of CSR activities undertaken by PKN ORLEN and whether, in the respondents' opinion, these activities affect PKN ORLEN's image and loyalty. consumers. The sample selection was untargeted. Anyone could participate in the research. Basic information about the research is presented in Table 1. The sample characteristic is presented in Table 2.

**Table 1.**

*Basic information about the research*

<b>Specification</b>	<b>Research</b>
Research method	Survey
Research technique	CAWI (computer-assisted web interview)
Research tool	Electronic questionnaire
Sample selection	Untargeted
Sample size	Total: 166
Research date	May 2021 – May 2022

Source: own study.



**Table 2.***The sample characteristic (%)*

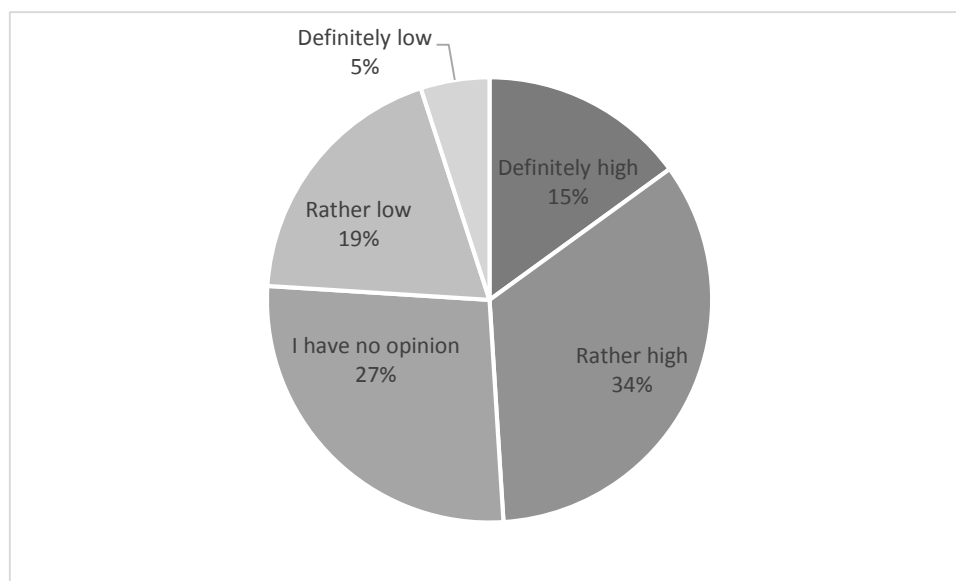
<b>Gender</b>	<b>Female</b>		<b>Male</b>	
<b>(%)</b>	<b>56</b>		<b>44</b>	
<b>Education</b>	Primary/Middle school	Vocational school	High school	A university degree
<b>(%)</b>	3	2	61	36
<b>Place of residence</b>	Village	City up to 50,000 residents	City from 50 to 100,000 residents	City of over 100,000 residents
<b>(%)</b>	50	23,5	23,5	3

Source: own study.

In order to answer the research questions, statistical analyzes were carried out using the IBM SPSS Statistics 29 package. It was used to perform cross-tabulation analyses, along with the chi-square independence test and Mann-Whitney U tests. The level of significance was  $\alpha = 0.05$ .

### 3.2. Results

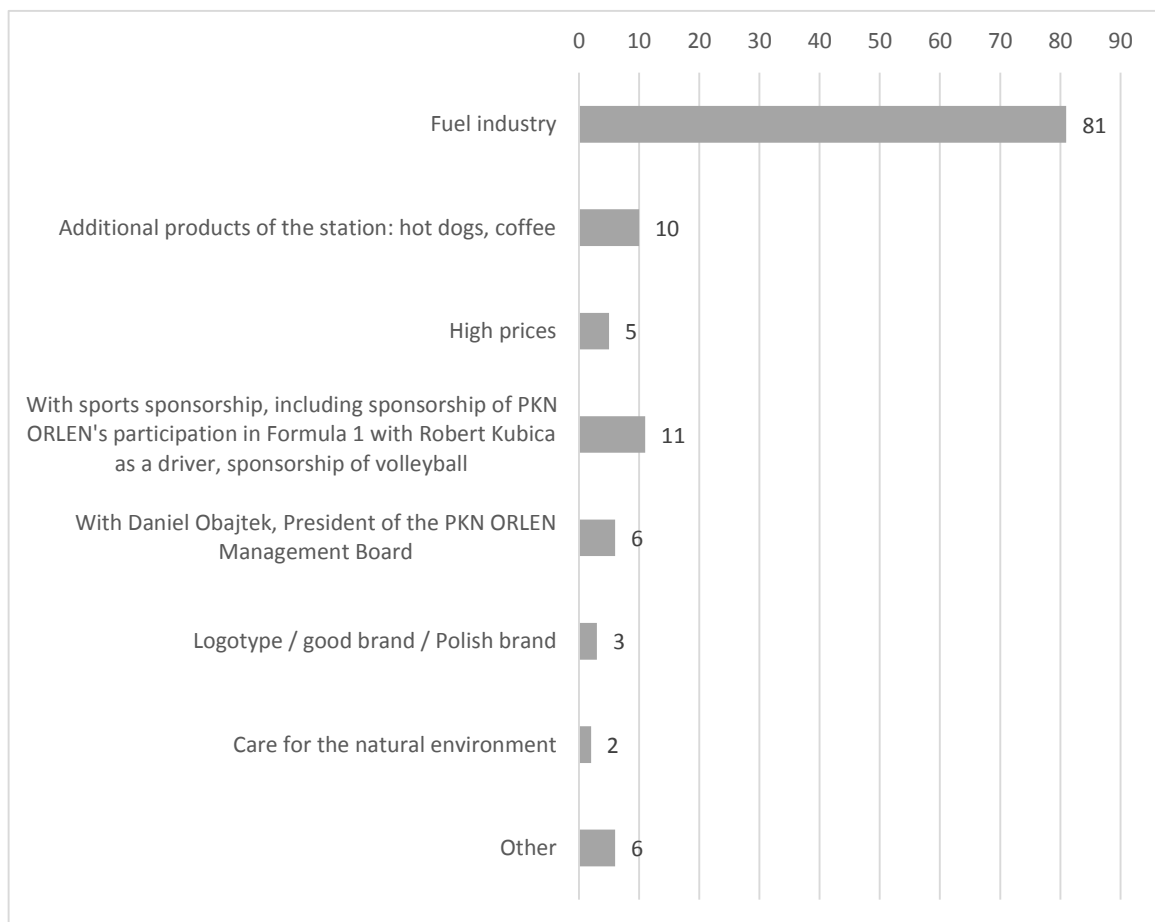
The respondents know the PKN ORLEN brand. It was confirmed by as many as 97% of respondents. Almost half of the respondents positively assess the degree of brand awareness in society. For 15%, the level of knowledge of PKN ORLEN brand is high and for 34% rather high. A relatively large group of respondents has no opinion. But only 5% think it is definitely low and 19% think it is rather low (Figure 1).

**Figure 1.** The perceived level of awareness of the PKN ORLEN brand.

Source: own research.

Most of the respondents associate the PKN ORLEN brand with the industry in which the company operates, i.e. the fuel industry (81%). However, the respondents also associate the brand with the activities that the company takes in the area of sports sponsorship (11%), in this group the majority of respondents indicated sponsoring the participation of the ORLEN Team in Formula 1, with Robert Kubica - a Polish racing and rally driver. The second was

sponsoring by PKN ORLEN volleyball. Indeed, since 2012, PKN ORLEN has been the main sponsor of the Polish Volleyball Federation. Another element with which the respondents associate the brand are food products that can be purchased at stations, such as coffee or hot dogs (10%). These products were the subject of the brand's advertising campaigns, so the association is justified. Next, respondents chose Daniel Obajtek, President of the Management Board of PKN ORLEN (6%). Unfortunately, in this case, some of the respondents emphasized negative connotations, pointing to ambiguities related to the property of Mr. Obajtek (Afera Obajtka). The respondents also associate the brand with high prices (5%), logotype or good (Polish) brand (3%) and care for natural environment (2%). Answers with less than 2% of responses were classified under the "other" category (Figure 2).

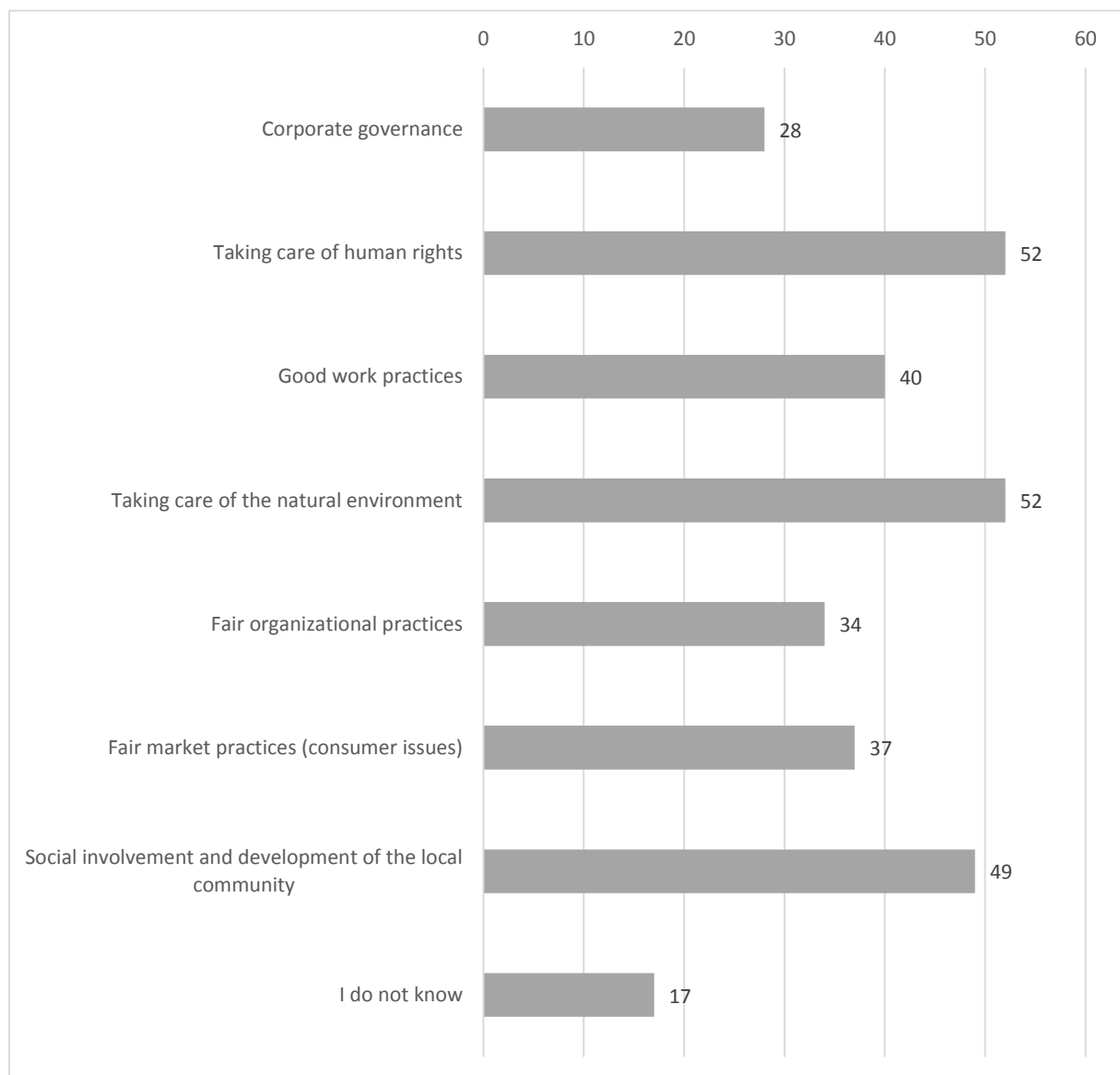


**Figure 2.** Associations related to the PKN ORLEN brand (%).

Source: own research.

Not all respondents know the concept of CSR. As many as 64% gave a negative answer to this question. Out of the remaining 36%, only 26% declared that they were able to define the concept of CSR, while 22% replied - "rather yes", and only 4% answered "definitely yes". 10% of respondents answered "I have no opinion", but only 4% indicated that they are rather unable to define the concept of CSR.

For more than half of the respondents, CSR means caring for human rights (52%), caring for the natural environment (52%) and social involvement and development of the local community (49%). Slightly fewer respondents indicated that, in their opinion, CSR is good work practices (40%), fair market practices (37%) and fair organizational practices (34%). For 28%, CSR is corporate governance, and 17% chose the answer "I don't know", which confirms that some of the respondents did not meet with this term or have no knowledge in this area. Due to the fact that the term CSR is relatively new in broad communication (including the media and social media), there is a high probability that there are people who may not have had contact with the definition of CSR. Even if they are recipients of advertisements indicating, for example, environmental responsibility, greater social involvement, or being a good citizen, they do not have to equate it with CSR. None of the respondents chose any other answer in this question, despite such a possibility (Figure 3).



**Figure 3.** Associations related to CSR (%).

Source: own research. The respondents could select more than one answer.

However, the question about knowledge of the concept was informative and was asked, among others, in order to later check whether there is a relationship between knowledge of the CSR concept and the perception of CSR activities undertaken by the Company. The main objective of the study was to determine how CSR activities undertaken by PKN ORLEN are perceived, what influences it and whether it affects the company's image. Therefore, the respondents were asked, *inter alia*, the question is whether, in their opinion, PKN Orlen is a socially responsible company, i.e. a company that engages, for example, in environmental protection, in the development of the local community, etc.? To this question, 34% answered "rather yes", which indicates the conditionality of the assessment, 7% answered "definitely yes", but as many as 49%, that is almost a half of them did not have an opinion on this subject. A total of 11% of the respondents gave a negative answer, i.e. 10% answered "rather no", and 1% of the respondents gave the answer "definitely not". In the case of the answer "probably no", as in the case of a positive answer, it is not a clearly negative answer. This answer contains partial doubts of the respondent, which may also result from the respondent's lack of knowledge about the activities undertaken by PKN ORLEN.

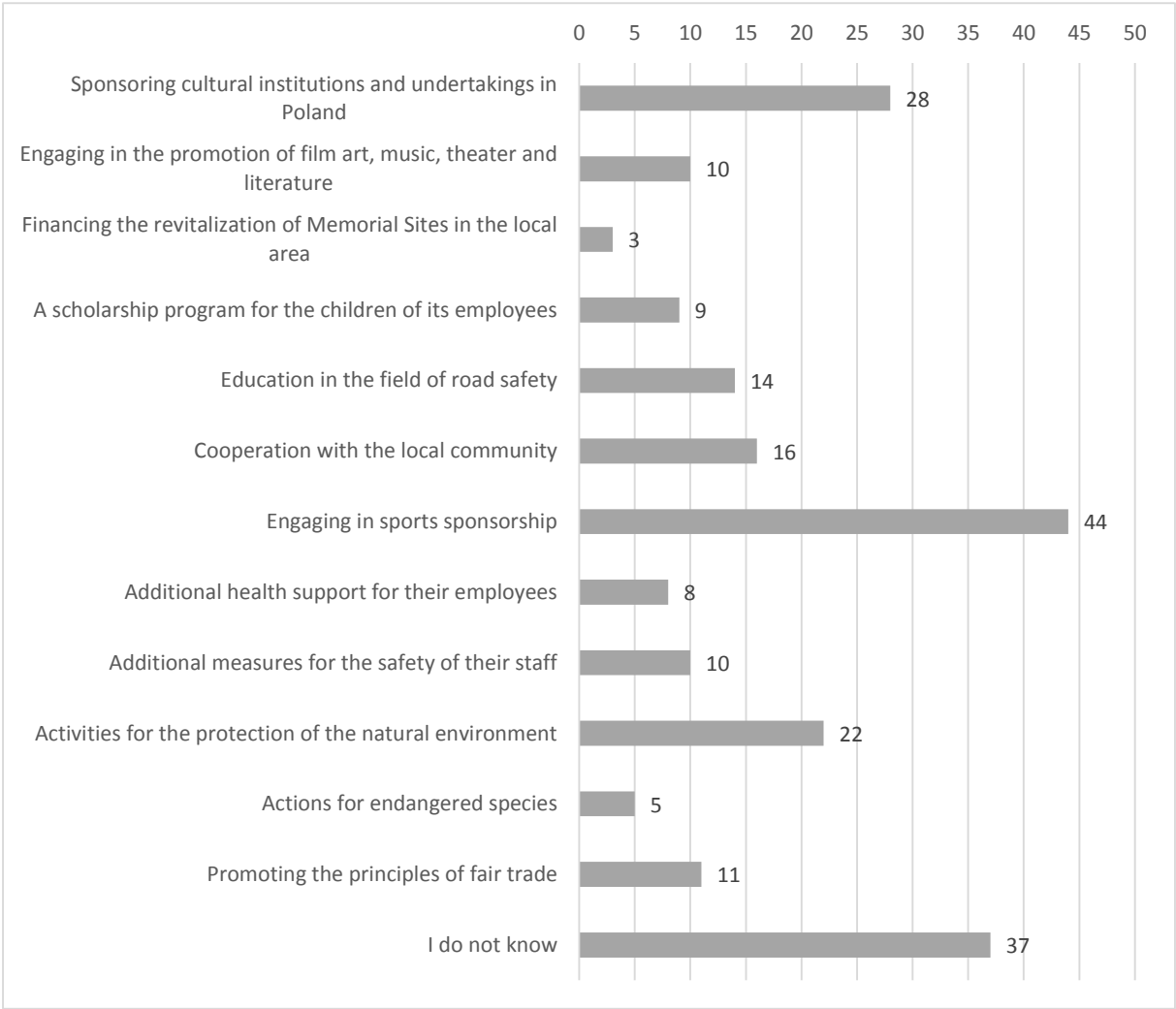
In order to clarify the information on the knowledge of the respondents about the CSR activities undertaken by PKN ORLEN, they were asked whether they knew the activities undertaken by the company in the CSR area. In this case, the greatest number of respondents answered "I have no opinion" - 39% and "rather not" - 37%. This means that most of the respondents either did not come across the information on the CSR activities of the audited company or did not pay attention to this information. Relatively many, as many as 11% of the respondents indicated that they definitely do not know the CSR activities undertaken by the surveyed company. Slightly more, because 12% answered that they rather know these activities and only 1% of respondents chose the answer "definitely yes", which means that these people know the activities undertaken by the company in the area of CSR.

The respondents had the opportunity to independently indicate the activities undertaken by the company in the area of CSR, as part of the so-called open-ended question. These activities were indicated by only 10% of the respondents.

Assuming reluctance to open questions, the respondents were asked an additional question about activities in the CSR area of PKN ORLEN, in which a list of actions actually taken by the company was indicated.

The answers to this question partially confirm the answers to the previous questions. Most respondents are aware of the activities that PKN ORLEN undertakes in the area of sports sponsorship (44% of respondents). In the second place, the respondents indicated sponsorship of cultural institutions and undertakings in Poland (28%), and the third - activities undertaken by PKN ORLEN to protect the natural environment (22%). The other activities are not as widely known. Activities in the area of promoting film art, music, theater and literature are known to only 10% of respondents. Exactly as many respondents know that the company promotes the principles of fair trade (10%). Slightly more people confirmed the knowledge of the company's

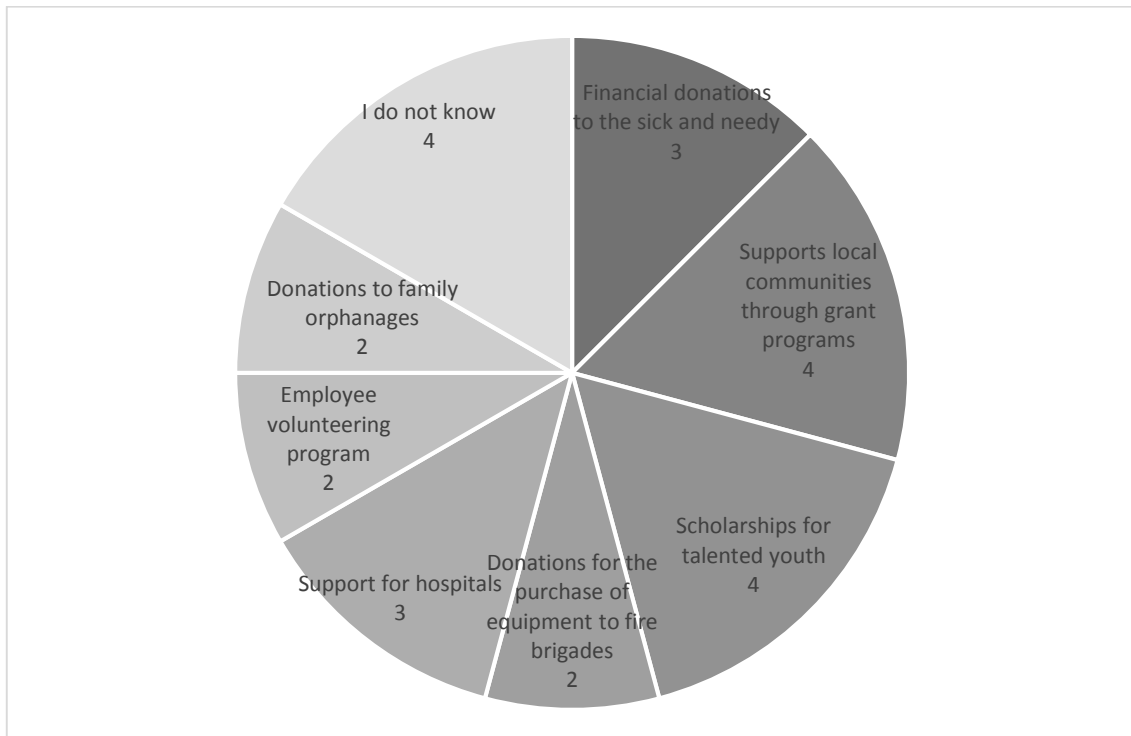
cooperation with the local community (16%) and the company's commitment to education in the field of road safety (14%). However, less known are the programs targeted at the company's employees, such as the scholarship program for employees' children (9%), additional measures for the safety of staff (10%) or additional health support for employees (8%). The least known is the involvement of PKN ORLEN in the revitalization of Memorial Sites in the local environment (3%) and the company's activities for endangered species (5%). Unfortunately, as many as 37% answered that they did not know the activities undertaken by the surveyed company (Figure 4).



**Figure 4.** Awareness of activities undertaken by the PKN ORLEN concern in the area of CSR among the respondents (%).

Source: own research. The respondents could select more than one answer.

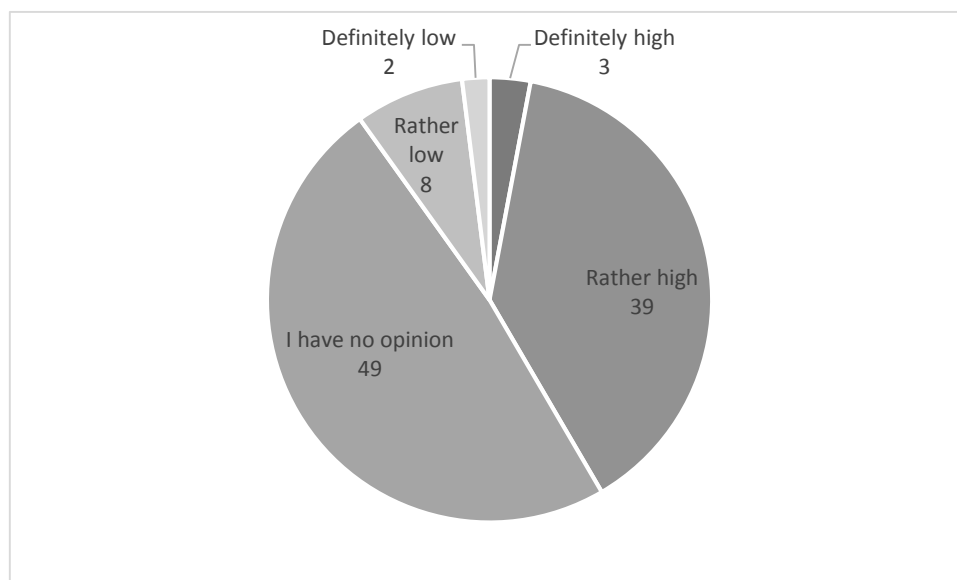
As many as 90% of respondents do not know the Orlen Foundation. The activities undertaken by the Foundation are also unknown. Most responses - 4% received support from the local community and scholarships for gifted youth. The Foundation's other activities were known to 3% of respondents or less (Figure 5).



**Figure 5.** The awareness of activities undertaken by the ORLEN Foundation (%).

Source: own research. The respondents could select more than one answer.

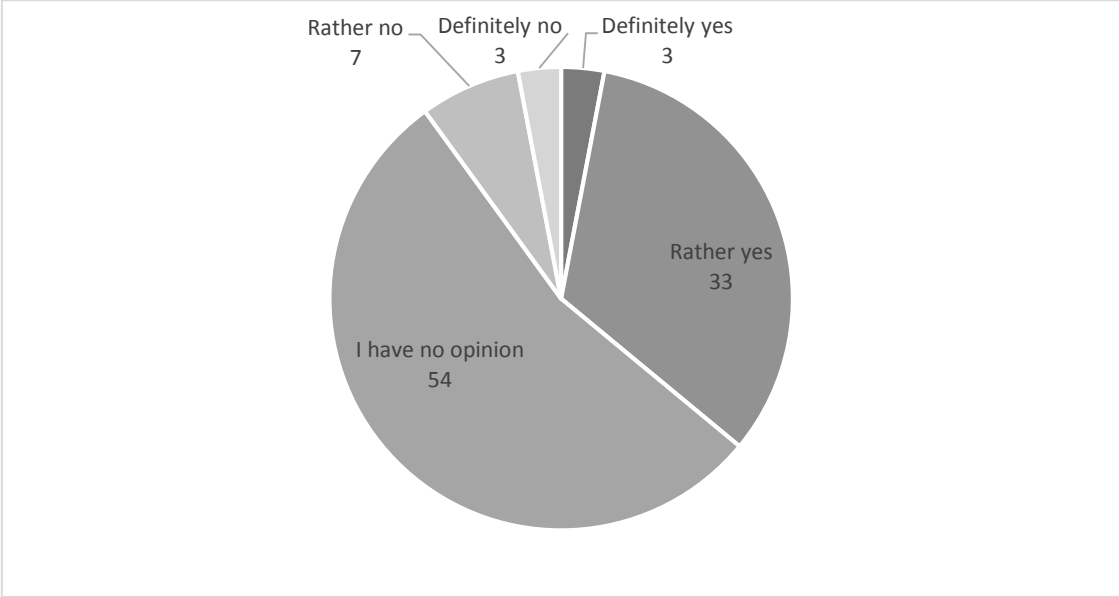
As many as 49% of the respondents to the question: How do you perceive the responsibility of PKN ORLEN? - replied "I have no opinion". Only 3% of respondents believe that this responsibility is definitely high, but the same number believe that the company's responsibility is definitely low. Partly optimistic is that 39% of respondents consider the responsibility of PKN ORLEN to be rather high, while only 8% believe that it is rather low (Figure 6).



**Figure 6.** Perception of PKN ORLEN responsibility (%).

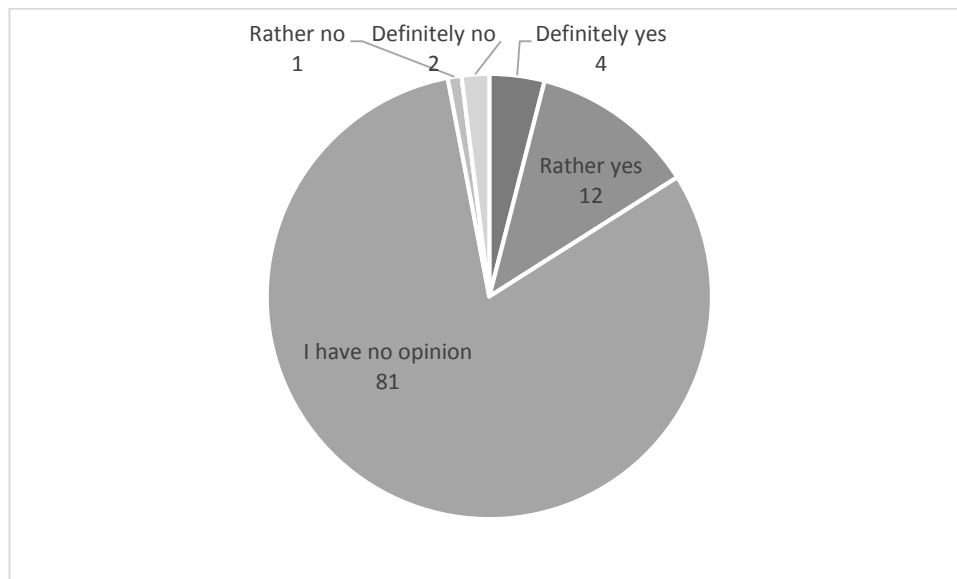
Source: own research.

This perception of PKN ORLEN's responsibility is confirmed by the responses to another question asked to the respondents, namely: Do you think the Corporate Social Responsibility strategy undertaken by PKN ORLEN is appropriate? The pattern of the answers is very similar. The vast majority - 54% answered that they did not know. 33% said rather yes, while only 7% said rather not. And 3% of respondents believe that the company's CSR strategy is definitely appropriate or definitely inappropriate (Figure 7). However, the results mainly confirm the lack of knowledge about the activities undertaken by PKN ORLEN in this CSR area.



**Figure 7.** The respondents' assessment if the CSR strategy undertaken by PKN ORLEN is correct (%). Source: own research.

The respondents were also asked whether, in their opinion, CSR activities undertaken by PKN ORLEN have a positive impact on its image. It should be emphasized at this point that the questions were not asked whether these activities affect the overall image of the company, but whether they have a positive impact. To this question, the vast majority replied that they did not know. Only 12% of respondents believe that such activities have a rather positive effect, and only 4% believe that they have a definitely positive effect. Responses that these activities did not have a positive impact were given by a total of 3% of respondents, while 2% believe that they definitely do not have a positive impact on the company's image, and 1% that they do not have such an impact (Figure 8).



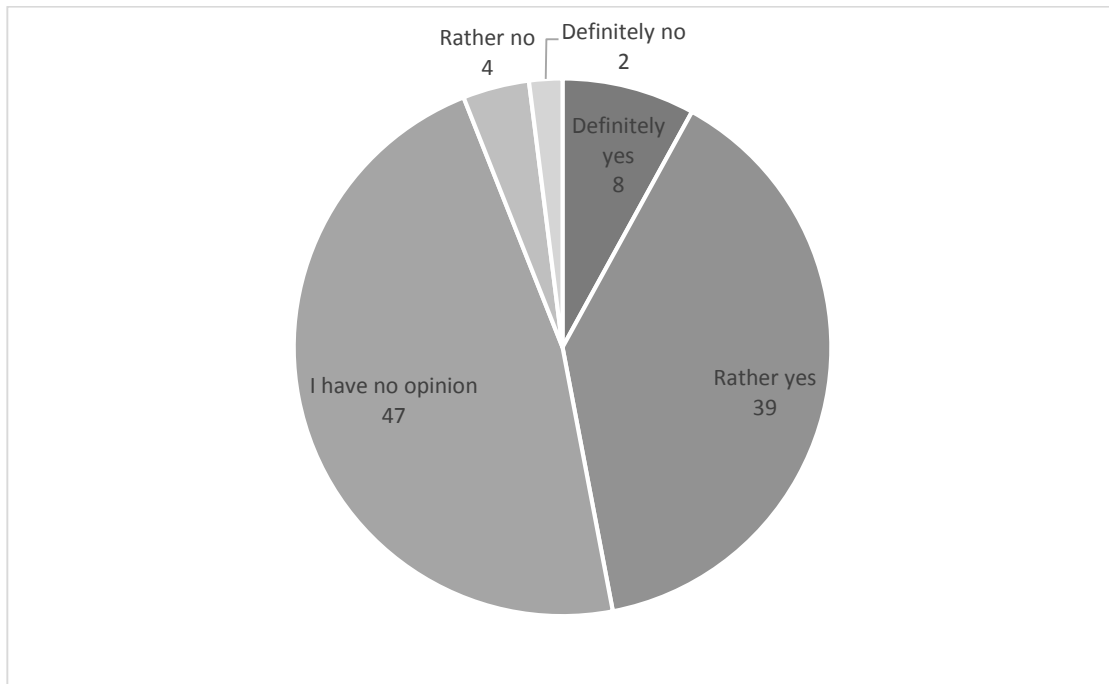
**Figure 8.** Assessment of the positive impact of activities in the area of social responsibility on the image of PKN ORLEN (%).

Source: own research.

The respondents had the opportunity to justify their position by completing an open-ended question. Only 11% of the respondents mentioned the reasons why they believe that taking CSR activities by PKN ORLEN has a positive effect on the company's image. All the answers combine the positive social perception that accompanies, for example, activities such as supporting sports, supporting local society, with the positive impact of such activities on the company's image. In the case of supplementing the negative answer, i.e. that these activities do not have a positive impact on the company's image, only 1% of respondents gave the reasons for such a position (2 people). One of the respondents indicated that he is a subcontractor, which is ambiguous, but may mean that he knows that these activities do not have a positive impact on the image of PKN ORLEN. The second one indicated that the company is a state-owned company. In this case, it is also difficult to clearly indicate how to interpret such an answer.

The respondents were also asked if, in their opinion, the CSR activities undertaken by PKN ORLEN had a positive effect on loyalty to the PKN ORLEN brand. A very large proportion of this question also answered "I don't know", but as many as 39% believe that such an impact rather exists and 8% definitely believe that such an impact exists. Only 4% believe that CSR activities undertaken by PKN ORLEN do not have a positive impact on brand loyalty PKN ORLEN, and 2% believe that it definitely does not have a positive effect on brand loyalty (Figure 9).

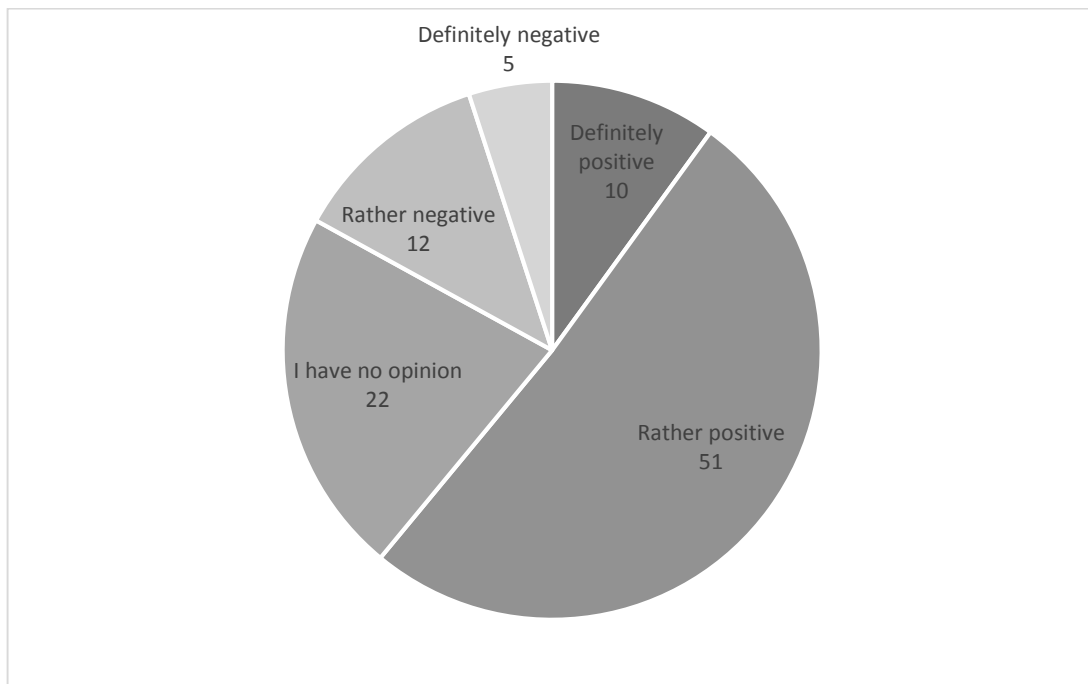




**Figure 9.** Assessment of the positive impact of activities in the area of social responsibility on loyalty to the PKN ORLEN brand (%).

Source: own research.

However, the majority of the respondents assessed positively the image of the PKN ORLEN brand. More than half - 51% believe that it is rather positive, and 10% believe that it is overwhelmingly positive. In this case, only 22% of respondents said that they did not have an opinion about it. However, 12% of respondents believe that the image of the PKN OLREN brand is rather negative, and 5% believe that it is definitely negative (Figure 10).



**Figure 10.** Assessment of the image of the PKN ORLEN brand (%).

Source: own research.

### 3.3. Results of statistical analysis

By examining the impact of demographic variables on the knowledge of CSR activities undertaken by PKN ORLEN, the first part of the analysis checked whether women differ from men in terms of knowledge of the CSR concept and knowledge of the Orlen Foundation. For this purpose, cross-tabulation analyzes and chi-square tests of independence were performed (Table 3).

**Table 3.**

*Gender and knowledge of the concept of CSR and knowledge of the Orlen Foundation - results of the chi square test*

Variables		Gender				Total		$\chi^2(1)$	<i>p</i>	$\phi$
		Women		Men						
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%			
Knowledge of the CSR concept	Yes	27	29.0%	33	45.2%	60	36.1%	4.64	<b>0.035</b>	0.17
	No	66	71.0%	40	54.8%	106	63.9%			
	Total	93	100.0%	73	100.0%	166	100.0%			
Knowledge of the Orlen Foundation	Yes	6	6.5%	11	15.1%	17	10.2%	3.30	0.077	0.14
	No	87	93.5%	62	84.9%	149	89.8%			
	Total	93	100.0%	73	100.0%	166	100.0%			

*Note. n - number of observations;  $\chi^2$  - chi square test result; p - statistical significance;  $\phi$  - effect strength index.*

Source: own study.

The analysis showed a statistically significant relationship between gender and knowledge of the CSR concept. Men declared knowledge of this concept significantly more often than women (45.2% vs. 29.0%). This correlation is weak. The results regarding the relationship between gender and knowledge of the Orlen Foundation turned out to be statistically insignificant.

In the next step, it was verified whether knowledge of the CSR concept and knowledge of the Orlen Foundation depended on the level of education. For this purpose, a group of people with higher education (university degree) was compared with a group of people with less than university education (i.e. primary school/middle school/vocational school/high school). Cross-tabulation analyzes were performed along with the chi-square test of independence (Table 4).

**Table 4.**

*Level of education and knowledge of the CSR concept and knowledge of the Orlen Foundation - results of the chi square test*

Variables		Level of education				Ogółem		$\chi^2(1)$	<i>p</i>	$\phi$
		Less than university degree		University degree						
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%			
Knowledge of the CSR concept	Yes	32	30.2%	28	46.7%	60	36.1%	4.51	<b>0.034</b>	0.16
	No	74	69.8%	32	53.3%	106	63.9%			
	Total	106	100.0%	60	100.0%	166	100.0%			
Knowledge of the Orlen Foundation	Yes	8	7.5%	9	15.0%	17	10.2%	2.32	0.128	0.12
	No	98	92.5%	51	85.0%	149	89.8%			
	Total	106	100.0%	60	100.0%	166	100.0%			

*Note. n - number of observations;  $\chi^2$  - chi square test result; p - statistical significance;  $\phi$  - effect strength index.*

Source: own study.

The result of the analysis regarding knowledge of the CSR concept was statistically significant. It turned out that people with higher education (university degree) declared knowledge of this concept significantly more often than people with less than higher education (46.7% vs. 30.2%). This relationship is weak. However, the relationship between the level of education and knowledge of the Orlen Foundation turned out to be statistically insignificant.

In the research also checked the relationship between place of residence (urban vs. rural or city vs. village) and knowledge of the CSR concept and knowledge of the Orlen Foundation. Cross-tabulation analyzes were again performed and a chi-square test of independence was performed (Table 5).

**Table 5.**

*Place of residence and knowledge of the CSR concept and knowledge of the Orlen Foundation - results of the chi square test*

Variables		Place of residence				Total		$\chi^2(1)$	<i>p</i>	$\phi$
		Village		City						
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%			
Knowledge of the CSR concept	Yes	32	38.6%	28	33.7%	60	36.1%	0.42	0.518	0.05
	No	51	61.4%	55	66.3%	106	63.9%			
	Total	83	100.0%	83	100.0%	166	100.0%			
Knowledge of the Orlen Foundation	Yes	9	10.8%	8	9.6%	17	10.2%	0.07	0.798	0.02
	No	74	89.2%	75	90.4%	149	89.8%			
	Total	83	100.0%	83	100.0%	166	100.0%			

Note. *n* - number of observations;  $\chi^2$  - chi square test result; *p* - statistical significance;  $\phi$  - effect strength index.

Source: own study.

The analyzes did not reveal any statistically significant relationships. This means that in the study group, the place of residence had no impact on the knowledge of the CSR concept or the knowledge of the Orlen Foundation.

The existence of gender differences in knowledge, attitudes and assessments regarding CSR and PKN Orlen was also verified. In order to compare women and men in terms of the described variables, due to their ordinal nature, a non-parametric Mann-Whitney U test was performed (Table 6).

**Table 6.**

*Results of the Mann-Whitney U test on indicators, compliance and evaluation regarding the CSR and PKN Orlen concepts between women and men*

Variables	Statistics	Gender		<i>Z</i>	<i>p</i>	<i>r</i>
		Women	Men			
Knowledge of the concept of CSR	<i>n</i>	93	73	-2.01	<b>0.045</b>	0.16
	<i>Q1</i>	1.00	1.00			
	<i>Q2</i>	1.00	1.00			
	<i>Q3</i>	3.00	4.00			
	medium rank	77.84	90.71			
Perception of PKN Orlen as a socially responsible company	<i>n</i>	93	73	-0.60	0.547	0.05
	<i>Q1</i>	3.00	3.00			
	<i>Q2</i>	3.00	3.00			
	<i>Q3</i>	4.00	4.00			
	medium rank	81.67	85.83			

Cont. table 6.

Knowledge of activities undertaken by PKN Orlen in the area of CSR	<i>n</i>	93	73	-1.91	0.056	0.15
	<i>Q1</i>	2.00	2.00			
	<i>Q2</i>	2.00	3.00			
	<i>Q3</i>	3.00	3.00			
	medium rank	77.56	91.07			
Perception of PKN Orlen's responsibility	<i>n</i>	93	73	-1.02	0.306	0.08
	<i>Q1</i>	3.00	3.00			
	<i>Q2</i>	3.00	3.00			
	<i>Q3</i>	4.00	4.00			
	medium rank	80.42	87.42			
Perception of the CSR strategy undertaken by PKN Orlen as appropriate	<i>n</i>	92	73	-0.85	0.396	0.07
	<i>Q1</i>	3.00	3.00			
	<i>Q2</i>	3.00	3.00			
	<i>Q3</i>	4.00	4.00			
	medium rank	85.52	79.82			
Assessment of the impact of PKN Orlen's CSR activities on the company's image	<i>n</i>	93	73	-0.07	0.945	<0.01
	<i>Q1</i>	3.00	3.00			
	<i>Q2</i>	3.00	3.00			
	<i>Q3</i>	3.00	3.00			
	medium rank	83.34	83.70			
Assessment of the impact of PKN Orlen's CSR activities on brand loyalty	<i>n</i>	93	73	-0.20	0.845	0.02
	<i>Q1</i>	3.00	3.00			
	<i>Q2</i>	3.00	3.00			
	<i>Q3</i>	4.00	4.00			
	medium rank	84.09	82.75			
Assessment of the PKN Orlen brand image	<i>n</i>	93	73	-1.27	0.205	0.10
	<i>Q1</i>	3.00	3.00			
	<i>Q2</i>	4.00	4.00			
	<i>Q3</i>	4.00	4.00			
	medium rank	87.37	78.58			

Note. *n* - number of observations; *Q1* – first quartile, *Q2* – second quartile (median), *Q3* – third quartile, *Z* - value of the test statistic; *p* - statistical significance; *r* - effect strength index.

Source: own study.

The analysis showed only one statistically significant result. The difference concerned knowledge of the concept of CSR. In this case, a higher degree of familiarity was observed in men compared to women - which was already noted earlier. This effect is weak. No statistically significant differences were observed in the remaining variables.

A similar comparison in terms of knowledge, assessment and evaluation of the CSR and PKN Orlen concepts was made for the respondents' places of residence (rural residents vs. urban residents) and the level of education (people with less than higher education, i.e. primary school/middle school/vocational school/high school vs. people with higher education - university degree). Analogous variables were used for the analyzes as in the previous analysis. In order to compare the groups, the Mann-Whitney U test was also performed (Tables 7 and 8).

**Table 7.**

Results of the Mann-Whitney U test comparing knowledge, attitudes and assessments regarding the concepts of CSR and PKN Orlen between people living in villages and cities

Variables	Statistics	Place of living		Z	p	r
		Village	City			
Knowledge of the concept of CSR	n	83	83	-0.45	0.655	0.03
	Q1	1.00	1.00			
	Q2	1.00	1.00			
	Q3	4.00	3.00			
	medium rank	84.92	82.08			
Perception of PKN Orlen as a socially responsible company	n	83	83	-0.88	0.377	0.07
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	86.53	80.47			
Knowledge of activities undertaken by PKN Orlen in the area of CSR	n	83	83	-0.07	0.941	<0.01
	Q1	2.00	2.00			
	Q2	3.00	3.00			
	Q3	3.00	3.00			
	medium rank	83.24	83.76			
Perception of PKN Orlen's responsibility	n	83	83	-0.70	0.482	0.05
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	85.89	81.11			
Perception of the CSR strategy undertaken by PKN Orlen as appropriate	n	82	83	-0.28	0.783	0.02
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	83.93	82.08			
Assessment of the impact of PKN Orlen's CSR activities on the company's image	n	83	83	-1.68	0.092	0.13
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	3.00	3.00			
	medium rank	79.24	87.76			
Assessment of the impact of PKN Orlen's CSR activities on brand loyalty	n	83	83	-1.69	0.091	0.13
	Q1	3.00	3.00			
	Q2	4.00	3.00			
	Q3	4.00	4.00			
	medium rank	89.27	77.73			
Assessment of the PKN Orlen brand image	n	83	83	-2.07	<b>0.038</b>	0.16
	Q1	3.00	3.00			
	Q2	4.00	4.00			
	Q3	4.00	4.00			
	medium rank	90.64	76.36			

Note. n - number of observations; Q1 - first quartile, Q2 - second quartile (median), Q3 - third quartile, Z - value of the test statistic; p - statistical significance; r - effect strength index.

Source: own study.

A statistically significant result was observed only for the assessment of the PKN Orlen brand image. People living in rural areas perceived the image of the PKN Orlen brand more positively than people living in cities. This effect is weak. In terms of the remaining tested variables, rural residents did not differ statistically significantly from urban residents.

**Table 8.**

*Results of the Mann-Whitney U test comparing knowledge, attitudes and assessments regarding the concepts of CSR and PKN Orlen between people with less than higher education and people with higher education*

Variables	Statistics	Level of education		Z	p	r
		Less than university degree	University degree			
Knowledge of the concept of CSR	n	106	60	-2.44	<b>0.015</b>	0.19
	Q1	1.00	1.00			
	Q2	1.00	1.00			
	Q3	3.00	4.00			
	medium rank	77.66	93.82			
Perception of PKN Orlen as a socially responsible company	n	106	60	-0.63	0.528	0.05
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	85.13	80.63			
Knowledge of activities undertaken by PKN Orlen in the area of CSR	n	106	60	-0.05	0.957	<0.01
	Q1	2.00	2.00			
	Q2	3.00	2.50			
	Q3	3.00	3.00			
	medium rank	83.64	83.25			
Perception of PKN Orlen's responsibility	n	106	60	-0.02	0.981	<0.01
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	83.56	83.39			
Perception of the CSR strategy undertaken by PKN Orlen as appropriate	n	105	60	-0.94	0.346	0.07
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	85.38	78.84			
Assessment of the impact of PKN Orlen's CSR activities on the company's image	n	106	60	-0.33	0.740	0.03
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	3.00	3.00			
	medium rank	82.87	84.62			
Assessment of the impact of PKN Orlen's CSR activities on brand loyalty	n	106	60	-0.17	0.862	0.01
	Q1	3.00	3.00			
	Q2	3.00	3.00			
	Q3	4.00	4.00			
	medium rank	83.95	82.71			
Assessment of the PKN Orlen brand image	n	106	60	-0.32	0.746	0.03
	Q1	3.00	3.00			
	Q2	4.00	4.00			
	Q3	4.00	4.00			
	medium rank	84.34	82.02			

*Note.* n - number of observations; Q1 – first quartile, Q2 – second quartile (median), Q3 – third quartile, Z - value of the test statistic; p - statistical significance; r - effect strength index.

Source: own study.

The analysis showed only one statistically significant difference. It concerned knowledge of the concept of CSR. A higher level of knowledge of this concept was observed in people with higher education compared to people with less than higher education, as already indicated

earlier. This difference is weak. The results for the remaining variables turned out to be statistically insignificant.

In the next step, it was verified whether knowledge of the activities undertaken by PKN Orlen in the area of CSR, as well as knowledge of the Orlen Foundation, was related to knowledge of the CSR concept. Knowledge of the activities undertaken by PKN Orlen in the CSR area was assessed on the basis of the question "Do you know the activities undertaken by PKN Orlen in the CSR area?". It was considered that people who chose the answer "Definitely yes" or "Rather yes" had knowledge of these activities, while people who chose one of the other answers ("I have no opinion", "Rather no" or "Definitely no") they don't know about such activities. In order to check the described relationships, cross-tabulation analyzes and chi-square tests of independence were performed (Table 9).

**Table 9.**

*Knowledge of activities undertaken by PKN Orlen in the area of CSR and knowledge of the Orlen Foundation and knowledge of the CSR concept - results of the chi square test*

Variables		Knowledge of the concept of CSR				Total		$\chi^2(1)$	<i>p</i>	$\phi$
		Yes		No						
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%			
Knowledge of activities undertaken by PKN Orlen in the area of CSR	Yes	17	28.3%	4	3.8%	21	12.7%	20.91	<0.001	0.35
	No	43	71.7%	102	96.2%	145	87.3%			
	Total	60	100.0%	106	100.0%	166	100.0%			
Knowledge of the Orlen Foundation	Yes	8	13.3%	9	8.5%	17	10.2%	0.98	0.323	0.08
	No	52	86.7%	97	91.5%	149	89.8%			
	Total	60	100.0%	106	100.0%	166	100.0%			

*Note. n - number of observations;  $\chi^2$  - chi square test result; p - statistical significance;  $\phi$  - effect strength index*

Source: own study.

The analysis showed a statistically significant relationship between knowledge of the CSR concept and knowledge of the activities undertaken by PKN Orlen in the area of CSR. People who knew the concept of CSR were significantly more likely to be aware of the activities undertaken by PKN Orlen in the area of CSR than people who did not know this concept (28.3% vs. 3.8%). This relationship is moderately strong. The relationship result for knowledge of the Orlen Foundation was statistically insignificant.

In the last part, the existence of a relationship between knowledge of the activities undertaken by PKN Orlen in the area of CSR, knowledge of the Orlen Foundation and knowledge of the definition of the concept of CSR was checked. Knowledge of the activities undertaken by PKN Orlen in the area of CSR and knowledge of the definition of the concept of CSR were assessed on the basis of the questions "Can you define the concept of CSR?" and "Do you know the activities undertaken by PKN Orlen in the area of CSR?" The answers "Definitely yes" or "Rather yes" were considered to indicate knowledge in a checked area, while the answers "I have no opinion", "Rather no" or "Definitely no" were treated as lack of knowledge in a that area. In order to test the relationships, cross-tabulation analyzes were performed along with the chi-square test of independence (Table 10).

**Table 10.**

*Knowledge of activities undertaken by PKN Orlen in the area of CSR and knowledge of the Orlen Foundation and knowledge of the definition of the concept of CSR - results of the chi square test*

Variables		Knowledge of the definition of the concept of CSR				Total		$\chi^2(1)$	<i>p</i>	$\phi$
		Yes		No						
		<i>n</i>	%	<i>n</i>	%	<i>n</i>	%			
Knowledge of activities undertaken by PKN Orlen in the area of CSR	Yes	12	27.9%	9	7.3%	21	12.7%	12.22	<0.001	0.27
	No	31	72.1%	114	92.7%	145	87.3%			
	Total	43	100.0%	123	100.0%	166	100.0%			
Knowledge of the Orlen Foundation	Yes	6	14.0%	11	8.9%	17	10.2%	0.87	0.384	0.07
	No	37	86.0%	112	91.1%	149	89.8%			
	Total	43	100.0%	123	100.0%	166	100.0%			

*Note. n - number of observations;  $\chi^2$  - chi square test result; p - statistical significance;  $\phi$  - effect strength index.*

Source: own study.

A statistically significant result was observed for the relationship between knowledge of the definition of the concept of CSR and knowledge of the activities undertaken by PKN Orlen in the area of CSR. People who knew the definition of the concept of CSR were significantly more likely to know what activities are undertaken by PKN Orlen in the area of CSR compared to people who did not know the definition of this concept (27.9% vs. 7.3%). This relationship is weak. However, the result for the relationship between knowledge of the definition of the concept of CSR and knowledge of the Orlen Foundation was statistically insignificant.

## 4. Discussion

Respondents know the PKN ORLEN brand. Most respondents associate the PKN ORLEN brand with the industry in which the company operates, i.e. the fuel industry. Respondents also associate the brand with activities undertaken by the company in the area of sports sponsorship, i.e. sponsoring the participation of the ORLEN Team in Formula 1, sponsoring volleyball or sponsoring cultural institutions and events in Poland. Respondents also associate the brand with food products that can be purchased at stations, such as coffee or hot dogs. The vast majority of people associate the company positively. However, despite knowledge of the company's involvement in numerous activities and high awareness of the PKN ORLEN brand, respondents do not assess PKN Orlen as a socially responsible company, nor do they show spontaneous knowledge about CSR activities undertaken by PKN ORLEN. Supported awareness of the CSR activities of the surveyed company is slightly greater, i.e. respondents indicated more activities undertaken by the company when they had a list with ready-made answers. However, there is no demographic variables describing the respondents were identified that would influence their perception of CSR at PKN Orlen. Hypothesis H1 was not confirmed. As many as 90% of respondents did not know the Orlen Foundation or any activities undertaken by it, despite its considerable activity.



The lack of knowledge about companies' activities in the area of CSR is nothing new. Consumers do not pay attention to companies' CSR activities. This was noticed by, among others, such authors as Pomeroy and Dolnicar (2009), Kot (2014) and others. However, the conducted research proved that knowledge about the company's CSR activities depends on the respondents' knowledge of the CSR concept, and more precisely, that people with greater knowledge in the field of CSR know better the activities undertaken by PKN Orlen in the area of CSR. However, hypothesis 3 was not fully confirmed. The research showed a statistically significant relationship between knowledge of the CSR concept and knowledge of the activities undertaken by PKN ORLEN in the area of CSR, however, no statistically significant relationship was demonstrated between knowledge of the CSR concept and the way of perceiving the CSR of the surveyed company, including, among others, recognizing it as socially responsible.

As already indicated, more and more authors emphasize the need for companies to communicate CSR. They also agree that communicating CSR is not easy. Previous research analyzed, among others: what, how and where to communicate in the field of CSR (see Ellerup Nielsen, Thomsen, 2007; Ziek, 2009; Go, Bortree, 2017). Meanwhile, the results of the conducted research prove that there is a relationship between the demographic variables describing the respondents and their knowledge of the CSR concept. According to the results obtained, men more often declare knowledge of the CSR concept. People with higher education also declare such knowledge. Thus, hypothesis H2 was confirmed. However, there is no statistically significant relationship between place of residence and the examined variable.

The research did not identify a relationship between the demographic variables describing the respondents and their perceived impact of CSR on brand image or brand loyalty. Hypotheses H4 and H5 were not confirmed.

## 5. Conclusions

The research shows that when consumers are aware of what CSR is, CSR can actually lead to positive attitudes and stronger behavioral intentions towards products from a socially responsible company, because, above all, the actions it undertakes will be noticed by consumers. However, communicating CSR is not sufficient for these activities to be noticed. The lack of knowledge about CSR seems to block the reception of information about the social involvement of enterprises, even in the case of such a large company as PKN ORLEN and despite its high social involvement. An important aspect of communicating CSR should therefore be the educational aspect, which will lead to understanding the concept of CSR and the need for its application by a wide group of recipients.

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## INTEGRATION OF AQAP 2110 STANDARD REQUIREMENTS WITH INFORMATION SECURITY REQUIREMENTS ACCORDING TO ISO 27001

Natalia JAGODZIŃSKA

BTCH Systemy Zarządzania; natalia.jagodzinska@outlook.com

**Purpose:** Presentation of the possibilities of implementing an integrated management system AQAP 2110 and ISO 27001.

**Design/methodology/approach:** The comparative method presents the common elements and differences of the AQAP 2110 and ISO 27001 standards and the possibility of their integral implementation in the organization.

**Findings:** During the analysis, information was obtained that, to a significant extent, the requirements of both AQAP 2110 and ISO 27001 standards are consistent and their integration is very beneficial for the organization.

**Research limitations/implications:** Demonstrated ability to integrate the requirements of AQAP 2110 and ISO 27001 and may be an indication for integration with other systems, e.g. ISO 14001, ISO 45001.

**Practical implications:** The analysis will simplify the process of implementing ISO 27001 and AQAP management systems, which will reduce implementation costs and shorten implementation time.

**Social implications:** The analysis is addressed to enterprises and has no impact on the society around us.

**Originality/value:** The article presents the possibilities of integrating the requirements of the AQAP 2110 and ISO 27001 standards that apply to organizations implementing projects in the military sector.

**Keywords:** AQAP 2110, ISO 27001, systems integration AQAP 2110 and ISO 27001.

### 1. Introduction

Many companies carrying out projects for the military are obliged to ensure NATO and information security standards. That is why these companies decide to implement the NATO standard - AQAP 2110 NATO requirements for quality assurance in design, development and production and the ISO 27001 standard - Information Security Management System.

Integrating the requirements of the AQAP 2110 standard with the information security requirements of ISO 27001 is possible because both standards have many elements in common that relate to information security and risk management.

AQAP 2110 is a NATO standard that deals with quality management in defense projects. This standard requires organizations to meet specific requirements for the quality, security, and availability of information. ISO 27001, on the other hand, is an information security management standard that specifies requirements for processes, procedures, and controls related to information protection.

In order to integrate the requirements of the AQAP 2110 standard with the information security requirements of ISO 27001, it is first necessary to identify common areas and set appropriate integration goals. For this purpose, the PDCA (Plan-Do-Check-Act) methodology (Rogala, 2020), used in most ISO standards (most often ISO 9001, ISO 14001, ISO 5000, etc.), can be used, which will allow to ensure continuous improvement of processes related to information security.

The next step is to conduct a risk analysis to identify threats and determine their impact on the achievement of the organization's goals. On this basis, it is possible to determine appropriate controls and procedures that will ensure information security (Skrzypek, 2000) and meet the requirements of AQAP 2110 and ISO 27001 standards.

During the integration of requirements, it is also necessary to take care of documentation that will confirm that the requirements of both standards are met. It is also important to remember about regular reviews and audits to monitor the effectiveness of the solutions used and identify areas for further improvement.

To sum up, the integration of the requirements of the AQAP 2110 standard with the information security requirements of ISO 27001 requires a detailed analysis and determination of appropriate controls and procedures that will ensure information security and compliance with the requirements of both standards. Implementing requirements integration can allow for better control of processes, reduce the risk of information security incidents, and improve the efficiency of the organization's operations.

## **2. About AQAP 2110 and ISO27001**

### **2.1. AQAP Standard**

AQAP 2110 (AQAP 2110, 2016) is a NATO standard for quality management in the design, manufacture and supply of defence products. This standard is designed to ensure high quality and reliability of products and compliance with NATO requirements.

This standard defines the requirements for a quality management system that should be met by suppliers of defense products. It also outlines the procedures and processes to be followed to ensure quality in various areas such as design, manufacturing, quality control, supplier management, and after-sales service.

The requirements of this standard (AQAP 2110 SRD1, 2016) include, m.in, establishing and documenting policy, process planning and monitoring, configuration control, product identification and traceability, risk management, and ensuring the secure flow of information. Ensuring high quality products is crucial for NATO to ensure that the defence products supplied meet all safety and reliability requirements.

The AQAP 2110 standard is available for suppliers who wish to provide services or products for NATO. Its use allows for the standardization of processes and procedures, which facilitates the exchange of information and cooperation between suppliers and NATO allies.

## **2.2. ISO 27001 Standard**

ISO 27001 is an international standard that specifies the requirements for information security management in an organization. This standard describes the processes, procedures, policies, and practices that should be implemented for effective information risk management.

The main purpose of ISO 27001 is to ensure the confidentiality, integrity and availability of information, as well as to minimize the risk of loss, destruction or unauthorized disclosure of information. This standard assumes that information security management should be managed in a systematic manner and integrated with other processes of the organization.

The ISO 27001 standard covers many areas (ISO 27002, 2023), including: risk assessment, information security policy, management of resources such as human resources, infrastructure and technology, physical security, communication and operations management, information security incident management.

ISO 27001 is flexible and can be adapted to different types of organizations and industries. Its implementation allows for effective information security management and minimization of the risk of cyber threats.

## **3. AQAP 2110 and ISO 27001 Integration Elements**

The integration of the implementation of AQAP 2110 (NATO) with ISO 27001 is aimed at ensuring consistency and comprehensive management of information security in defense-related organizations. The common elements between the AQAP 2110 standard and the ISO 27001 standard are primarily related to issues related to information security and risk management. Here are some of those items:

Risk analysis - both standards require a risk analysis to identify threats to information and determine the actions to be taken to minimize the risk of incidents.

Security Controls – Both AQAP 2110 and ISO 27001 require organizations to apply appropriate security controls to protect information from unauthorized access, loss, damage, or theft.

Incident Management – Both standards require organizations to have appropriate procedures in place for responding to and reporting on information security incidents.

Information Security Policy – Both AQAP 2110 and ISO 27001 require organizations to have a clearly defined information security policy that will provide a framework for information protection activities.

Internal Audit – Both standards require organizations to conduct regular internal audits to assess the effectiveness of information security activities and identify areas for further improvement.

Business continuity – both AQAP 2110 and ISO 27001 require organizations to have adequate follow-up plans in place when incidents such as disasters, natural disasters, or cyber-attacks occur.

Integrating the requirements of the AQAP 2110 standard with the information security requirements of ISO 27001 can allow for more effective risk management and protection of information against various threats.

### **3.1. Risk analysis**

Risk analysis is the process of identifying, assessing, and managing information security risks in an organization. Both the AQAP 2110 standard and the ISO 27001 standard require this analysis to be performed as a core component of an information security management system.

In AQAP 2110, risk analysis is an important part of the process of identifying threats to information related to systems that are designed, developed, or maintained by organizations involved in the defense sector. As part of the risk analysis in AQAP 2110, many factors should be considered, such as the probability of the hazard occurring, its effects, as well as the risks coming from the system itself, its users, applications, or the external context. All of these factors need to be assessed and appropriate countermeasures implemented to reduce the risk to systems and the information associated with them.

On the other hand, in ISO 27001, risk analysis refers to the identification of risks related to information security in the organization, such as threats from cybercriminals, malware attacks, unauthorized access to data, user errors, or hardware and software failures. This process consists of several steps, including asset identification, hazard identification, and risk assessment. Once the risk has been assessed, appropriate security controls should be put in place to help minimize the risk of information security incidents.



In both standards, AQAP 2110 and ISO 27001, the risk analysis process is crucial to ensure an appropriate level of information security and risk management. Conducting this analysis allows you to identify potential threats, determine their effects, and develop appropriate countermeasures to minimize the risk to the information and systems associated with them.

### **3.2. Security check**

Security controls are a key element of information security management in organizations. Both the AQAP 2110 standard and the ISO 27001 standard require the implementation of appropriate security controls to minimize the risk of information security incidents.

The following are examples of security controls that are recommended under AQAP 2110 and ISO 27001.

- Access controls: restricting access to systems and information to only authorized users.
- Configuration checks: Monitoring and managing the configuration of systems to minimize the risk of information security incidents.
- IT tool management checks: deploy software updates to address vulnerabilities.
- Physical access control controls: control access to buildings, premises, and equipment to minimize the risk of information security incidents.
- Risk management controls: identifying and assessing information security risks and implementing appropriate countermeasures.

In addition, in the ISO 27001 system we have monitoring controls: monitoring systems and information for early detection and response to irregularities, and training and awareness checks: training employees in information security and increasing their awareness of threats.

Security controls in AQAP 2110 and ISO 27001 are essential to ensure an appropriate level of information security and risk management.

### **3.3. Incident management**

Incident management is a key component of information security management in organizations. Both the AQAP 2110 standard and the ISO 27001 standard require the implementation of appropriate incident management procedures and plans to effectively respond to information security threats. Incident response procedures should be developed and implemented to enable a rapid and effective response to any information security incidents. As a result of the monitoring, a contingency plan should be created that should be available and up-to-date to enable rapid action in the event of a system or network failure. The implemented procedures are designed to quickly and effectively recover systems in the event of a disaster. These activities should be supported by procedures for incident reporting, incident handling and security plans.

Incident management in AQAP 2110 and ISO 27001 is essential to ensure effective information protection and minimize the risk of information security incidents.

### **3.4. System Policy**

The Information Security Policy for ISO 27001 or the Quality Policy for AQAP2110 the foundation of the management system. Both the AQAP 2110 standard and the ISO 27001 standard require organizations to have a clearly defined information security policy and Quality Policy, which is the basis for activities related to ensuring security, risk supervision and information protection. Common elements that can be included in an information security and quality policy in accordance with AQAP 2110 and ISO 27001 are:

- Management involvement.
- Compliance with laws and regulations.
- Protecting the confidentiality, integrity and availability of information.
- Management of access rights.
- Employee training.
- Risk management.
- Monitoring and audits.

### **3.5. Internal audits**

Internal audits are an important part of management according to both the AQAP 2110 and ISO 27001 standards. Their purpose is to assess the effectiveness of the management system and to identify areas for improvement. Here, the requirements of both standards are consistent and include:

- a) **Audit scheduling:** Both AQAP 2110 and ISO 27001 require organizations to schedule internal audits on a systematic and regular basis. Audit planning should take into account the importance of individual elements of the information security management system and their criticality for the organization.
- b) **Conducting an audit:** Internal audits should be conducted by individuals who are independent of the areas being audited. In the case of AQAP 2110 and ISO 27001, auditors should have relevant qualifications and experience in the field of information security management.
- c) **Conformity Assessment:** During internal audits, both AQAP 2110 and ISO 27001 require an assessment of compliance with the requirements of the standard and the information security policy. The conformity assessment should take into account both technical and organizational aspects.
- d) **Identification of corrective actions:** Internal audit should identify areas for improvement and corrective actions. In the case of AQAP 2110 and ISO 27001, auditors should identify information security risks and recommend appropriate countermeasures.

- e) Reporting audit results: Both AQAP 2110 and ISO 27001 require that the results of internal audits be reported at an appropriate level within the organization. The reports should include information on identified non-conformities, corrective actions and recommendations for the Management Board. Reports should also be made available to the audited areas to enable the implementation of corrective actions.

### **3.6. Business continuity**

Business continuity management is a key element of management for both standards. It ensures that your organization is ready to handle incidents and maintain business continuity in the event of disruptions. According to the AQAP 2110 and ISO 27001 standards, business continuity should be implemented on the basis of the following model:

- a) Business continuity analysis: Organizations should conduct a regular business continuity analysis. This analysis should include risk identification and assessment, as well as the determination of critical business processes and their dependencies.
- b) Business continuity planning: Based on the business continuity analysis, organizations should develop a business continuity plan that outlines strategies and procedures for dealing with incidents. The plan should include, m.in. defining the role and responsibilities of employees, contingency procedures, and data recovery plans.
- c) Implement and test plans: It's important for organizations to implement business continuity plans and test them regularly to assess their effectiveness.
- d) Review and update: Standards require organizations to regularly review and update business continuity plans. This review should take into account changes in the organization, changes in the business environment, and the results of plan tests.
- e) Awareness and training: Employee awareness of business continuity plans and their role and accountability in the event of incidents is required. Employees should be trained in crisis management and the implementation of business continuity plans.

## **4. Different in risk and security management requirements in AQAP 2110 and ISO 27001 standards.**

AQAP 2110 and ISO 27001 are two different standards related to risk management and information security management, and their approach to managing this area differs in several aspects. The following are some key differences in the approach to management in both standards:

- a) **Scope and purpose:** AQAP 2110 is a standard for the defense sector, while ISO 27001 is a general standard that can be used in various sectors. AQAP 2110 focuses on specific information security threats and requirements in the defense sector, and ISO 27001 in all business areas.
- b) **Documentation:** AQAP 2110 requires detailed documentation, including information security-related plans and procedures, while ISO 27001 focuses on the performance and performance of an information security management system, allowing for greater flexibility and customization to meet the specific needs of an organization.
- c) **Importance of risk:** AQAP 2110 assumes that risk assessment is a key element of project management (including information security) and requires organizations to conduct regular risk analysis and implement appropriate preventive measures. ISO 27001 also requires a risk assessment especially for information assets, but the approach to it is more formal and factual and depends on the individual needs and context of the organization.
- d) **Segregation of responsibilities:** AQAP 2110 assumes that responsibility for information security rests with the entire organization, not just a dedicated team or department. ISO 27001, on the other hand, requires that all persons in the organization be responsible for security and requires the appointment of a person responsible for the information security management system.
- e) **Regulatory requirements:** AQAP 2110 requires organizations to comply with legal requirements and regulations related to information security in the defense sector, and ISO 27001 focuses on complying with general information security-related regulations that apply to all organizations.

In conclusion, AQAP 2110 and ISO 27001 have similar objectives, i.e., ensuring information security in an organization, but their approach and requirements vary depending on the sector in which the organization operates and the individual needs and context of the organization.

## **5. Different in risk and security management requirements in AQAP 2110 and ISO 27001 standards.**

Integrating the requirements of AQAP 2110 and ISO 27001 can face some difficulties and challenges. Here are some of the most important difficulties:

- a) **Differences in scope of application:** AQAP 2110 is a specific industry standard for the defense sector, while ISO 27001 is a general standard used in all sectors. This means that AQAP 2110 requires less specific and specific safety requirements, and some of these requirements may not have equivalents in ISO 27001. Therefore, integrating the

requirements of AQAP 2110 and ISO 27001 may require a thoughtful approach and alignment of requirements with the specific needs of the organization.

- b) Differences in language and terminology: AQAP 2110 and ISO 27001 use different terms and language, which can introduce confusion and make it difficult to integrate requirements. In the case of requirements integration, it may be necessary to define and explain terms precisely and to provide clear definitions for key concepts.
- c) Complicated certification procedure: Both AQAP 2110 and ISO 27001 require a certification procedure to confirm an organization's compliance with the requirements of the standards. These procedures are complex and time-consuming, which can be challenging for organizations looking to achieve certification against both standards.
- d) Need to adapt to changing requirements: Both standards require organizations to constantly adapt to changing information security requirements. This means that organizations must monitor and update their security procedures and controls to meet the requirements of both standards.
- e) Required management involvement: The integration of AQAP 2110 and ISO 27001 requirements requires the involvement of the organization's leadership to ensure that the organization is adequately prepared and has adequate resources to implement the requirements of both standards. Management must also be aware of the benefits of requirements integration and the difficulties and challenges that may arise.

## **6. Summary.**

The combined requirements of AQAP 2110 and ISO 27001 are used in organizations that are engaged in the production, supply, or operation of systems and services related to national defense and security. For example, companies that provide military equipment, IT services for military services, software providers or telecommunications services for government institutions dealing with security. The requirements of both standards are used together in such organizations to provide a comprehensive approach to information security management that takes into account the specific requirements related to the defense and national security sector, as well as the general requirements related to information security management. This allows organizations to better secure their systems and data, protecting them from threats such as cyberattacks and computer crime.

The integration of AQAP 2110 and ISO 27001 requirements has many benefits for organizations that use these standards, such as:

- Comprehensive approach to information security management: Requirements integration enables organizations to develop a comprehensive approach to information security management that takes into account both defense-specific requirements and general information security requirements.
- Improve security: Integration of requirements allows you to improve the security of your systems and data by identifying and assessing threats, managing risks, and applying appropriate security controls.
- Increase trust: The use of standards allows organizations to increase the trust of customers, business partners, and government institutions in their services and products by ensuring that their systems and data are adequately secured.
- Resource optimization: Implementing an integrated system allows you to optimize the use of resources such as time, people, and money by ensuring that security efforts are thoughtful, efficient, and effective.
- Compliance with legal requirements: The use of standards allows organizations to meet legal requirements related to information security and data protection, which in turn can minimize the risk of unpleasant legal and financial consequences.

The integration of AQAP 2110 with ISO 27001 allows for coordinated implementation and management of information security in all areas of the organization. ISO 27001 is an international standard for information security management that provides a general framework and requirements for identifying, managing, and minimizing information security risks.

The integration of these two standards allows for the establishment of consistent and coordinated procedures, policies and controls related to information security, both in the context of NATO and in the organisation in general. This enables the organization to more effectively manage information security risks, minimize risks, and ensure data confidentiality, integrity, and availability.

## **7. Notes in the main text**

Standardization trend in quality management (Rogala, 2020).

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## PREFERENCES OF GENERATION Z AT THE BEGINNING OF PROFESSIONAL CAREERS ON THE EXAMPLE OF POLISH AND CROATIAN STUDENTS

Tomasz KAWKA<sup>1\*</sup>, Senka BOROVIAC-ZEKAN<sup>2</sup>

<sup>1</sup> University of Gdansk, Faculty of Management, tomasz.kawka@ug.edu.pl, ORCID: 0000-0003-2274-5399

<sup>2</sup> University of Split, The University Department for Professional Studies; sborovac@oss.unist.hr,

ORCID: 0000-0002-6130-4337

\*Correspondence author

**Purpose of paper:** This research paper examines the expectations of Generation Z (Gen Z) in relation to today's labor market in a case study sample comparing peers from Poland and Croatia. This article aims to analyze this generation's unique expectations, values and aspirations for the workplace. An additional goal of the article is to identify differences and similarities between Gen Z representatives in Poland and Croatia and to propose new model of HR dedicated for Gen Z.

**Design/approach:** In order to achieve the intended purpose, a quantitative survey was conducted on Polish and Croatian management students. The article consists of 3 parts. The first deals with the theoretical context - as a brief review of related literature to recognize Generation Z in a brief description of the local (Polish and Croatian) labor market context. The second part includes a brief assumptions of the adopted methodology and presentation of research results related to the recognition of careers and workplace expectations of Polish and Croatian Generation Z on a preliminary research sample. The last part is the conclusions and an attempt to conceptualize our own proposal for a new HRM model for this new, non-examined so in depth generation.

**Practical implications:** The study's primary outcomes revealed that Generation Z members value job security and financial stability, exhibiting a preference for employment within large corporations. Despite being commonly referred to as those proficient in digital technology, they must establish solid interpersonal connections with their colleagues and express their thoughts and opinions openly. Despite the cultural variations and various national identities, the representatives of Generation Z from Poland and Croatia had very similar outcomes regarding their aspirations and perspectives. Therefore, it can be deduced that the most recent cohort of individuals joining the workforce in the surveyed student population possesses a perception of a widespread and consistent comprehension of their occupational obligations.

**Social implications:** There can be assumed some implications of the findings for employers, policymakers, and educators in both countries. Provide insights into how organizations can better attract, retain, and support the career development of Generation Z in light of their unique expectations, in particular in a lack of social competency in perspective of employers.

**Findings:** This study offers empirical evidence that supports the prevailing notion of Generation Z as a universally homogeneous cohort about their attitudes and behaviours within the workplace context.

**Originality/value:** Comparing the expectations of the Polish and Croatian Generation Z entering the labor market could offer a valuable contribution to the field of cross-cultural studies, labor market research, and generational dynamics. Here are some potential points of originality and value for such presented results of research: cultural differences in work values between Poland and Croatia, educational systems and career preparedness, technological influences by how technology, digitalization, and connectivity have influenced the expectations of Generation Z in both countries, implications for employers and policymakers in both countries in proposition of 10 factors approach to new model of HCM dedicated to expectations of Gen Z.

**Keywords:** Generation Z, Human Capital Management, Labour Market, Expectations, HRM, Poland, Croatia.

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

## 1. Introduction

This paper aims to provide an overview of the main findings and conclusions of the study comparing Generation Z expectations toward the labour market between Polish and Croatian students. Generation Z refers to a cohort of individuals who exhibit common characteristics regarding their birth years, life experiences, and cultural influences. The contemporary generation that has garnered significant interest from researchers and practitioners is Generation Z. The term "they" refers to individuals born in 1995 and onwards who exhibit a distinct trait of digital nativism and possess distinctive attributes Stillman & Stillman (2017). This study aims to understand how Generation Z differentiates itself from preceding generations, particularly in its ideals, attitudes, and actions towards the labour market.

The transition of Generation Z from education to the labor market has sparked interest among researchers and employers alike. Understanding the expectations of this cohort is crucial for organizations seeking to optimize their recruitment and retention strategies (Deloitte, 2018). This research paper aims to identify the critical expectations of Generation Z in the contemporary labor market. Such knowledge will let us analyze the factors influencing Gen Z's career choices and workplace preferences. Thanks to such an approach, it is possible to explore the implications for organizations and propose strategies to meet the expectations of Gen Z employees. Finally, it provides an opportunity to reinvent a new H.R.M. model dedicated to supporting Generation Z at the first stage of their careers in the labor market.

The youngest employees are commonly called a Snow-Flake Generation, Homeland Generation, Digital Natives, iGeneration, Always Clicking Generation, C Gen (connected), Online Generation, Com Generation, Gen Tech, or App Generation (Grow, Young, 2018; Dolot, 2018; Agarwal, Vaghela, 2018; Diaconu, Dutu, 2020). These tables indicate specific

characteristics of this young population. They are susceptible, insecure about their surroundings, hiding behind technology, the most critical link to the world, which they do not want to enter, staying in their comfort zone and preferably in the family home, and not taking on responsibilities and challenges.

Generation Z is commonly defined as individuals born between the mid-1990s and the early 2000s. Growing up in the age of technology, Gen Z is characterized by its digital nativism, global outlook, and emphasis on individuality (Twenge, 2023; Stillman, Stillman, 2017; Sholz, 2020; Jaytissa, 2023; Ozkan, Solmaz, 2015; Pavlić, ukić, 2019; Priporas et al., 2017). Recent above indicated studies suggest that Gen Z values meaningful work, career growth, and a healthy work-life balance. This generation is also known for its tech-savviness, expecting workplaces to leverage advanced technologies and provide a flexible and collaborative environment. Recently, in the literature, the topic of Generation Z, which has not taken part in the business community, answers the question of what kind of worker is waiting for the managers in the future on the studies being done (Barhate, Dirani, 2021). Gen Z's expectations in the labour market are shaped by a desire for job security, financial stability, and a preference for big companies (Mărginean, 2021). Gen Z-ers appreciate a secure job and economic stability and prefer working for big companies.

The most important criteria for Gen X candidates are predominantly social. They prioritize a positive team atmosphere and supportive relations with colleagues and superiors, with a focus on the "how" of work rather than the "what" (Zehetner, Zehetner, 2019). The working atmosphere, the latest technology, and benefits packages are also important factors for them (Bieleń, 2020). Firms and organizations should consider development reports on adjustments to generational change in the labour market. Gen Z talents expect a fun work environment, a positive team atmosphere and supportive relations with colleagues and superiors. There are gender differences in these expectations, with women prioritizing a fun work environment and work-life balance, while men prioritize career advancement and job security (Lassleben, Hofmann, 2023). A study applied to university students showed that Generation Z will participate or participate in the labour force shortly before their expectations differ from other employees (Ozkan, Solmaz, 2015).

### **Croatian Perspective**

Research on the Croatian labour market and Generation Z reveals several key findings. Chareewan et al. (2020) highlight differences in career goals and work expectations between Generation Y and Generation Z, with a gender moderation effect. They found that females of Generation Y showed significantly higher career goals than males of the same generation.

Pavlić and Vukić (2019) further explore the decision-making styles of Generation Z, finding gender differences in recreational, hedonistic, price-value-conscious, and impulsive behaviours. They find female appears to be more recreational and hedonistic, less price-value conscious and less impulsive than the male gender. Jakšić and Rogic (2019) discuss the

challenges and opportunities for older workers in the Croatian labour market, emphasizing the need for more extended labour market participation.

The labour market in Croatia could be more dynamic. Generally, Croatian employees are less mobile than employees in other countries, and organizations need to be more flexible. Therefore, employee retention is an issue that requires a systematic approach because it directly hits organizational productivity and efficiency (Zivkovic et al., 2020).

Lastly, Håkansson and Bejakovic (2020) underscores Croatia's low labour market resilience, attributing it to a lack of labour mobility and skill shortages. They concluded that the Croatian labour market adapts poorly to both recession and the booming economy. The study conducted by Borovac Zekan et al. (2023) emphasises the impact of digitalization on the respondents' environments. They illuminated that, whether in their present workplace or educational institution, it was prominently manifested in various facets. Particularly discernible were its effects on knowledge dissemination, innovative practices, collaborative endeavors, networking initiatives, and modes of communication.

Collectively, these studies emphasize the need for a better understanding of the Croatian labour market and the unique characteristics of Generation Z within it. Thus, the Croatian labor market, which is only reaching the level of the E.U. market in the coming years, may differentiate the attitudes and expectations of the youngest workers entering the workforce in the context of Polish employment conditions and economic development. Moreover, significant differences in the population of both countries may also affect the results of comparative research.

The critical comparison provides a basis for conducting comparative research and presents indicators describing the labour market in both countries. Regarding the overall unemployment rate, the situation in Poland is significantly better than in Croatia, where the overall unemployment rate and the surveyed group are twice as high. However, regarding comparisons presented by G.U.S. (Central Statistical Office) and its Croatian counterpart – Državni Zavod za Statistiku, data regarding the indicators of professional activity for the youngest generation entering the job market are similar. This fact can be considered the basis for conducting comparative research on the selected group of Generation Z. As we can see, there is some differentiation in favor of the labor market conditions in Poland considering the following indicators for the 2022 year (World Bank, 2023; Trading Economics, 2023):

- Croatia - Youth unemployment rate, age group (15-24) – 18.0%.
- Poland - Youth unemployment rate, age group (15-24) – 10.8%.
- Croatia - Youth employment rate, age group (20-29) - 61.00%.
- Poland- Youth employment rate, age group (20-29) - 67.70%.
- Croatia unemployment rate– 6.20%.
- Poland unemployment rate– 5.00%.

The above data indicate that the Polish job market has a more favourable organizational environment and conditions for starting a professional career. An important research question in this context may be whether this fact is reflected in different expectations and motivations to start a professional career by Gen Z in Poland and Croatia.

### **Polish Perspective**

Kawka (2018) emphasized the need to indicate contemporary directions and tools to organise the architecture of the personnel function in the New Economy Organization. His study (Kawka, 2021) has shown that despite their cultural differences and nationalities, the results of Generation Z's Polish and Croatian representatives are very similar in expectations and attitudes.

Generation Z attempts to assert their perspectives on the functioning of organisations and their notions on professional careers. The main implications related to research findings about attitudes and expectations of Polish Z-ers are as next.

Employees of the new economy transfer their passions, hobbies, and interests into the realm of professional values (Rudawska, Szarek, 2014). When entering the workforce, they choose a work environment that offers flexible working hours, utilitarian use of modern technologies for digitized data transmission and personal contact transmission, work in a home office mode, or participation in international projects associated with a high degree of globality and mobility.

The new economy generation expects employers to apply the latest technologies to all aspects of professional life, friendly, often informal close contact with superiors, in flat, matrix, and project organizational structures. Generation Z employees are characterized by a higher level of education and proficiency in foreign languages (Żarczyńska-Dobiesz, Chomątowska, 2014). The youngest cohorts entering the Polish job market, in terms of the overall population share, compared to other groups in a given society, are the most highly educated professional generation (Mazur-Wierzbicka, 2015). Young people entering the job market today are specialists in multitasking projects, easily adapting to changes, though they are incredibly impatient individuals. They do not identify with the employer, brand, or workplace, as it is just a stage in their development (Gadomska-Lila, 2015). To engage the youngest employees, the following could be beneficial (Robak, 2018; Różańska-Bińczyk, 2022)

- Tools and methods promoting high flexibility and mobility at work.
- A social communication system based on the need for constant feedback.
- Implementation of teamwork methods, functioning in virtual and network teams.
- Shaping a work climate based on an informal atmosphere.
- Flexible solutions for professional development.
- Promotion of work-life balance practices.
- Adequate high compensation, especially in terms of non-monetary components.

- Reducing power distance in collaborative, good relationships with superiors.
- Activating tasks that utilize multitasking.
- FOMO problems.

To summarize what has been indicated so far, Generation Z, the demographic cohort following the millennials, is entering the job market with unique expectations and priorities. Growing up in a time of rapid technological advances, economic uncertainty and heightened social awareness. Although some attempts have been made to address this issue, there is still a need for a deeper understanding of nature of career preferences and characteristics of Generation Z at the beginning of their careers. A comparative study on the example of Polish and Croatian students.

## 2. Findings

The purpose of this study is to analyze the perceptions and expectations of Generation Z's work. For this purpose, a survey was conducted using a questionnaire for 187 university students of management in Poland, Gdansk (101) and Croatia, Split (86). The questionnaire consisted of three parts, using the organizational behavior scale used in the author's previous research (Kawka, 2021), i.e. the P.A.S.Z model – original author job satisfaction scale (Borowska-Pietrzak, 2023), Herzberg model (1965) or Kolodinsky approach (Kolodinsky et al., 2008), and the scale for assessing the value of success at work based on the models of Eby, Butts, Lockwood (2003) and Firkowska-Mankiewicz (1997).

The study examined the career preferences and expectations of Generation Z members in Poland and Croatia in 2022 and 2023. A quantitative approach was used to collect and analyze data from a representative sample of students from both countries. The structured questionnaire assessed participants' attitudes towards job security, financial stability and career preferences, expectations of the work environment, the role of technology in life and work, mobility and social attitudes. The 3-step questionnaire included closed sentences to gain comprehensive insight into their perspective.

A total of 186 university students from Poland and Croatia took part in the study. The sample was not evenly distributed between the two countries, but there were similar pools in each country, especially in terms of gender. Participants in the survey were between the ages of 20 and 25, representing Generation Z in both similar categories.

An in-depth analysis of quantitative data has not yet been performed. The results presented in the article are a presentation of preliminary process, based on a simple comparison of the average results of the indicated scales. The presented results will be used next year in the Statistical Package for the Social Sciences (SPSS) program to enhance and recognize more complex findings related to expectations of Gen Z in beginning of professional career activities.

Descriptive statistics, including frequencies, percentages, and means, were used to summarize participant responses. All participants were informed about the purpose of the study and gave informed consent before participating in it. The anonymity and confidentiality of participants' responses were maintained throughout the study.

**The Factors determining career preferences as the attitudes and values of Gen Z.**

The first part of the questionnaire, built on P.A.S.Z.'s proprietary tool for measuring job satisfaction attributes (Borowska-Pietrzak, 2023), consisted of 40 sentences describing a set of organizational attitudes and behaviors (see Table 2). The purpose of this part of the tool was to identify and attempt to scale a multidimensional assessment of Generation Z's statements of behavior in the workplace. The surveyed students were asked the following question: Do the given sentences describe you - rate if you agree with these sentences? The scale has been used like follow:

**Table 1.**  
*Questionary and Anchored scale of first part of questionnaire*

<b>Strongly disagree</b>	<b>Disagree</b>	<b>I don't know</b>	<b>Agree</b>	<b>Strongly agree</b>
1	2	3	4	5

**Table 2.**  
*Claims as the factors determining career preferences*

Questions as the factors determining career preferences		POLISH GEN Z	CROATIAN GEN Z
		average score	
1	I prefer to specialize in depth in one specific area	3,38	2,89
2	I don't like people influencing my decisions	3,83	3,95
3	I prefer to work alone than in a team	3,25	3,05
4	It is not a problem for me to work with people who think differently as me	3,46	3,47
5	At work, I'm only interested in focusing on my own task	3,67	3,74
6	I believe that IT technology is indispensable and necessary for my life	4,25	3,89
7	I am always open to changes and will flexibly adapt to them	3,63	3,58
8	I am a confident person and always know what to do	3,50	3,21
9	I speak foreign languages well	3,29	3,16
10	It would not be a problem to be a colleague of my boss at work	4,00	3,74
11	I try to solve my problems on my own	4,33	3,84
12	I am a mentally resilient person and not afraid of anything	3,25	2,95
13	Navigating the world of technology is not a problem for me	4,25	3,74
14	I care deeply about my career	4,42	3,79
15	Studying will allow me to achieve a career and expect high salaries	3,58	4,00
16	I don't like to be criticized	3,63	4,26
17	I am not afraid to take challenges and risks in my decisions	3,42	3,21
18	I have no problem being open with people older than me	3,96	3,84
19	I would like to make a lot of contacts with other people at work	3,54	3,95
20	My goal is to be very good and professional in my learned specialty	4,33	4,05
21	I overcome all difficulties with ease	3,42	2,79
22	I would like to start a family soon	2,38	2,37
23	It is not a problem for me to work anywhere in the world	3,21	3,68
24	I think my peers are too overprotective	2,96	3,26

Cont. Table 2.

25	I'm not afraid to say what's on my mind	3,50	3,53
26	I would like to continue my education and formal learning after graduation	3,00	3,74
27	I believe that IT technology is the basis of today's work	4,54	4,21
28	I can only count on myself in life and work problems	2,79	2,68
29	After graduation, I will want to move out of the house	4,42	3,84
30	I look for knowledge and news only on the web	2,92	3,32
31	The diversity of behavior, and people's preferences is obvious	4,67	3,42
32	I'd rather talk to someone else via a mobile app than face to face	2,25	2,95
33	I expect constant feedback on myself	2,38	3,16
34	I prefer the company of people my age	2,88	3,42
35	I would like to leave the place where I live after graduation	2,33	3,53
36	I have my close friends and I can always count on them	3,96	3,79
37	I feel that I am always right in what I say and do	2,75	3,37
38	I'd rather write my opinion on the Internet/text message than tell a person directly	1,88	2,32
39	I believe that at work it should be easy and pleasant	2,46	4,11
40	I'm looking for professional challenges related to world travel	2,75	4,26

Source: on own research data.

Taking the scale values to pre-value the responses, it can be assumed that responses whose mean was above 4.00 can be interpreted as a significant value for the surveyed pool of students, i.e. they identify with the given statement as a determinant of their career start. Similarly, responses whose mean was below 2.00 may suggest a lack of identification of the surveyed group with the given examples of behaviour in the work environment.

A synthetic assessment of the comparisons of response values shows relatively high similarities in the responses of both Polish and Croatian students. The correlation coefficient between the responses of Poles and Croats was +0.6, indicating a significant overlap in the trends of the results. It can be assumed that, in principle, the attitudes and expectations regarding their behaviour at the beginning of their careers declared by the groups of young workers from both countries are similar.

On the other hand, the detailed analyses of the individual items from this part of the survey are fascinating, but they indicate some differentiation between the two nationality groups. For the Polish representatives of Gen Z (the result in the table highlighted in green with red font), the most descriptive of their attitudes include the following:

1. The diversity of behavior, and people's preferences is obvious – rank 4,67.
2. I believe that IT technology is the basis of today's work – rank 4,54.
3. I care deeply about my career – 4,42.
4. My goal is to be very good and professional in my learned specialty – rank 4,33.
5. I try to solve my problems on my own – rank 4,33.

Similarly, for their Croatian peers, the most representative attitudes seem to be like:

1. I don't like to be criticized – rank 4,26.
2. I'm looking for professional challenges related to world travel – rank 4,26.
3. I believe that IT technology is the basis of today's work – rank 4,21.
4. I believe that at work it should be easy and pleasant – 4,11.
5. My goal is to be very good and professional in my learned specialty – rank 4,05.



As it can be seen from the comparative calculation above, only two statements overlap as the most important for the Polish and Croatian students surveyed. Recognizing the importance of IT technology in their lives and basing their careers on the chosen specialty they are studying. For Polish Gen Z, the dominant attitude is to appreciate the diversity of the work environment and to take care of their own careers and rely on themselves at work. Croatian peers emphasized a reluctance to criticize and a very stereotypical (which is not confirmed among Polish students) approach - the job is supposed to be easy and fun, and preferably it should be related to world travel. By the way, the rather low score in this two areas for Poles indicates confirmation of the widely used description of Gen Z - Homeland Generation. Young Poles don't care about leaving their hometown like young Croats do. The biggest differences between the two nations' responses were in factors #31 and #39. In the case of item no. #31, Polish Generation Z takes the issue of diversity and tolerance very seriously, which, as an average level achieved by their Croatian counterparts, seem to be less exposed. However, for young Croats, the key issue that most distinguishes Polish responses, as indicated in the previous paragraph, is the emphasis on staying within their comfort zone of easy, light, and enjoyable work associated with fun.

Interesting insights can be derived by analyzing the lowest indications from this part of the questionnaire. Behaviors that will least characterize attitudes at the beginning of their professional career in the Polish job market were indicated also almost the same by the Croatian surveyed students:

1. I'd rather write my opinion on the internet/text message than tell a person directly – rank 1,88 for Poles and rank for Croats – rank 2,32.
2. I'd rather talk to someone else via a mobile app than face to face – 2,25 for Poles and rank for Croats 2.95.
3. I would like to leave the place where I live after graduation – rank 2,33 for Poles and rank for Croats – 3,53.
4. I would like to start a family soon – 2,38 for Poles and rank for Croats – 2,37 (the lowest level obtained for them).

The above comparison indicates several interesting implications. It does not confirm, in this specific surveyed group (which may be due to the fact that these are graduates of management and business faculties), the limitation to social contacts only through social media. Furthermore, it confirms that the surveyed group consists of very young individuals, and in this generation, they generally do not consider starting a family. They express a desire to extend their comfort zone - being single and without family commitments is considered natural.

### **The expected values in the workplace as a desired motivation system**

The second part of the study consisted in recognizing Generation Z's declarations about the potential values they expected in the first stage of work as a desirable motivational system (see Table 3). The individual elements of this tool were designed based on assumptions anchored in two models, the old and the newest. The first is Herzberg Motivation Theory (1965),

and second is approach described by Kolodinsky, R., Giacalone, R. and Jurkiewicz, C. (2008). It consisted of 20 sentences describing a set of various organizational aspects of the motivation system intended for new generations, such as Y or Z. The surveyed students were asked the following question: "Evaluate the following values that you expect from your workplace". A scale has been used like that:

**Table 3.**

*Anchored scale of second part of questionnaire*

Completely irrelevant	Not important	I have no opinion	It's important	The most important
1	2	3	4	5

**Table 4.**

*The expected values in the workplace*

	Expected values in the workplace	POLISH GEN Z	CROATIAN GEN Z
		average score	
1	Friendly and sociable relationship with the supervisor	3,79	3,58
2	Durable and loyal attachment to the employer	2,71	3,84
3	Tolerance and diversity	3,92	4,47
4	Flexibility and diversity of tasks	3,88	4,42
5	Work Life Balance	4,88	3,84
6	Independence and autonomy of action	3,88	4,21
7	Friendly and relaxed atmosphere with other colleagues	4,04	4,47
8	Online work	3,50	3,37
9	Using mobile technology at work	3,92	3,37
10	Stability and a sense of security	4,00	4,16
11	Changing work environment and task challenges	3,21	3,47
12	Ambitious, complex uncommon tasks	3,42	3,53
13	Get rich quickly by working	4,17	3,68
14	Realizing your own passions and hobbies at work	3,58	4,11
15	Multiculturalism	2,71	3,89
16	Multitasking	3,42	3,95
17	Group project work	2,67	3,58
18	Continuous development and improvement	4,33	4,05
19	High salary adequate to the requirements	4,63	4,05
20	A well-known and prestigious employer brand	2,42	3,16

Source: on own research data.

Due to the same five-point scale, the interpretation of the results in terms of numerical distribution is similar to that in the case of the first part of the survey. Polish students indicated the following values as the most expected actions from the employer in terms of building a motivational offer:

1. Work Life Balance – rank 4,88.
2. High salary adequate to the requirements – rank 4,63.
3. Continuous development and improvement – rank 4,33.
4. Get rich quickly by working – rank 4,17.
5. Friendly and relaxed atmosphere with other colleagues – 4,04.

The factors indicated constitute a quite commonly established set of expectations towards the employer, which can be found in research on the millennial generation. The most important is work life balance which should be paid handsomely and provide a peaceful and comfortable life. This is complemented by a nice, pleasant atmosphere at work, which is a natural extension of functioning in a world devoid of worries, problems and professional challenges. A very interesting analysis of the results are the responses of young Croatians, which largely coincide with the responses of Poles from Gen Z, but we can find two interesting observations here. Most of the high indications, i.e. over 4.00, coincide with the indications of Polish colleagues (i.e. #18, #19 or #7), while the two highest motivational values are definitely higher for Gen Z from Croatia compared to the assessment of Poles. It's about values such as:

1. Tolerance and diversity – rank 4,47.
2. Flexibility and diversity of tasks – rank 4,42.

An exciting result is the comparison of data from the first part of the survey, where for young Poles, tolerance and diversity are their most characteristic attitude. However, for young Croatians who did not indicate this feature in themselves as clearly outstanding in part 1 of the survey - this is what they expect most from an employer. This may result from specific cultural differences or negative experiences in this area from previous attempts to work part-time during studies. The second result (#4) is also puzzling. They are relatively highly marked by the indicator in Part 1 - "My goal is to be very good and professional in my learned speciality" - meaning they want to focus on their specialization. However, they expect interesting, flexible, and diverse forms of work from the work environment. This is an exciting challenge that modern H.R. must face shortly. The factor that most differentiates Poles and Croatians turns out to be the factor of multiculturalism (#15). At the level obtained (level 2.71), it does not matter much for Poles, but for Croatians - in the context of the motivational offer the employer offers - it does. This is a logical consequence of their approach to the issue of diversity management, where Polish representatives of the Zeters generation treat this aspect as an everyday custom in their environment. This brings enormous value to the Adriatic nation (level 3.89).

### **Factors of professional success by Gen Z**

The last part of the study was devoted to identifying the perspective of Generation Z, what may be their professional success (see Table nr 5). The tool was created based on the approach to career success models by Eby L.T., Butts M., Lockwood A. (2003) and Firkowska-Mankiewicz A. (1997). The surveyed students were asked the following question: "What is career success to you? Please put in order from most important to least important the factors of professional success in your opinion. Dedicated scale to operate this part of survey (12 - most important success factor, 1 - least important success factor).

**Table 5.**  
*Potential factors of professional success*

No.	Factors of professional success	POLISH GEN Z	CROATIAN GEN Z
A.	Opportunities for rapid growth	9,00	7,74
B.	Achieving high performance at work	7,67	6,79
C.	Start your own business without the restrictions of others	7,04	5,58
D.	Work in a very well-known and recognizable company	2,63	5,00
E.	Work in a learned profession	3,25	3,95
F.	Satisfying work that matches my interests	8,63	6,26
G.	Stable work giving a sense of job security	7,50	8,26
H.	Performing work that is consistent with the education	4,33	6,79
I.	Performing a prestigious and appreciated profession	5,71	6,16
J.	High earnings and wealth accumulation	10,00	8,05
K.	Higher education and high professional competence	7,08	5,58
L.	Durable personal contacts, good friendships at work	5,13	8,16

Source: on own research data.

The last part of the study complemented the attempt to assess Generation Z's preferences for entering the labor market by diagnosing the understanding of career success in their, very fresh, career-starting perception of work. Here, in this case, the scale is a consequence of the forced ranking of the ordered sequence of choices from the indicated manifestations of professional success, where 1 denotes the least significant manifestation of success for the respondents, while 12 indicates the most entrenched pattern of success. Similarly to earlier sections of the survey, in this case, we observe a rather partial than completely fitted overlap of results in the dataset of young workers in the Polish and Croatian job markets. In the perspective of both nations, a manifestation of professional success, according to their declarations, is going to be:

1. High earnings and wealth accumulation for Poles – rank 10,00.
2. Opportunities for rapid growth for Poles – rank 9,00.
3. Satisfying work that matches my interests for Poles – rank 8,36.
1. Stable work giving a sense of job security for Croats - rank 8,26.
2. Durable personal contacts, good friendships at work for Croats - rank 8,16.
3. High earnings and wealth accumulation–for Croats - rank 8,05.

As it can be noticed, there are some noticeable differences here. The only factor that is generally higher for both countries is high wages and wealth accumulation, with significantly higher scores for the Polish survey. An interesting result is the significant difference in the factor: "Durable personal contacts, good friendships at work", which, in the eyes of Polish colleagues, does not deserve to be considered a clear and important manifestation of success. On the other hand, in the perspective of the Croatian youngest human capital, this is the second most important manifestation of career satisfaction. It can be assumed that in the case of Polish Gen Z representatives - our Polish social and cultural assumption of being friendly in the workplace is something unconditionally expected. For Croats, building interpersonal relationships seems to be a very important aspect of the career path.

In the case of negative choices of indicating what they see as a sign of success, the two nations tended to agree. All in all, for us, for university researchers and teachers, a kind of warning sign may be the result indicating that the youngest generation does not identify career success with the factor called “Work in a learned profession”. This is the last level, the lowest rank for both groups of surveys. This gives rise to the assumption that for Generation Z it does not matter what type of profession they can work in. What really matters is that it is well paid, with a pleasant atmosphere, provides a basis for development or matches own interests. Interestingly, Croatian responses were more egalitarian than those of Poles. Although the sample of surveys among Polish students was slightly larger, which may affect the higher degree of dispersion of results, but this is a difference of about 15% in the size of the surveyed groups. To calculate the index of variation, calculate the quotient of the standard deviation from the vector under study to the mean value for the data set. Taking into account the data from all 3 parts of the survey, the indicators are as follows:

**Table 6.**  
*Response variation rates for all 3 parts of the tool*

Parts of survey	Polish Gen Z	Croatian Gen Z
1. Factors determining career preferences as the attitudes and values of Gen Z	21%	14%
2. The expected values in the workplace as a desired motivation system	18%	10%
3. Factors of professional success by Gen Z	36%	21%

Source: on own research data.

The above results indicate that the responses of the surveyed groups of students from the University of Gdansk and Split are very similar in most areas of manifested attitudes, expectations and perspective on the beginning of their careers. On the other hand, the dispersion index unequivocally shows that the group of students from Croatia is more consistent and convergent in their responses. Polish students were more diverse in providing answers. This may be a result of the fact that in the examined sample, the Polish Gen Z was, on average, slightly older by 1.5 years (more master's degree students) compared to the population from Split. However, as a principle, the main direction and trend of responses to the majority of questions and issues provided the basis for proposing a relatively consistent picture of Generation Z and attempting to define their career preferences at the beginning of their professional careers.

The knowledge obtained regarding preferences, attitudes, and expectations at the initial stage of entering the job market should be utilized to enrich HR practices and serves as a good starting point for attempting a new perspective on the architecture of HR processes related to the youngest generation. The last part of this article will be dedicated to these considerations.

### 3. Practical and research implications

The key findings proposed on the basis of the analysis of the results obtained can form the basis for the adoption of a new model of human capital management aimed at attracting, retaining and motivating Generation Z in the modern work environment. Despite the emerging small but noticeable differences between peers from Poland and Croatia, the presented results indicate a global, homogeneous and very similar mechanism of expectations and perspectives on the beginning of their emerging career path on the labor market.

In the case of significant differences between the results for Polish and Croatian Gen Z, it was indicated which of the following 10 factors is potentially more applicable to the given cultural and social conditions of the both two Slavonic studied countries (Chareewan et al., 2020; Kawka, 2021; Stillman, Stillman, 2017):

1. **Meaningful Work and Purpose:** Gen Z is driven by a desire to impact the world and contribute to something meaningful positively. They seek employment that aligns with their values and allows them to make a difference. This translates into a preference for companies that demonstrate social responsibility, environmental sustainability, and ethical practices.
2. **Work-Life Balance:** Gen Z prioritises a healthy work-life balance and values flexibility in their work arrangements. They are less inclined to adhere to traditional all day hours schedules and prefer work environments that offer remote work options, flexible hours, and unlimited paid time off.
3. **Continuous Learning and Development:** Gen Z is a highly adaptable and tech-savvy generation, constantly seeking opportunities to learn and grow. They value companies that invest in their employee's professional development and provide opportunities for upskilling and reskilling.
4. **Diversity, Equity, and Inclusion (DEI):** Gen Z is the most diverse generation in history and expects workplaces to reflect this diversity. They are drawn to companies that promote DEI initiatives, foster inclusive cultures, and value different perspectives.
5. **Transparency in Compensation and Benefits:** Gen Z values transparency in compensation and benefits packages. They want to understand their earning potential, career progression opportunities, and potential employers' comprehensive benefits.
6. **Technology Adoption and Innovation:** Gen Z is accustomed to using technology all their lives and expects workplaces to be technologically advanced. They are drawn to companies that embrace innovation, utilise technology effectively, and provide modern tools and equipment.
7. **Effective Communication and Feedback:** Gen Z craves open and transparent employer communication. They value regular feedback, clear expectations, and a collaborative work environment.

8. **Entrepreneurial Spirit:** Gen Z is unafraid to take risks and pursue their ventures. They are attracted to companies that foster an entrepreneurial spirit and support those with innovative ideas.
9. **Social Responsibility and Sustainability:** Gen Z is deeply concerned about social and environmental issues. They are drawn to companies prioritising sustainability, engaging in ethical practices, and giving back to the community.
10. **Authentic Leadership and Mentorship:** Gen Z values authentic leadership and seeks mentors to guide and support. They appreciate leaders open to feedback, encouraging collaboration, and empowering their teams.

#### 4. Originality/value

As noted in the introduction to the research section, there is no in-depth statistical study of the collected material in the text, so the present proposal should be treated as a kind of hypothetical assumption, which the authors wish to further explore and develop with more sophisticated statistical tools.

Based on a preliminary interpretation of the results from the applied research model, 10 areas were singled out that form the foundation of such a modern approach to understanding this new, different, fascinating, but difficult generation (Kawka, 2021). For each area, a brief description of the meaning of the sub-function was offered. This may constitute the added value of the research and its originality, pointing to trends and directions for building a new approach to human capital management - based on the idea of a balanced approach of including the youngest, difficult, but very necessary, generation Z in the work processes.

#### 5. Contribution

The findings of this study hold significant implications for both Polish and Croatian employers and policymakers. To effectively attract, engage, and retain Generation Z employees, employers should prioritize creating meaningful and purposeful workplaces that align with the values and aspirations of this generation, regardless of which country they come from. In this case, comparative research is alternative when it comes to the generation that comes from two different, but identical - Slavic countries.

Furthermore, fostering a continuous learning and development culture is essential to provide ample opportunities for upskilling and reskilling, enhancing employee growth, and fostering long-term retention. Moreover, promoting diversity, equity, and inclusion initiatives is crucial to cultivating a workplace that reflects the diverse perspectives and backgrounds of Generation Z. Additionally, ensuring transparency in compensation and benefits packages is vital to attracting and retaining top talent by clearly communicating earning potential, career progression opportunities, and comprehensive benefits. Furthermore, embracing innovation and technology adoption is essential to providing modern tools and equipment, fostering an environment that encourages creativity and technological advancement, and aligning with the tech-savvy nature of Generation Z.

Cultivating authentic leadership is also crucial to creating a culture where leaders are open to feedback, encourage collaboration, and empower their teams to contribute meaningfully to the organisation's success. To prepare for the future labour market and support the aspirations of Generation Z individuals, policymakers should invest in education and training programs to develop a skilled workforce equipped with the necessary skills and knowledge to meet future demands. Furthermore, implementing policies and initiatives that promote entrepreneurship is essential to provide resources, support, and mentorship to encourage innovation and business creation among Generation Z individuals, fostering economic growth and prosperity.

Moreover, encouraging and supporting sustainable business practices is crucial to align with the values of Generation Z by creating incentives and regulations that promote environmental protection and social responsibility. Fostering a more inclusive and equitable labour market is essential to address systemic barriers and promote equal opportunities for all individuals, regardless of their background or demographics, ensuring a fair and just labour market for the future. By addressing the expectations and aspirations of Generation Z, employers and policymakers can collaboratively create a more attractive, sustainable, and equitable labour market for the future, one that aligns with the values, priorities, and talents of this emerging generation.

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## ANALYSIS OF THE IMPACT OF DEMOGRAPHIC AND BEHAVIORAL VARIABLES ON ONLINE SHOPPING BEHAVIOR: ESTIMATION USING THE MAXIMUM LIKELIHOOD METHOD

Maria KOCOT<sup>1\*</sup>, Artur KWASEK<sup>2</sup>, Adam DEPTA<sup>3</sup>

<sup>1</sup> University of Economics in Katowice, maria.kocot@ue.katowice.pl, ORCID: 0000-0001-5150-3765

<sup>2</sup> University of Technology and Economics in Warsaw; artur.kwasek@uth.edu.pl,  
ORCID: 0000-0003-4386-1444

<sup>3</sup> Lodz University of Technology; adam.depta@p.lodz.pl, ORCID: 0000-0001-5957-0794

\* Correspondence author

**Purpose:** The aim of the article is to analyze the impact of demographic and behavioral variables on online purchasing behavior. The study also aims to estimate these impacts using the maximum likelihood method.

**Design/methodology/approach:** To achieve the research objectives and verify the hypotheses, primary research was conducted using a survey method. In June 2021, online questionnaires were distributed. The CAWI (Computer Assisted Web Interviewing) technique standards were applied during the study.

**Findings:** (mandatory) The most important factors influencing online purchasing decisions are price and product quality. Other factors, such as user interface or delivery speed, have a significantly lesser impact. The demographic variable with the greatest impact is gender, while the variable with the least impact is the field of study.

**Research limitations/implications:** One of the limitations of the study is its temporal and geographical scope. Further research in this area is recommended to include various demographic groups and markets.

**Practical implications:** The study has significant implications for marketing practice. Knowledge about the impact of demographic and behavioral factors on purchasing decisions can help companies target appropriate market segments and effectively adjust their sales strategies.

**Social implications:** The study may influence social attitudes by showing that ecological awareness is still not the main motivation for the majority of consumers in the context of online shopping. This could also affect corporate policies in the context of corporate social responsibility.

**Originality/value:** The value of this article lies in filling the existing gap in research on the impact of demographic and behavioral variables on online purchasing behavior. The article is addressed to researchers in the fields of marketing, behavioral economics, and entrepreneurs interested in better understanding their customers.

**Keywords:** Purchasing Behavior, Demographic Analysis, Maximum Likelihood Method, Econometrics, Online Marketing.

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

## 1. Introduction

In the era of growing popularity of online shopping, understanding the mechanisms guiding consumer decisions is becoming increasingly important. The aim of this article is to analyze the impact of demographic and behavioral variables on online purchasing behavior. Using the maximum likelihood method, key decision-making aspects such as price, product quality, delivery speed, and many others were estimated.

During the study, demographic variables such as age, gender, place of residence, and financial situation were considered. These were juxtaposed with behavioral factors, including price and product quality, to understand how these elements interact in the purchasing process. The ultimate goal is not only to identify the most important motivators for online shopping but also to understand how different segments of the population differ in their preferences and purchasing behaviors.

These findings have the potential not only to deepen academic understanding of consumer behavior online but also to provide practical guidance for entrepreneurs and marketers. This knowledge can be used to target specific market segments, optimize marketing and sales strategies, and build long-term relationships with customers.

## 2. Literature Review

### 2.1. History and Evolution of Online Shopping

Online shopping has become one of the most important aspects of the modern economy. The origins of this phenomenon date back to the 1990s when the internet began to become increasingly accessible. The first shopping platforms were simple and had limited functions, but over the years they have become increasingly sophisticated. In the initial phase, online shopping was treated as a novelty and did not enjoy much consumer trust. However, this changed with the advent of trusted payment platforms and mechanisms to secure transactions. As broadband internet access became more widespread, online shopping grew increasingly popular (Online Shopping, 2014).

The development of online shopping has had a significant impact on traditional retail. Many brick-and-mortar stores began to introduce online shopping options, and some have completely transitioned to the online sphere (Fihartini, Helmi, Hassan, Oesman, 2021). The introduction of technologies such as "click and collect" has allowed for the merging of online and offline shopping experiences (Clausen, 2018). In recent years, online shopping has become increasingly personalized. Through data analysis and algorithms, online stores can offer personalized recommendations and deals. Additionally, the development of mobile technology has made online shopping increasingly accessible and convenient (Lokesh, 2020).

As online shopping grows in popularity, security issues have become increasingly important. Research indicates that consumers are becoming more aware of cybersecurity threats and are looking for stores that offer advanced security mechanisms (Amer et al., 2014).

## **2.2. Online Consumer Decision-Making Mechanisms**

Consumer decision-making mechanisms online are complex and diverse, affecting the way people make purchasing decisions in the digital environment. In an era of increasing online transactions and access to a wide range of information, understanding these mechanisms becomes essential for entrepreneurs, marketers, and researchers (Online shopping behavior of Chinese and Japanese consumers, 2018). In the online environment, consumers are exposed to various stimuli, such as reviews from other users, algorithmic recommendations, or elements of the user interface, which can influence their final choice of product or service (Ringbeck, Seeberger, Huchzermeier, 2019). Additionally, the availability of various communication channels, such as social media or online forums, allows consumers to exchange opinions and experiences, which also affects their purchasing decisions (Cambridge University Press, 2013; Routledge, 2020; IGI Global, 2023).

Purchasing behavior in the digital environment is also shaped by various aspects related to the design of internet systems and legal-social interactions (Dingee, 2019; Winer, 2018; Rozenkowska, 2023). For example, the way websites are designed can influence how consumers make purchasing decisions (Jones, 2011). Elements such as page layout, color scheme, or the availability of filtering options can affect consumers' final choices (IGI Global, 2011a).

Moreover, in the online environment, there is also the phenomenon of consumer complaints, which can affect a brand's reputation and its products. Consumers are more inclined to share negative experiences online, which can influence the decisions of other potential customers (IGI Global, 2011b).

It's also worth noting that consumer decision-making processes online are often framed by various conceptual models that take into account both psychological and technological factors. For example, models like "e-Search" propose frameworks for understanding how consumers use various sources of information in the decision-making process (IGI Global, 2011c).

### 2.3. Factors Influencing Online Customer Loyalty

Customer loyalty online is a key factor for the success of many companies operating online. Understanding the factors that influence customer loyalty can help businesses increase customer retention and lifetime value. The quality of online services, such as page loading speed, ease of navigation, and customer service quality, can significantly impact the level of customer loyalty (Pratminingsih, Lipuringtyas, Rimenta, 2013). Trust in the brand or online store is also a key factor affecting customer purchasing decisions. Transaction security, privacy protection, and the authenticity of other customers' reviews can influence the level of customer trust. Additionally, personalizing offers and communications to individual customer needs and preferences can increase their engagement and loyalty to the brand (Wang, 2011).

It's worth noting additional aspects that can influence the relationship between consumers and brands in the online environment (Wang, Lei, 2017; Factors Influencing..., 2023; Yoo, Kim, 2018). For example, loyalty programs offering various rewards and benefits can be an effective tool in increasing customer loyalty (Zhao, 2022). Moreover, transparency in communication and company actions, such as clear and fair return policies, can also impact the level of trust and loyalty among consumers (Sherman, 2011). The role of social media, which is becoming an increasingly important communication channel between brands and consumers, should not be overlooked (Hong, Lee, 2011). These interactions can both positively and negatively affect the perception of the brand and its products or services (Nacif, 2012).

Factors affecting customer loyalty online are diverse and complex, encompassing both technical and psychological aspects. One of the key elements affecting customer loyalty is shopping satisfaction, often shaped by the opinions of other consumers available online (Hendrayati, Atrisia, 2018). Research shows that consumer reviews and online ratings have a significant impact on customer satisfaction and their intent to return to a particular online store (Camilleri, Filieri, 2023).

Another important factor is the mechanisms of group purchases online, which can affect customer loyalty by offering attractive discounts and promotions. In this context, both price and social aspects of shopping, such as recommendations from friends, play an important role (Wu, Zhang, 2014).

In the educational context, student loyalty to online programs is also significant (Hsu, Chang, Chen, 2011; Kim, Hyun, 2007; Kim, 2021). Research in this area suggests that student retention in online programs is related to various factors (Male Consumers..., 2020), such as the quality of educational materials, interactions with instructors and other students, and access to technical support (International Association for Computer Information, 2020).



## **2.4. Technologies Supporting Online Shopping**

The development of technologies such as data mining has significantly impacted online shopping experiences. Thanks to advanced algorithms, online stores can now analyze user behavior and offer products that best match their needs and preferences (IJRTER, 2017). Additionally, technologies like E-tagging enable a "one-stop shopping" experience where customers can easily compare products and prices from different stores (Latimer, 2003). It's also worth noting that different shopping channels, such as online and catalog shopping, have their own unique factors influencing consumer choice, which are also supported by modern technologies (Madlberger, 2011).

In the context of technologies supporting online shopping, attention should be given to the growing role of artificial intelligence and machine learning (Demangeot, Broderick, 2010; What Happens..., 2011; Darley, 2010). These technologies allow online stores not only to analyze user behavior but also to forecast future needs and preferences (The MIT Press, 2018). Moreover, the application of blockchain technology in online shopping is becoming increasingly popular, providing greater transparency and transaction security (Oxford University Press, 2018). It's also worth noting that the motives for online shopping can vary depending on the industry; for example, in the hospitality industry, shopping motives may be related to personality and purchasing values (Science & Engineering Research Support Society, 2016).

## **3. Analysis of the Impact of Demographic and Behavioral Variables on Online Shopping Behavior – Empirical Study Results**

### **3.1. Research Methodology**

In June 2021, scientific research was conducted with the aim of identifying important aspects of decision-making in online purchases. Additionally, to analyze the impact of demographic and behavioral variables on online shopping behavior, an estimation was made using the maximum likelihood method. The analysis using the maximum likelihood method allowed for the estimation of a structural model that fits well with the empirical data, as confirmed by the RMSEA value and Cronbach's alpha coefficient, suggesting the reliability and validity of the data. All of this provides valuable insights for entrepreneurs and marketers regarding the online community segments they can target for their promotional activities and product offerings.

The hypothesis was posed that demographic and behavioral factors have a significant impact on the importance of various aspects of decision-making in online purchases. To achieve the research objectives and verify the hypothesis, primary research was conducted. A survey method was employed for this purpose. In June 2021, an online questionnaire was distributed to respondents. During the study, CAWI (Computer Assisted Web Interviewing) technique standards were applied. The results of these studies will have a significant impact on understanding consumer online shopping behavior, identifying important trends and patterns. This topic was chosen due to its high relevance and timeliness, as well as the existing, clear gap in previous research in this area.

### 3.2. Presentation of Research Findings

The research sample consisted of 945 individuals, representing various generations. The study included respondents from different age groups, of which about 10% were born between 1965-1980, 28% between 1981-1995, and the largest group consisted of those born after 1995, about 62%. Of the respondents, about 67% were women, and 33% were men. Regarding the place of residence, only a small percentage, about 17%, live in rural areas, while the rest live in cities of various sizes; most, about 55%, live in cities with a population of over 200,000 residents.

From the surveyed group, about 13% rated their financial situation as very good, 58% as good, and about 26% as average. Only a small percentage, about 3%, described it as poor. In terms of employment status, most people, about 73%, work full-time. About 9% work part-time, and about 9% are unemployed. About 60% of respondents have a bachelor's degree, 34% have a master's degree, and a small percentage, about 2%, are at the doctoral level. As for fields of study, there is a wide variety. The most popular are management and economics, chosen by about 33% and 16% of respondents, respectively. Next are finance and accounting, and internal security, chosen by about 11% and 12% of respondents. Finally, the majority of people, about 77%, study in a non-residential mode, while the rest, about 23%, study in a residential mode.

The study was also aimed at identifying important aspects for respondents when making online purchasing decisions. Detailed information on this topic is provided in Table 1.

**Table 1.**  
*Important Aspects During Online Purchase Decision-Making*

Aspect	Definitely Unimportant	Somewhat Unimportant	No Opinion	Somewhat Important	Definitely Important	Total
Price	22	25	26	295	577	945
User-Friendly UX (User Experience)	28	76	343	360	138	945
Product/Service Quality	20	13	17	264	631	945
Delivery Speed	16	49	49	350	481	945
Warranty	19	49	79	342	456	945

Cont. table 1.

Product Information	20	23	49	332	<b>521</b>	<b>945</b>
Payment Method	28	67	65	369	<b>416</b>	<b>945</b>
Reviews from Other Users	28	55	85	383	<b>394</b>	<b>945</b>
Post-Sale Service	31	104	180	367	<b>263</b>	<b>945</b>
Ecological Origin of Products	106	167	263	277	<b>132</b>	<b>945</b>

Source: own.

Table 1 presents how various aspects influence consumers' online purchasing decisions. The study is divided into several key categories, such as price, product quality, delivery speed, and others. Regarding price, the majority of respondents (61%) consider it "definitely important," and an additional 31% consider it "somewhat important." This suggests that price is one of the most critical factors affecting online purchasing decisions.

The issue of user-friendly interface (UX) is viewed differently. About 38% of respondents think it's "somewhat important", but only 15% consider it "definitely important". It's also noticeable that a large group (36%) has no opinion on this matter. Product or service quality is another key element. A whopping 67% of respondents consider it "definitely important", and an additional 28% consider it "somewhat important". Delivery speed is also important, but to a slightly lesser extent. About 51% of respondents consider it "definitely important", and 37% consider it "somewhat important". In the context of warranties, 48% consider it "definitely important", and 36% consider it "somewhat important".

Product information is important for 55% ("definitely important") and 35% ("somewhat important"). Payment methods and reviews from other internet users have moderate importance; about 44% and 42% consider them "definitely important", and 39% and 41% consider them "somewhat important", respectively. After-sales service has varying importance for different people; 28% consider it "definitely important", and 39% consider it "somewhat important". The least important for respondents is the ecological origin of products, with only 14% considering it "definitely important" and 29% considering it "somewhat important". Overall, the table shows which aspects are most important for consumers when making online purchasing decisions. Price and product quality are the most important, while the ecological origin of products is the least important.

To assess the impact of demographic and behavioral variables on online shopping behavior, structural models were estimated using the maximum likelihood method. There was no basis for rejecting the null hypothesis that the residual values of the empirical and theoretical matrices are equal to zero ( $\chi^2 = 540.587$ ;  $p = 0.001$ ). The Root Mean Square Error of Approximation (RMSEA = 0.139) indicates that the model can be considered well-fitted to the data. To determine the reliability of the data, the value of Cronbach's alpha coefficient was calculated, which was 0.751.

The structural models estimated by the maximum likelihood method (Fig. 1) include the following:

**A. Observable Endogenous Variables**

p\_1 – Age

p\_2 – Gender

p\_3 – Place of Residence

p\_4 – Financial Situation

p\_5 – Employment Status

p\_6 – Level of Education

p\_7 – Field of Study

p\_8 – Type of Study

p\_9 – How often do you make purchases online?

p\_11 – How much money do you spend on online shopping per month?

p\_16\_a – Price

p\_16\_b – User-Friendly UX

p\_16\_c – Product/Service Quality

p\_16\_d – Delivery Speed

p\_16\_e – Warranty

p\_16\_f – Product Information

p\_16\_g – Payment Method

p\_16\_h – Reviews from Other Internet Users

p\_16\_i – After-Sales Service

p\_16\_j – Ecological Origin of Products

p\_17 – Do you leave your own online reviews about purchased products?

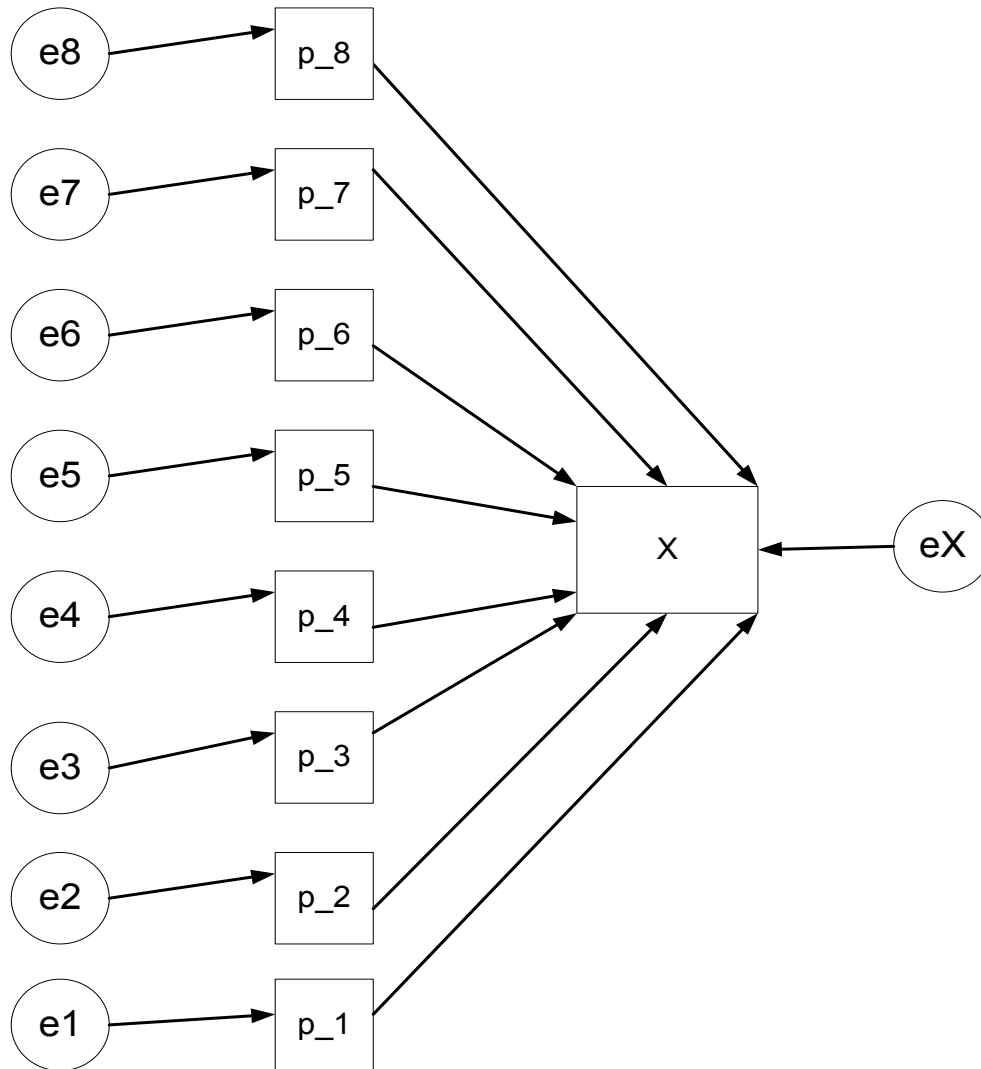
p\_19 – Have you ever used personalized offers while shopping online?

p\_21 – Do you respond to questions from other users online seeking information about a product?

p\_22 – Have you ever suggested changes to a product to the manufacturer?

**B. Unobservable Exogenous Variables:**

*e1, e2, e3, e4, e5, e6, e7, e8, e9.*



Note: In the model, X represents the observable endogenous variables, ranging from p\_9 to p\_22, and eX represents the random errors associated with these variables.

**Figure 1.** Estimated Structural Model.

Source: own.

Unstandardized and standardized coefficients are presented in Tables 2 and 3.

Unstandardized coefficients of the model indicate by how many units the dependent variable will change when the value of a given independent variable increases by one unit. Standardized coefficients, on the other hand, describe by how many standard deviations the value of the dependent variable will change when the value of the independent variable increases by one standard deviation (Bollen, 1989; Kline, 2005).

**Table 2.**  
*Unstandardized Model Coefficients*

Variables	Estimated Parameter Values															
	Observable Endogenous Variables															
	p_9	p_11	p_16_a	p_16_b	p_16_c	p_16_d	p_16_e	p_16_f	p_16_g	p_16_h	p_16_i	p_16_j	p_17	p_19	p_21	p_22
p_1	-0,072	-0,099***	-0,019	-0,225***	-0,045	-0,078	-0,194***	-0,053	-0,105***	0,004	-0,191***	-0,339***	-0,042***	0,129***	-0,024	-0,033
p_2	-0,011	-0,003	0,189***	0,099	0,109***	0,232***	0,288***	0,232***	0,279***	0,116	0,666***	0,024	0,024	0,023	-0,052	-0,094***
p_3	-0,017	0,028	-0,011	0,059***	0,009	0,008	-0,039	-0,035	-0,042	-0,036	-0,016	-0,029	-0,006	-0,013	0,004	0,015
p_4	-0,303***	0,415***	-0,069***	0,150***	0,074***	0,133***	0,032	0,033	0,007	0,03	0,052	0,062	0,003	0,061***	0,033	0,012
p_5	-0,178***	0,245***	-0,014	0,008	0,008	-0,050	-0,084	-0,002	0,052	-0,002	0,042	-0,071	0,037	0,020	0,005	-0,004
p_6	-0,007	-0,044	0,021	0,001	-0,054***	-0,024	-0,034	-0,016	-0,052	-0,014	-0,032	-0,027	-0,050***	-0,017	-0,008	0,007
p_7	-0,008	0,014	0,003	-0,016	0,001	-0,005	0,002	-0,008	-0,003	-0,007	0,010	-0,001	0,003	0,002	-0,010	-0,002
p_8	-0,017	0,066	0,207***	-0,133	0,101	0,169***	0,085	0,269***	0,069	0,131	0,096	-0,115	0,003	0,027	-0,069	-0,091***

Note: \*\*\* indicates  $p < 0.001$ .

Source: own.

**Table 3**  
*Standardized Coefficients of Models*

Variables	Estimated Parameter Values															
	Observable Endogenous Variables															
	p_9	p_11	p_16_a	p_16_b	p_16_c	p_16_d	p_16_e	p_16_f	p_16_g	p_16_h	p_16_i	p_16_j	p_17	p_19	p_21	p_22
p_1	-0,039	-0,064	-0,015	-0,162	-0,038	-0,058	-0,137	-0,042	-0,069	0,003	-0,120	-0,189	-0,057	0,176	-0,035	-0,060
p_2	-0,004	-0,001	0,103	0,050	0,065	0,120	0,014	0,158	0,107	0,132	0,051	0,259	0,023	0,022	-0,052	-0,118
p_3	-0,016	0,032	-0,015	0,074	0,013	0,011	-0,049	-0,048	-0,049	-0,043	-0,018	-0,028	-0,015	-0,031	0,009	0,046
p_4	-0,164	0,270	-0,055	0,108	0,064	0,099	0,022	0,026	0,005	0,021	0,033	0,035	0,004	0,083	0,047	0,021
p_5	-0,099	0,162	-0,011	0,006	0,007	-0,038	-0,061	-0,001	0,035	-0,002	0,027	-0,041	0,051	0,029	0,007	-0,007
p_6	-0,006	-0,042	0,024	0,001	-0,068	-0,026	-0,035	-0,018	-0,050	-0,014	-0,029	-0,022	-0,097	-0,034	-0,017	0,018
p_7	-0,024	0,048	0,012	-0,060	0,005	-0,019	0,008	-0,035	-0,009	-0,026	0,033	-0,003	0,018	0,015	-0,078	-0,018
p_8	-0,006	0,027	0,101	-0,060	0,054	0,078	0,038	0,132	0,029	0,055	0,038	-0,040	0,002	0,023	-0,062	-0,103

Source: own.

The above interpretations are only valid when the values of the other variables remain unchanged. The coefficient values thus describe the direction (positive/negative) and the strength of the influence of the independent variable on the dependent variable. The strength of the influence on the dependent variable can be compared between independent variables using standardized coefficients. This is because the values of the unstandardized coefficients depend on the units in which the variables are measured (Domański, 1990; Konarski, 2010; Osińska, 2008; Osińska, Pietrzak, Żurek, 2011).

#### 4. Conclusions

Based on the analysis of the conducted research, several key conclusions can be drawn. Price and quality of the product or service are the most important factors influencing consumers' online purchasing decisions. This suggests that most consumers are looking for products that offer good value for the price. User interface and delivery speed also have some impact, but they are less prioritized compared to price and quality. Warranty and product information are also important but at a medium level of importance.

Payment methods and opinions from other internet users have a moderate impact on purchasing decisions. This may suggest that consumers value flexibility and additional information, but these are not key elements in their decisions. After-sales service is important for a large group of consumers, but it is not a critical choice factor for everyone.

The least important for consumers is the ecological origin of products. This may indicate that ecological awareness is still not the main motivation for most consumers in the context of online shopping. Generally speaking, online consumers are mainly focused on economic and quality aspects, while other factors such as ecology or payment method are less important to them.

Moreover, based on the presented data and analysis results, several key conclusions can be drawn regarding the impact of demographic and behavioral variables on online shopping behavior:

##### Demographic Factors:

Age (p\_1): The younger generation, especially those born after 1995, show more online shopping activity. The coefficient value for age is negative, indicating that shopping activity decreases with age.

Gender (p\_2): Women are significantly more active in online shopping than men. This is evident from the significant coefficient values for this group.

Place of residence (p\_3): People living in larger cities are more active in online shopping, which is intuitive – they probably have better access to the Internet and are more oriented towards new technologies.

Financial situation (p\_4): People with a better financial situation are more inclined to shop online, which confirms the positive coefficient for this variable.

Behavioral Factors:

Price (p\_16\_a) and product quality (p\_16\_c) are the most important factors in the shopping process.

Delivery speed (p\_16\_d) and product information (p\_16\_f) are also important but to a lesser extent.

Opinions from other internet users (p\_16\_h) and payment method (p\_16\_g) have moderate importance.

Ecological origin of products (p\_16\_j) is the least important for respondents.

Additionally, the results of statistical analyses suggest significant relationships between various factors and online shopping behavior. The main variable affecting most of the analyzed aspects of online shopping is the buyer's gender (variable p\_2), while the field of study (variable p\_7) generally has the least impact. Specifically, the financial situation has the greatest impact on the frequency of online shopping and the amount spent monthly. Interestingly, gender is the least influential factor here. However, in the context of other aspects, such as price, user-friendly interface, product or service quality, and many others, gender shows the strongest influence. In relation to some specific categories, such as warranty and after-sales service, age turns out to be the most important factor. In the matter of responding to questions from other online users, the most important factor turns out to be the field of study. These findings can be key to understanding how different consumer groups make online purchasing decisions. Identifying these correlations can help in targeting the appropriate market segments and effectively adjusting the sales strategy, especially since the buyer's gender turned out to be the main variable affecting shopping behavior.

The added value of conclusions from the statistical model concerning online shopping behavior is based on several key points:

**Understanding Demographics:** The model highlights the difference in shopping behavior depending on gender. Understanding this aspect can help sellers in adjusting their offer and marketing strategy in such a way as to attract a specific demographic group.

**Adjusting the Offer:** Understanding how different factors (such as age, financial situation, field of study) affect shopping behavior can help companies in adjusting their offer – from price to warranty and after-sales service.

**Targeting Market Segments:** Finding correlations between factors and shopping behaviors allows companies to focus on specific market segments, which can lead to greater effectiveness of marketing and sales activities.

**Optimizing Online Interaction:** Since the model indicates that the field of study affects interaction in the form of responding to questions from other online users, companies can use this information to better engage their online community.



**Building Greater Loyalty:** Understanding what drives the purchasing decisions of different consumer groups can help companies in building greater loyalty among customers by delivering products and services more tailored to their needs.

**Basis for Further Research:** Each statistical analysis can also provide a basis for further research. For example, since gender has such a large impact on some shopping behaviors, it would be worth investigating what other variables may be related to this difference.

**Strategic Application in Business:** Conclusions from the model can be used strategically by companies to predict trends, plan investments in advertising, create new products or services, and also to adjust pricing strategy.

**Basis for Customer Education:** Understanding what factors affect shopping behavior can help companies in educating their customers, which in turn can lead to better purchasing decisions by consumers.

Further research directions can focus on several aspects. First, there is a need for a deeper understanding of the role of gender in shopping behavior. Gender turned out to be a significant factor, but it would be worth investigating how other variables, such as personality or level of education, affect differences in shopping behavior between men and women. Second, an interesting direction could be to investigate the impact of geographic location on the availability and choice of different shopping options. People living in different regions may have different experiences and expectations that would be worth analyzing. The third potential research direction is the impact of the financial situation on shopping behavior. Although the research pointed to its importance, the detailed mechanisms of this impact are not known, especially in the context of different demographic groups.

The fourth direction is the analysis of how consumer priorities change depending on age. Since age turned out to be important in the context of warranty and after-sales service, it would be worth investigating how different generations approach other aspects of shopping, such as ecology or payment method. Finally, it would also be reasonable to investigate how education and consumer awareness affect their purchasing decisions. Since gender and demographics are so important, it would be important to understand whether education on various aspects of shopping, from ecology to quality and price, could affect a change in these behaviors. Each of these research directions could significantly contribute to understanding how different consumer groups make online purchasing decisions.

In the context of the impact of gender on online shopping behavior, there are also other studies that can be compared with the presented analysis. For example, a study conducted in the United Arab Emirates focuses on impulsive buying and differences between genders in this aspect (Karim, Nisa, Imam, 2021). Additionally, a study on attitudes towards online shopping also notices differences between men and women (Hasan, 2010). It is also worth noting a doctoral thesis that analyzes the impact of the characteristics of the website interface on shopping behavior, although it does not focus strictly on gender (Hong, 2014). These studies can provide additional context and deeper understanding for the analysis, especially in the aspect of the impact of gender on online purchasing decisions.

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## ORGANIZATIONAL AGILITY IN THE ASPECT OF SUSTAINABLE DEVELOPMENT OF THE ORGANIZATION

Maria KOCOT

University of Economics in Katowice; maria.kocot@ue.katowice.pl, ORCID: 0000-0001-5150-3765

**Purpose:** The study aims to examine the impact of organizational agility on the ability of companies to achieve sustainable development. It focuses on agile behaviors and strategies employed by organizations in various industries and their impact on the economic, social, and environmental aspects of sustainable development.

**Design/methodology/approach:** A research method based on a survey was used, conducted on a sample of 806 individuals representing diversity in gender, age, positions, work experience, company size and type, company's operational period, and industries. The study allows for a detailed analysis of organizational agility in various contexts and operating conditions of companies.

**Findings:** The study found that organizational agility has a positive impact on the ability of companies to achieve sustainable development. The results show that organizations capable of quickly responding to market changes, effectively recognizing customer needs, identifying opportunities and threats, ensuring high-quality products, introducing innovations, and offering personalized products and services perform better in the context of sustainable development.

**Research limitations/implications:** A limitation of the study is the use of the survey method, which may not fully capture the complexity and dynamics of organizational agility in various business contexts. Future research could include expanding the sample to more industries and regions, as well as employing more complex research methods such as case studies or long-term observations.

**Practical implications:** The study emphasizes the importance of investing in organizational agility to achieve sustainable development. Companies should focus on developing decision-making speed, adapting to changing market needs, social engagement, promoting innovation and growth, and integrating economic, social, and environmental goals into their strategies.

**Social implications:** The study indicates that developing organizational agility can contribute to better alignment of companies with social and environmental requirements, which is crucial in today's dynamic times. Engaging in social initiatives and collaborating with local communities can build positive social impact and strengthen the organization's image.

**Originality/value:** The article provides a new perspective on the relationship between organizational agility and sustainable development, illustrating how these two aspects are interconnected. The study offers valuable insights for companies aiming for sustainable development through the development of organizational agility.

**Keywords:** organizational agility, sustainable development, organization.

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

## 1. Introduction

In the face of a constantly changing business environment, organizational agility becomes a key factor enabling companies to effectively adapt to new challenges. Sustainable development, encompassing economic, social, and ecological aspects, is equally important in the context of long-term success of enterprises. This article aims to examine how organizational agility affects the ability of companies to achieve sustainable development, focusing on the analysis of agile behaviors and strategies used by organizations in various industries and their impact on the three main aspects of sustainable development.

The research questions focus on identifying key agile behaviors and assessing how these behaviors contribute to the success of the organization. The research hypothesis assumes that organizations exhibiting greater agility are more effective in achieving sustainable development goals. The research method is based on a survey conducted on a sample of 806 individuals, representing diverse gender, age, positions, length of service, size and type of company, period of operation, and industries. This data enables a detailed analysis of organizational agility and its impact on the ability of companies to achieve sustainable development.

## 2. Literature Review

### 2.1. Organizational agility in the business environment

Organizational agility is a key element in the dynamic business environment, referring to a company's ability to quickly adapt to market and technological changes while maintaining efficiency and effectiveness (Kumkale, 2022). In the context of agility, it is important to understand the various aspects that comprise this capability.

Strategic flexibility is one of the main components of organizational agility. It means the ability to quickly adapt business strategies in response to changing market conditions (Skyrius, Valentukevi, 2021). Companies that can quickly respond to changes often have a competitive advantage, as they can seize new opportunities before their competitors do (Cappelli, Tavis, 2018).

A culture of innovation is another key aspect of organizational agility. Promoting a culture that encourages innovation and experimentation is essential for agile organizations. This approach allows for the rapid testing of new ideas and adaptation to changing market demands (Cegarra-Navarro, Sánchez-García, Marco-Lajara, García-Pérez, 2021).

Operational agility is the ability to quickly and effectively adjust internal processes and resources in response to changing business needs. This includes managing human and technological resources, as well as production and logistical processes (Overby, Bharadwaj, Sambamurthy, 2006).

Communication and collaboration are also important for organizational agility. Effective communication within the company and with external partners allows for faster problem-solving and seizing new opportunities. Collaboration between different departments and teams is crucial for the rapid implementation of changes and innovations (McNamee, Schoch, Oelschlaeger, Huskey, 2012).

In the context of organizational agility, continuous learning and development are also important. Organizations that invest in their employees' development and encourage continuous learning are better prepared to adapt to new challenges and technologies (Bray et al., 2019).

In summary, organizational agility is a complex set of capabilities that enable companies to quickly respond to changing market and technological conditions. This includes strategic flexibility, a culture of innovation, operational agility, effective communication and collaboration, as well as continuous learning and development. Companies that develop these aspects are better prepared to achieve success in the rapidly changing business world (Narasimhan, Talluri, Mahapatra, 2006; Fosso Wamba, 2022; Rahman, 2022).

## **2.2. Organizational agility and the sustainable development of organizations**

Sustainable development in organizations is a key element in today's business world, where the shift from traditional development models, focusing mainly on economic aspects, to more balanced models that also consider environmental and social issues, becomes both a challenge and a source of numerous benefits (Helfat et al., 2007; Ivory, Brooks, 2018). Sustainable development strategies allow organizations to reduce their negative impact on the environment, build better reputation and trust, engage in social development, and promote ethical business practices (Crane et al., 2008; Crane et al., 2013).

Sustainable development, a key issue in management, requires organizations to find a balance between economic development, environmental protection, and social responsibility, which is a fundamental challenge for long-term success (Hendy et al., 2012; Hahn et al., 2015; Hahn et al., 2016).

At the same time, sustainable development enables organizations to build a positive image and reputation (Jones et al., 2004). There is increasing attention to the social responsibility of organizations, and sustainable development principles can increase customer trust and loyalty, and attract investors (He, Harris, 2020). There are many strategies that organizations can use to achieve sustainable development, including the implementation of sustainable environmental management policies (Junni et al., 2015) and investing in social development (Carroll, Shabana, 2016).

Organizational agility has become a key element of sustainable development (Kocot, Kwasek, 2022). Investing in continuous process improvement, building flexible structures, and promoting a culture of innovation and learning are important activities in this area (Helfat, Peteraf, 2003; Knight, Paroutis, 2017).

In conditions of market uncertainty, organizations must be able to quickly respond to new challenges, while maintaining a balance between economic efficiency, environmental protection, and social responsibility (Aras, Crowther, 2008; Damayanti et al., 2023; Cowling et al., 2020; Iavicoli et al., 2021).

By developing organizational agility, organizations can better adapt to changing market and socio-ecological conditions, enabling effective achievement of sustainable development goals (Kadenic, Tambo, 2023; Kereluik et al., 2013). Moreover, engaging in social initiatives and collaborating with local communities contributes to building positive social impact and strengthening the organization's image. Such actions not only contribute to the development of local communities but also build a positive image of the organization, which in turn translates into greater trust from customers and investors (Brueller et al., 2014; Matten, Moon, 2018).

Developing organizational agility in the context of sustainable development enables organizations to effectively respond to changing social, environmental, and economic requirements, which is important in these dynamic times (Kettunen et al., 2021). Adopting organizational agility as the foundation of sustainable development allows organizations to achieve long-term success, minimizing the negative impact on the environment and contributing to the creation of positive social changes (Doz, Kosonen, 2010; 2011).

In the context of increasing digitization and digital transformation, organizations must adapt to new business models and technological innovations (Hartzband, Groopman, 2008; Hess et al., 2016; Javornik, 2016). These changes open up new opportunities for organizations, but at the same time require them to be flexible and innovative to remain competitive in the changing market (Hashem, AboelMaged, 2023; Homrozi, 2009).

In summary, sustainable development in organizations is not only a response to growing environmental and social challenges but also a key strategy enabling organizations to achieve long-term success in the dynamic business world. By integrating the principles of sustainable development, investing in organizational agility, and engaging in social initiatives, organizations can effectively build a lasting competitive advantage and contribute to creating a better future for themselves, society, and the natural environment.



### 3. Materials and methods

The aim of the article is to investigate how organizational agility affects the ability of companies to achieve sustainable development. The subject of the study is agile behaviors and strategies used by organizations in various industries and their impact on the three main aspects of sustainable development: economic, social, and environmental.

The research questions focus on identifying key agile behaviors and assessing how these behaviors contribute to the success of organizations in the context of sustainable development. The research hypothesis assumes that organizations that exhibit greater agility are more effective in achieving sustainable development goals.

The research method used in this article is a survey. It was conducted on a sample of 806 individuals, representing diverse genders, ages, positions, tenure, company size and type, period of company operation, and industries. This data allows for a detailed analysis of organizational agility in various contexts and operating conditions of companies. The research findings, presented in tables, enable an understanding of how various aspects of organizational agility affect the ability of companies to achieve sustainable development.

In the study conducted on a group of 806 people, sociodemographic data were collected, which allow for a deeper understanding of the profile of participants. Among them, 53.1% were women and 46.9% were men. The age group was diverse: 30.3% of respondents were below 25 years old, 27.7% were between 26-35 years, 29.5% were 36-45 years old, and 12.5% were over 45 years old.

Regarding the positions held, 5.1% were top management, 36.6% middle management, 18.4% lower management, and 40% were employees. In terms of tenure, 29.4% had up to 5 years of experience, 27.5% worked for 6-10 years, 13.2% for 11-15 years, 18.6% for 16-20 years, and 11.3% for over 20 years.

The size of the companies where the respondents worked was also diverse: 20.3% worked in micro-enterprises, 34.5% in small, 29.9% in medium, and 15.3% in large enterprises. Regarding the period of company operation, 8.6% had been operating for over 1 year, 31.6% from 1 to 3 years, 27.5% from 4 to 7 years, and 32.3% for over 8 years.

Among the industries, the most respondents (49.4%) came from retail trade, followed by 32.8% from other industries, 8% from the automotive industry, 7.6% from education, and 2.4% from healthcare. The geographic scope of the companies' operations was as follows: 14.5% local, 33.5% regional, 32.1% national, and 19.9% international.

The assessment of the financial situation of the companies indicated that 25.2% of respondents considered it very good, 52.2% good, 3.9% bad, 1.6% very bad, and 17.1% had difficulty assessing.

#### 4. Research results

Table 1 presents the results of a study on agile behaviors in organizations, involving 806 participants. The highest percentage of respondents (72.1%) indicated that their organizations can quickly respond to market changes, demonstrating a high adaptability of these firms. Furthermore, 59.3% of respondents emphasized that their companies effectively recognize customer needs, which is crucial in the context of customer orientation.

Additionally, 61.4% of study participants indicated that their organizations are capable of identifying opportunities and threats, an important element of risk management. High-quality products are provided by 53.2% of the companies, and 52.1% of them introduce innovations, highlighting their pursuit of continuous development and improvement of their offerings.

Offering personalized products and services is characteristic for 55.8% of the surveyed companies, which may indicate flexibility in adapting to individual customer needs. Adapting to market requirements is a feature of 49.7% of organizations, which may reflect their agility in responding to external factors.

Being able to predict changes is true for 46.1% of companies, which is significant in the context of strategic planning. Modifying operating strategies to better solve business problems is practiced by 50.9% of the surveyed organizations. In terms of market position, 34.7% of companies assess that they are performing excellently, and 35.1% use advanced technologies, which may indicate their modernity and innovativeness. Finally, 29.5% of respondents stated that their companies grade market opportunities, which may indicate a strategic approach to exploiting market opportunities. These results reflect the various aspects of organizational agility that can impact a company's success in a dynamic business environment.

**Table 1.**

*Agile Behaviors of Organizations, N = 806*

	N	%
Can quickly respond to market changes	579	72,1%
Can recognize customer needs	476	59,3%
Can identify opportunities and threats	493	61,4%
Provides high-quality products	427	53,2%
Introduces innovations	418	52,1%
Offers personalized products and services	448	55,8%
Adapts to market requirements	399	49,7%
Can anticipate changes	370	46,1%
Modifies its operational strategy for better business problem-solving	409	50,9%
Excels in the market	279	34,7%
Uses advanced technologies	282	35,1%
Grades market opportunities	237	29,5%

Source: own.

The study was focused on understanding how agile behaviors in organizations translate into sustainable development, as shown in Table 2 with the participation of 806 respondents. These data reflect various aspects of agility and their impact on the development of organizations in the economic, social, and ecological context.

The first aspect concerns the speed of decision-making. The majority of respondents (402 "rather yes" and 311 "definitely yes") indicated that their organizations respond quickly to changing circumstances, which is crucial for agility. Only a small percentage (12 "definitely not" and 26 "rather not") expressed the opposite opinion.

Next, adaptation to market needs and requirements is another important element. Here again, the majority (507 "rather yes" and 135 "definitely yes") confirmed that their companies are flexible in responding to changing market conditions.

In the context of promoting innovation and continuous development, the majority of respondents (401 "rather yes" and 227 "definitely yes") recognized that their organizations actively implement new solutions and focus on development. Engagement in social activities, which is an important aspect of sustainable development, was also positively assessed by the majority of respondents (471 "rather yes" and 156 "definitely yes").

Finally, the emphasis on economic, social, and ecological aspects, which are the foundation of sustainable development, was confirmed by the majority of respondents (452 "rather yes" and 193 "definitely yes"). These results show that organizations focus on various aspects of agility, which have a significant impact on their ability to achieve sustainable development. This indicates an awareness and effort of organizations towards integrating agility with the principles of sustainable development.

**Table 2.**

*Agile Behaviors in the Aspect of Sustainable Development of Organizations, N = 806*

	<b>Definitely NOT</b>	<b>Rather NOT</b>	<b>No opinion</b>	<b>Rather YES</b>	<b>Definitely YES</b>
Makes decisions at a fast pace (1)	12	26	55	402	311
Adapts to market needs and requirements (2)	4	23	137	507	135
Promotes innovation and continuous development (3)	10	29	139	401	227
Engages in social activities (4)	24	35	120	471	156
Emphasizes economic, social, and ecological aspects (5)	12	33	116	452	193

Source: own.

The analysis of the correlation table (Table 3) indicates significant relationships between the variables studied, reflecting the flexibility of organizations in the context of sustainable development. It is noted that the variable "Speed of decision-making" (1) shows significant connections with the other variables, highlighting the importance of rapid response in the context of organizational flexibility and sustainable development. An exceptionally strong correlation of this variable with "Promotion of innovation and continuous development" (3) and

"Focus on economic, social, and ecological aspects" (5) may indicate a deep link between innovativeness, sustainability, and the speed of decision-making.

The variable "Adaptation to market needs and requirements" (2) shows the highest correlation with "Engagement in social activities" (4), which may suggest that adapting to market trends is closely tied to an organization's involvement in social matters. This variable also strongly correlates with "Focus on economic, social, and ecological aspects" (5), indicating that market adaptation often involves considering these three elements of sustainable development.

The variable "Promotion of innovation and continuous development" (3) exhibits strong links with the other variables, especially with "Speed of decision-making" (1) and "Focus on economic, social, and ecological aspects" (5). This may indicate that the ability to innovate and continually develop is crucial for organizational flexibility and its sustainable development.

Finally, "Engagement in social activities" (4) and "Focus on economic, social, and ecological aspects" (5) show the strongest connections with all the other variables, suggesting that these two aspects are integrally linked to an organization's flexibility and its ability to adapt to changing conditions.

**Table 3.**

*Agile Behaviors in the Context of Sustainable Development of Organizations, N = 806*

	<i>1</i>	<i>2</i>	<i>3</i>	<i>4</i>	<i>5</i>
1	1				
2	0,84	1			
3	0,94	0,95	1		
4	0,87	0,99	0,962	1	
5	0,92	0,98	0,98	0,99	1

Source: own.

The analysis of the presented correlation table indicates strong connections between various aspects of agility and sustainable development of organizations. Several important observations can be made:

Variable 1 ("Speed of decision-making"): Shows a strong correlation with all other variables, particularly with variable 3 ("Promotion of innovation and continuous development") and variable 5 ("Focus on economic, social, and ecological aspects"). This indicates that the speed of decision-making is crucial for innovativeness and considering aspects of sustainable development.

Variable 2 ("Adaptation to market needs and requirements"): Has the strongest correlation with variable 4 ("Engagement in social activities"), suggesting that market adaptation is closely linked with social engagement. Its strong correlation with variable 5 also suggests considering the three elements of sustainable development.

Variable 3 ("Promotion of innovation and continuous development"): Has strong connections with all variables, highlighting its importance for the flexibility and sustainable development of organizations.

Variables 4 and 5: Show the strongest connections with all other variables, indicating their central role in ensuring organizational flexibility and adaptation to changing conditions.

Subsequently, a statistical significance analysis of the correlations for each pair of variables was conducted. The results are as follows:

Variable 1-2 (correlation: 0.84): t-value = 43.90, p-value  $\approx$  0.0.

Variable 1-3 (correlation: 0.94): t-value = 78.12, p-value  $\approx$  0.0.

Variable 1-4 (correlation: 0.87): t-value = 50.03, p-value  $\approx$  0.0.

Variable 1-5 (correlation: 0.92): t-value = 66.56, p-value  $\approx$  0.0.

Variable 2-3 (correlation: 0.95): t-value = 86.27, p-value  $\approx$  0.0.

Variable 2-4 (correlation: 0.99): t-value = 198.99, p-value  $\approx$  0.0.

Variable 2-5 (correlation: 0.98): t-value = 139.64, p-value  $\approx$  0.0.

Variable 3-4 (correlation: 0.962): t-value = 99.90, p-value  $\approx$  0.0.

Variable 3-5 (correlation: 0.98): t-value = 139.64, p-value  $\approx$  0.0.

Variable 4-5 (correlation: 0.99): t-value = 198.99, p-value  $\approx$  0.0.

All the p-values are very close to zero, which means that the observed correlations are statistically significant at a very high level. These results indicate statistically significant relationships between the variables studied.

## 5. Discussion

The conclusions derived from the conducted analysis of the statistical significance of correlations in the context of the article on organizational agility and sustainable development of organizations are as follows:

1. **Strong Significance of Decision-Making Speed:** The high correlation of the variable "Speed of decision-making" with other aspects of agility and sustainable development (especially with "Promotion of innovation and continuous development" and "Focus on economic, social, and environmental aspects") confirms that quick and effective decisions are a key element of organizational agility. This indicates that organizations capable of rapid response and adaptation have better chances of achieving sustainable development.
2. **Market Adaptation and Social Engagement:** The very strong correlation between "Adaptation to market needs and requirements" and "Engagement in social activities" suggests that companies that are sensitive to changing market conditions and actively participate in social initiatives can better respond to the needs of sustainable development.

3. **The Role of Innovation and Development:** Correlations of the variable "Promotion of innovation and continuous development" with other aspects show that innovativeness and a continual pursuit of development are important for organizational agility. Organizations that focus on innovation are more flexible and better adapted to change, which favors sustainable development.
4. **Integrated Approach to Sustainable Development:** High correlations of "Focus on economic, social, and ecological aspects" with all other variables emphasize that an integrated approach to these three dimensions is key for agility and sustainable development of organizations. This means that organizations must balance economic, social, and ecological goals to achieve lasting success.
5. **Interconnectedness of Agility and Sustainable Development:** Overall, these results confirm that organizational agility and sustainable development are closely linked. Organizations that are flexible, innovative, and socially responsible are better prepared to cope with the challenges of the modern business world while contributing to sustainable development.

## 6. Conclusions

Based on the analysis in the article, several key conclusions can be drawn regarding the relationship between organizational agility and sustainable development. Firstly, there is a strong correlation between the speed of decision-making in organizations and their ability to innovate and incorporate aspects of sustainable development. This indicates that organizations capable of quickly responding to market changes and adjusting their strategies have better chances of achieving sustainable development.

Secondly, market adaptation and social engagement are closely linked. Organizations that are sensitive to market changes and simultaneously engage in social activities show a greater ability to meet the requirements of sustainable development. The high correlation between these aspects suggests that organizational agility encompasses both business flexibility and social responsibility.

The third conclusion indicates that promoting innovation and continuous development are key to organizational agility. Organizations focusing on innovation and development show greater flexibility and better adapt to changing market conditions, which favors their sustainable development.

The fourth aspect is the integrated approach to sustainable development, combining economic, social, and environmental aspects. High correlations between these dimensions and other aspects of agility indicate that balancing these three areas is crucial for the long-term success of organizations.

In summary, the research findings emphasize that organizational agility and sustainable development are closely related. Organizations that are flexible, innovative, and socially responsible are better prepared to cope with the challenges of the modern business world and simultaneously contribute to sustainable development.

Based on the analysis in the article, the following recommendations for companies can be made. Firstly, increasing decision-making speed through better communication and data utilization is crucial for rapid adaptation to market changes. Then, companies should continuously adapt their products and services to changing market needs, based on thorough research and customer feedback.

Another important element is social engagement, which not only strengthens the company's image but also facilitates a better understanding and response to social challenges. Promoting innovation through investments in research and development and creating a culture that supports experimentation is also key to agility and sustainable development.

Companies should also integrate economic, social, and environmental goals in their strategies, striving for a balanced approach that considers the long-term impact of their actions. Strengthening organizational flexibility through the adaptation of business models and investment in technologies is also important, as well as investing in employee skills development in agility and sustainable development.

Finally, building partnerships with various organizations can strengthen a company's capabilities in innovation and sustainable development. In summary, companies should strive to become more agile, innovative, and socially responsible, which will contribute to their success and promote sustainable development.

The research presented identifies several limitations. One of them is the use of a survey-based research method, which may not fully capture the complexity and dynamics of organizational agility in different business contexts. Additionally, the sample size, although large, may not have covered sufficient industry diversity, potentially limiting the generalizability of the results.

Future research directions could include expanding the sample to more industries and regions to better understand how agility affects sustainable development in different economic contexts. More complex research methods, such as case studies or long-term observations, could also be used to provide deeper insight into firms' adaptive processes. Additionally, it would be valuable to explore the impact of organizational culture and leadership on agility and sustainable development, to better understand how these internal factors contribute to organizational effectiveness.

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## THE IMPACT OF THE MACROECONOMIC AND FINANCIAL SITUATION ON THE SUSTAINABLE DEVELOPMENT OF THE LOGISTICS SECTOR IN POLAND

Magdalena KOWALSKA<sup>1</sup>, Anna MISZTAL<sup>2</sup>, Agata GNIADKOWSKA-SZYMAŃSKA<sup>3\*</sup>

<sup>1</sup> Faculty of Economics and Sociology, University of Lodz; magdalena.kowalska@uni.lodz.pl,  
ORCID: 0000-0002-5821-0305

<sup>2</sup> Faculty of Economics and Sociology, University of Lodz; anna.misztal@uni.lodz.pl,  
ORCID: 0000-0002-7455-5290

<sup>3</sup> Faculty of Economics and Sociology, University of Lodz; agata.gniadkowska@uni.lodz.pl,  
ORCID: 0000-0002-7321-3360

\* Correspondence author

**Purpose:** The main aim of this paper is to assess the impact of the macroeconomic and financial situation on the sustainable development of the logistics sector in Poland from 2008 to 2020.

**Design/methodology/approach:** We normalize diagnostic variables into synthetic indicators to verify the hypothesis. We use the classical least squares method (OLS) and the seemingly unrelated regression (SUR) method to estimate equations.

**Findings:** The results indicate a positive trend in the sustainable development of the logistics sector in Poland from 2008 to 2020. Moreover, macroeconomic conditions are crucial for sustainable development, and it should be noted that the financial situation impacts the economic and social development of the sector.

**Research limitations/implications:** The availability of data, the choice of normalization method and the choice of estimation method for both the one-equation model and the structural equation model.

**Practical implications:** The research results indicate that managers of entities from the logistics sector should first analyze the macroeconomic situation and consider the financial and property situation of enterprises.

**Social implications:** The social development of the logistics sector is visible, and it is necessary to take further actions to improve working conditions and quality.

**Originality/value:** The novelty in the paper is the creation of models of the impact of macroeconomic conditions and the financial situation on the sustainable development of logistics enterprises. The paper addresses many recipients interested in developing the logistics sector.

**Keywords:** sustainable development, logistics sector, macroeconomic conditions, financial situation.

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

## 1. Introduction

Currently, sustainable development is the subject of a wide scientific discourse, covering various disciplines, and occupies an important place in economic practice (Dasgupta, 2007; Acosta Castellanos, Queiruga-Dios, 2022). The literature on the subject emphasizes its complex, holistic nature, which manifests itself in different approaches to its conceptualization (Mathiasson, Jochumsen 2022). The most common definition comes from the 1987 report *Our Common Future* (Brundtland Report), who pointed out that sustainable development is development that meets the needs of the present and does not jeopardize the ability of future generations to meet their needs. Sustainable development is an approach that takes into account the simultaneous fulfillment of economic, social and environmental goals. This is a long-term strategy that assumes that companies should act responsibly and with future generations in mind. Economic goals involve achieving profits and financial growth, which is essential for the operation and success of an enterprise. Sustainable development assumes that economic goals should be achieved in an ethical manner and with respect for the community in which the company operates and the natural environment. The implementation of the concept of sustainable development requires the participation of states, international institutions, and organizations as well as entire communities (Bansal, 2002; Kolk, van Tulder, 2010; Bose, Khan, 2022; Szychta, 2022).

The main aim of this paper is to assess the impact of the macroeconomic and financial situation on the sustainable development of the logistics sector in Poland from 2008 to 2020. We normalize diagnostic variables into synthetic indicators to verify the hypothesis. We use the classical least squares method (OLS) and the seemingly unrelated regression (SUR) method to estimate equations.

The study includes an introduction, materials and methods, research methodology, results, discussion, and conclusion. The review of scientific publications was based on the Scopus and Web of Science lists. The data for the analysis come from Eurostat databases. For the calculations, we used Statistica and Gretl software.

The research results indicate that managers of entities from the logistics sector should first analyze the macroeconomic situation and consider the financial and property situation of enterprises. The social development of the logistics sector is visible, and it is necessary to take further actions to improve working conditions and quality. The novelty in the paper is the creation of models of the impact of macroeconomic conditions and the financial situation on the sustainable development of logistics enterprises. The paper addresses many recipients interested in developing the logistics sector.

## 2. Sustainable development of enterprises- definition

Sustainable development of enterprises, also known as corporate sustainable development or business sustainability, refers to the practice of conducting business operations in a way that not only ensures financial success but also takes into account the long-term social, environmental, and economic impacts of these operations (Pieloch-Babiarz et al., 2021; Mao et al., 2018). Sustainable development for enterprises involves a commitment to responsible and ethical business practices that balance profit generation with the well-being of people and the planet (Pererva et al., 2021; Ghauri, 2022; Diaz- Sarachaga, 2021).

Key aspects of enterprise sustainable development include:

- economic sustainability - ensuring the long-term financial viability of the business by generating profits, managing costs and promoting economic growth; this can involve responsible financial management, diversification and investment in innovation (Mio et al., 2020);
- social sustainability - focusing on the well-being of employees, customers, and the enterprise's communities; this includes providing safe and fair working conditions, promoting diversity and inclusion and participating in philanthropic activities (Anh et al., 2022; Sribna et al., 2023);
- environmental sustainability - reduce the environmental impact of business operations by minimizing resource consumption, managing waste and emissions, and adopting sustainable practices (Sribna et al., 2023; Hysa, 2020);
- ethical governance - implementing ethical and transparent business practices, such as adhering to fair trade principles, ensuring ethical supply chain management and promoting corporate social responsibility (Lu et al., 2019; Fotaki et al., 2020);
- long-term perspective - embracing a long-term perspective and considering the potential impacts of business decisions on future generations; this involves risk management, scenario planning and a commitment to sustainable practices over short-term gains (Teixeira et al., 2019);
- innovation and adaptation - encourage innovation to develop more sustainable products, services and processes (Hanaysha et al., 2022; Chege et al., 2020);
- stakeholder engagement - engaging with a wide range of stakeholders, including employees, customers, investors, government agencies and civil society, to gather input and build partnerships that promote sustainable development (Wojewnik-Filipkowska et al., 2019);

Sustainable development is the subject of a wide scientific discourse covering various disciplines and occupies an important place in economic practice (Dasgupta, 2007; Acosta et al., 2022). The literature on the subject emphasizes its complex and holistic nature, which manifests itself in different approaches to its conceptualization (Mathiasson, Jochumsen, 2022).

Sustainable development is driven by ethical considerations and increasingly by market and regulatory pressures. Consumers and investors are becoming more aware of sustainability issues, and governments are enacting policies and regulations to encourage sustainable business practices (Haldar, 2019; Utting, 2000).

Implementing sustainable development requires the participation of states, international institutions and organizations, and whole communities (Bose, Khan, 2022; Szychta, 2022). A special place is occupied by companies widely recognized as the entities that have contributed the most to environmental degradation (Brzezinski, Pyza, 2021; D'Angelo et al., 2022). Therefore, they must take active measures to combat climate change and protect natural resources (Pishdar et al., 2022; Keshavarz-Ghorabae et al., 2022).

### **3. Sustainable development of logistics sector in Poland**

Poland's transport and logistics sector is a critical and rapidly developing part of the country's economy, serving as a vital link in the supply chains of Poland and the broader European region. Sustainable development in Poland's transport and logistics sector is of paramount importance as it directly impacts the country's economy, the environment, and society (Klimecka-Tatar et al., 2021; Ogryzek et al., 2021; Sadowski et al., 2020). The selection of such a research group results from the fact that this sector is important for maintaining economic stability and social and political cohesion and is also characterized by a high negative impact on the natural environment (high greenhouse gas emissions according to Eurostat reports) (Camporek et al., 2022; Danilevičius et al., 2023; Martišius et al., 2022).

Sustainable development in the transport and logistics sector in Poland not only contributes to environmental conservation and social well-being but also improves the sector's competitiveness and resilience. It aligns with global efforts to combat climate change and positions Poland as a responsible player in the international logistics and transportation landscape. Collaboration among stakeholders, including government, businesses, and communities, is essential to drive sustainable practices and achieve long-term economic and environmental goals (Vuković et al., 2022; Jacyna et al., 2014; Przybylska et al., 2023).

The TLS sector in Poland is a vital component of the country's economy, driven by its strategic location, infrastructure development, and role in European supply chains. The sector is well-positioned to capitalize on the growth of e-commerce and increasing international trade. Poland continues to invest in its transport infrastructure to support the sector's expansion, making it an attractive destination for logistics companies and a critical gateway for goods in Europe (Brdulak et al., 2021; Camporek et al., 2021). Unfortunately, further challenges for TSL, such as the war in Ukraine, do not bode well for the future (Report "ROAD TRANSPORT IN POLAND 2021+"). Many doubts in the coming years due to the actions of the European



Union on climate policy. This is due to the draught law prohibiting the production of trucks and tractor units powered by internal combustion engines, the entry into force of which is associated with the emergence of costly transformations of entire fleets and a change in the working model of transport companies (Report "ROAD TRANSPORT IN POLAND 2021+").

#### **4. Macroeconomic and financial conditions on the sustainable development**

Enterprise value management refers to identifying, measuring, monitoring, and managing the value a company generates for its owners, investors, customers, and other stakeholders (Koller et al., 2010; Lin et al., 2023). Company value can be understood as the ability to generate financial flows, stability, market reputation, innovation, intellectual capital, and many other factors that contribute to the company's long-term success (Stubelij, 2010; Subiada et al., 2018; Putra et al., 2021).

In today's global and competitive business environment, enterprise value management is becoming indispensable for managers and business owners. It allows for making informed business decisions, optimizing resource allocation, identifying valuable areas of activity, and adapting the strategy to changing market conditions (Venkataraman, Pinto, 2023).

The interconnections between the economy and the TLS sector are rooted in fundamental macroeconomic factors that can be divided into two distinct groups (Czyżewski, 2017):

- of a real nature: about the real pace of GDP change, the real rate of change in total consumption (as a value characterizing consumption), the real pace of changes in gross fixed capital formation (as a value characterizing investments), the real pace of changes in accumulation (as a value characterizing investments);
- of a monetary nature: the consumer price index (CPI), the pace of changes in the money supply, and the real level of interest rates.

In addition, financial conditions indeed have a significant impact on sustainable development. They play a critical role in enabling or constraining sustainable development efforts. Adequate financial resources, access to capital, favourable financing terms, and a supportive financial ecosystem are essential for implementing projects that address environmental conservation, social equity, and long-term economic growth. Aligning financial systems and practices with sustainable development objectives is crucial to achieving a more balanced and equitable form of development (Tien et al., 2020; Yakovlev et al., 2019; Al Ahabbi et al., 2019; de Castro Sobrosa Neto et al., 2020).

Globalization greatly improves capital movement, abolishes customs barriers, and influences other facilitations, leading to the abolition of the phenomenon of easy capital. It can be quickly placed where a higher rate of return will be obtained. Technical and technological progress, as well as economic growth, have resulted in the emergence of more

private capital on the market, characterized by high expectations regarding the maximization of the rate of return on investment. The development of information and telecommunication technologies has created unlimited possibilities for information transfer, which greatly facilitates investment decisions and capital transactions in any market. To effectively apply this concept, it is necessary to thoroughly understand all the mechanisms and tools for evaluating the effects of the companies used in this concept. It is also necessary to implement an active corporate governance system that would allow for the creation of a mechanism that integrates the goals of managers with the goals of owners and other stakeholders (Sarbah, Quaye, 2021; Salzman, 1999; Liu et al., 2022; Khan, 2022).

Macroeconomic and financial conditions have a significant impact on sustainable development. The economic environment in a country or region can facilitate or hinder progress toward sustainable development goals (Alhadhrami et al., 2019). Macroeconomic stability, including low inflation and interest rates, can make it more attractive for governments and businesses to invest in sustainable infrastructure projects, such as renewable energy, public transportation, and green buildings. Government fiscal policies, such as tax incentives and subsidies, can promote or hinder sustainable practices (Arena et al., 2023; Jan et al., 2023). Policymakers, businesses, and civil society must work together to create an environment that supports sustainable practices, including responsible investment, resource management, and income distribution. By aligning economic policies with sustainable development goals, societies can better address the complex and interrelated challenges of environmental protection, social equity, and economic growth (Rahim, 2017; Al-Ali et al., 2021; Alhadhrami et al., 2019; Pera, 2017).

## **5. Research methodology**

The research aims to assess the impact of macroeconomic conditions and the financial situation of the logistics sector on its sustainable development. We examined logistics companies (Section H) registered in Poland from 2008 to 2020. The research period covered the financial crisis due to the COVID-19 pandemic.

Due to this research goal, we have proposed the following hypothesis: “Macroeconomic conditions, not financial ones, have a decisive impact on the sustainable development of the logistics sector in Poland from 2008 to 2020”. This approach results from the fact that the logistics sector is largely dependent on macroeconomic conditions, as its development depends on the growth of other sectors of the economy.

Additionally, we formulated the following sub-hypotheses:

- Sustainable development of the logistics sector in Poland in 2008-2020 has a positive trend;
- Economic development shows higher growth dynamics compared to the social and environmental development of the logistics sector in Poland from 2008 to 2020;
- The impact of macroeconomic conditions and the financial situation on the three pillars of sustainable development - economic, social and environmental - varies in terms of statistical significance and the strength and direction of the influence in the logistics sector in 2008-2020.

We conducted the study in several stages:

1) We created synthetic indicators of:

- sustainable development (S) based on its three pillars:
  - economic (ED), including following stimulants: transport enterprises- number, turnover or gross premiums, production value, value added at factor cost, gross operating surplus, total purchases of goods and services, gross investment in tangible goods, investment rate;
  - social (SD): stimulants: wages and salaries, social security costs, employee-number, turnover per person employed, apparent labour productivity, gross value added per employee, growth rate of employment, investment per person employed and destimulants: personnel costs - million euro, share of personnel costs in production – percentage;
  - environmental development (EnvD), based on destimulants: carbon dioxide, methane, nitrous oxide, sulphur oxides (SO<sub>2</sub> equivalent), ammonia (SO<sub>2</sub> equivalent);
- financial situation (FS) based on its four pillars:
  - financial liquidity (FL): stimulants: classic current ratio, classic quick ratio;
  - profitability (P): stimulants: return on assets, return on sales, return on equity;
  - efficiency of operation (EO): stimulants: total asset turnover ratio and destimulants: inventory turnover ratio in days, receivables turnover ratio in days, payables turnover ratio in days, operating cycle in days;
  - debt (D): stimulants: rate of share of equity in asset financing, liability coverage ratio with tangible fixed assets and total debt ratio, debt equity ratio, long-term debt ratio;
- macroeconomic conditions (MC), stimulants: GDP, export, wages and destimulants: import, unemployment rate and HICP.

Sustainable development indicators were determined by the variable standardization method based on the following formula:

- for the stimulants:

$$Z_{ij} = \frac{x_{ij}}{\max x_{ij}}, \quad Z_{ij} \in [0; 1] \quad (1)$$

- for the destimulants:

$$Z_{ij} = \frac{\min x_{ij}}{x_{ij}}, \quad Z_{ij} \in [0; 1] \quad (2)$$

$Z_{ij}$  - the normalized value of the  $j$ -th variable in the  $i$ -th year,  
 $x_{ij}$  is the value of the  $j$ -th variable in the  $i$ -th year.

To calculate the indicator of sustainable development of the LOGISTICS sector ( $S$ ) and its components economic ( $E_D$ ), social ( $S_D$ ), and environmental ( $Env_D$ ) we use the formula:

$$S = \frac{\sum_{j=1}^n (E_{Dij} + S_{Dij} + Env_{Dij})}{n}, \quad S_{Dij} \in [0; 1] \quad (3)$$

- 2) We created a linear equation, which we estimated using the classic least squares method, based on formula:

$$S = \alpha_0 + \alpha_1 M_{Ct} + \alpha_2 M_{C(t-1)} + \alpha_3 M_{C(t-2)} + \alpha_4 F_{St} + \alpha_5 F_{S(t-1)} + \alpha_6 F_{S(t-2)} + \alpha_7 S_{(t-1)} + \alpha_8 S_{(t-2)} + \varepsilon_i \quad (4)$$

$$s(\hat{\alpha}_0, \dots, \hat{\alpha}_5) = \sum_{i=1}^n e_i^2 = \sum_{i=1}^n (S_{Di} - \hat{S}_{Di})^2 \rightarrow \min \quad (5)$$

- 3) We created the multi-equation models and use the SUR estimation method, the structural equations have the following formula:

$$\begin{aligned} E_D &= \alpha_0 + \alpha_1 S_D + \alpha_2 Env_D + \alpha_3 F_{St} + \alpha_4 F_{S(t-1)} + \alpha_5 M_{Ct} + \alpha_6 M_{C(t-1)} + \varepsilon_i \\ S_d &= \alpha_0 + \alpha_1 E_D + \alpha_2 Env_D + \alpha_3 F_{St} + \alpha_4 F_{S(t-1)} + \alpha_5 M_{Ct} + \alpha_6 M_{C(t-1)} + \varepsilon_i \\ Env_d &= \alpha_0 + \alpha_1 E_D + \alpha_2 S_D + \alpha_3 F_{St} + \alpha_4 F_{S(t-1)} + \alpha_5 M_{Ct} + \alpha_6 M_{C(t-1)} + \varepsilon_i \end{aligned} \quad (6)$$

We use feasible generalized least squares (FGLS) to estimate the SUR model. The residuals from our regression are used to estimate the elements of matrix (Takeshi, 1985):

$$\hat{\sigma}_{ij} = \frac{1}{R} \hat{\varepsilon}_i^T \hat{\varepsilon}_j \quad (7)$$

Then, we run generalized least squares regression for using the variance matrix:

$$\Omega \equiv E[(\varepsilon\varepsilon^T|X)] = \sum \Omega \otimes I_R \quad (8)$$

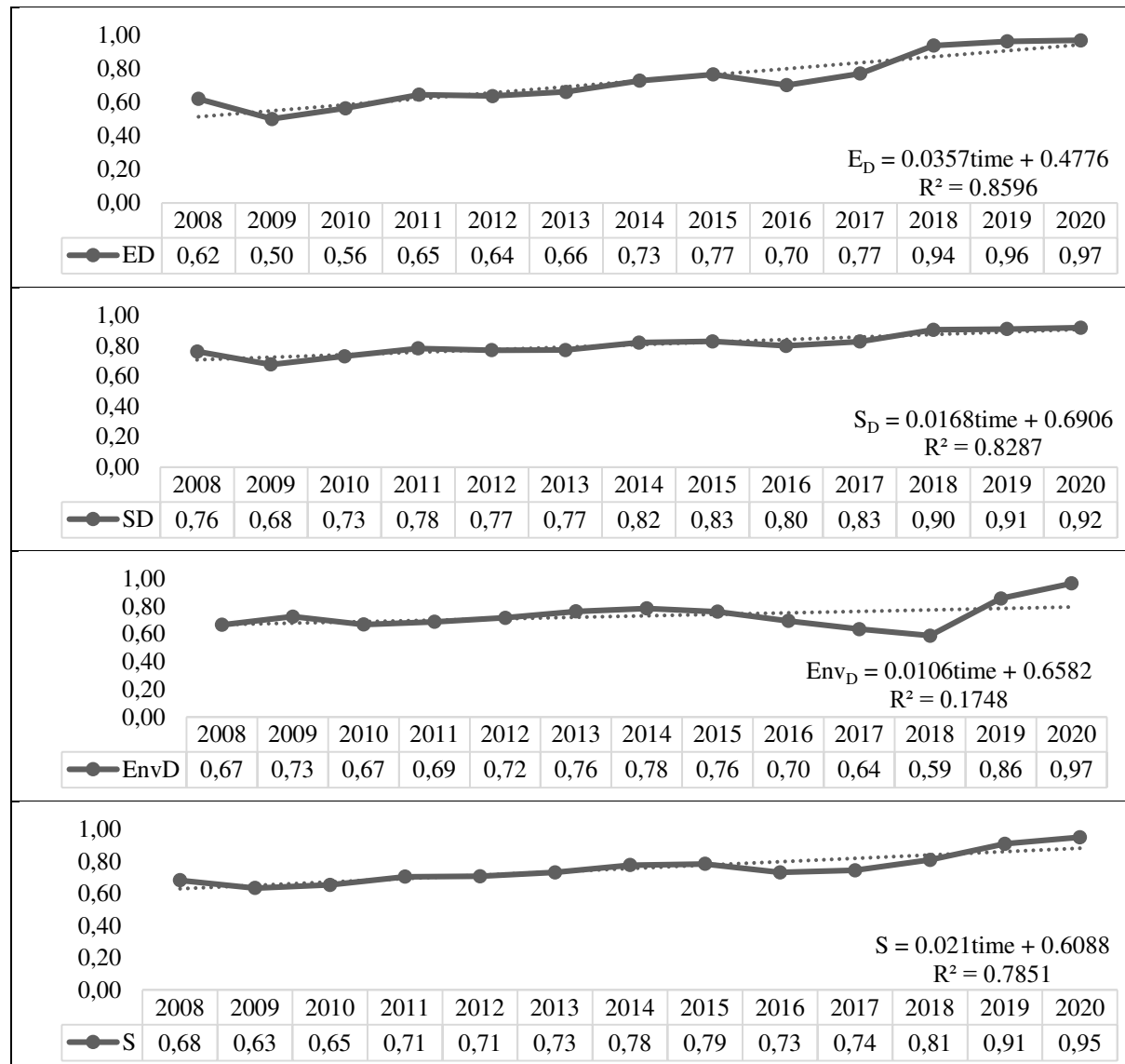
$$\hat{\beta} = (X^T (\hat{\Sigma}^{-1} \otimes I_R) X)^{-1} X^T (\hat{\Sigma}^{-1} \otimes I_R) y \quad (9)$$

The formula for the SUR estimator is as follows:

$$\sqrt{R}(\hat{\beta} - \beta) \xrightarrow{d} N(0, (\frac{1}{R} X^T (\hat{\Sigma}^{-1} \otimes I_R) X)^{-1}) \quad (10)$$

## 6. Research results

Figure 1 shows the synthetic indicator of the sustainable development of the logistics sector in Poland from 2008 to 2020 and its pillars (economic, social and environmental). The values of indicators vary. Moreover, all indicators increased in the analyzed period, a positive phenomenon. A noticeable higher degree of enterprise involvement is in implementing economically and socially responsible tasks. The activities undertaken for sustainable development of the logistics sector in Poland from 2008 to 2020 are efficient and effective.



**Figure 1.** The synthetic indicator of the sustainable development and its pillars (2008-2020, the logistics sector).

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 11.11.2023.

Table 1 presents the descriptive statistics of the synthetic indicator of the sustainable development of the logistics sector in Poland from 2008 to 2020 and its pillars (economic, social and environmental). During the period under review, the average level and median of indicators are relatively high. The maximum level of indicators was recorded in 2020, and the minimum in 2009 (except for the environmental indicator). Considering the years 2009 and 2020, it can be concluded that logistics sector enterprises took several actions aimed at sustainable development.

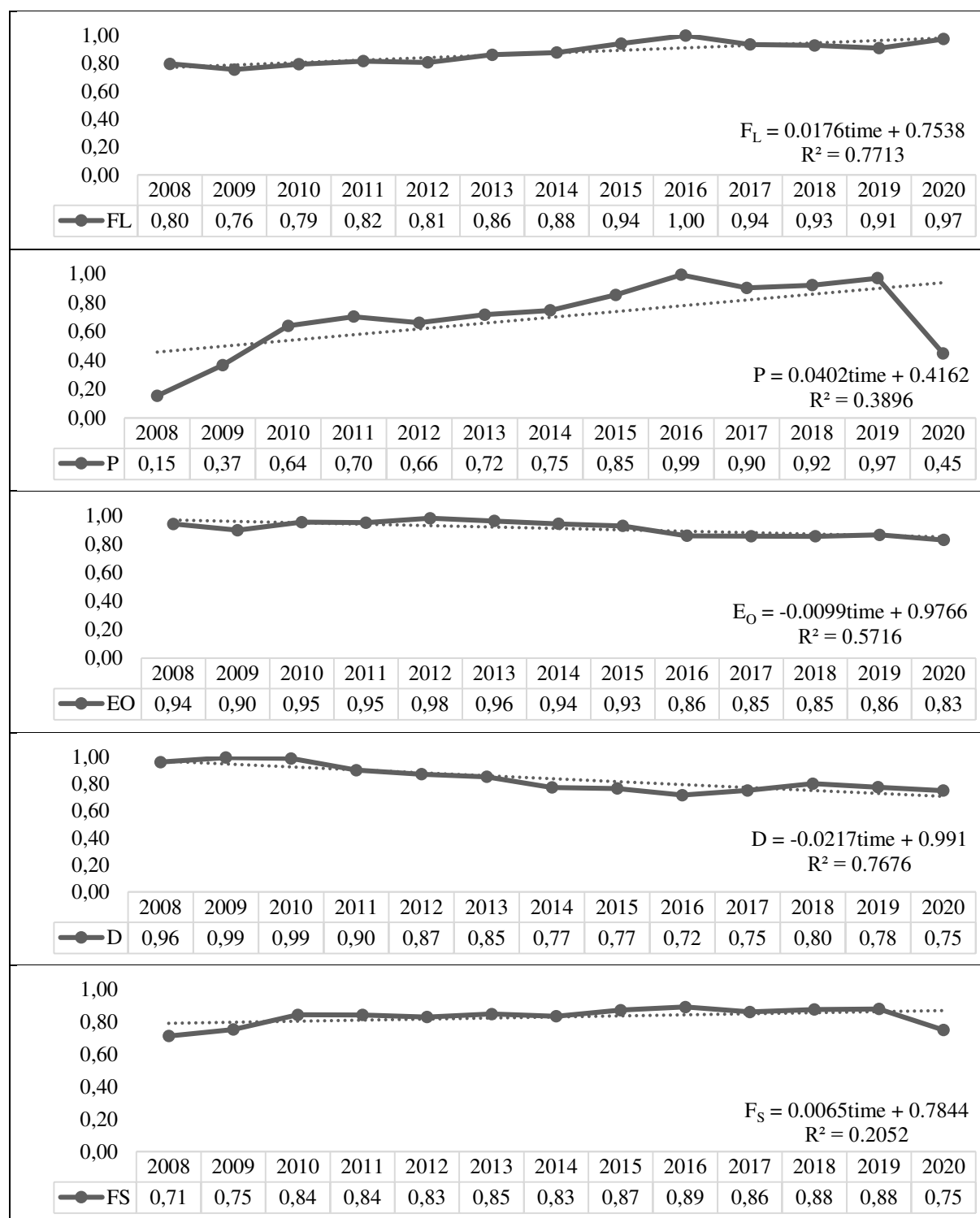
**Table 1.**

*The descriptive statistics of the synthetic indicator of the sustainable development and its pillars (2008-2020, the logistics sector)*

Country	Sector	Variable	Descriptive statistics				
			Mean	SD	Median	Max	Min
Poland	Logistic	E <sub>D</sub>	0.73	0.14	0.70	0.97	0.50
		S <sub>D</sub>	0.81	0.07	0.80	0.92	0.68
		Env <sub>D</sub>	0.73	0.09	0.72	0.97	0.59
		S	0.76	0.09	0.73	0.95	0.63

Source: own study on the basis of Eurostat <https://ec.europa.eu/eurostat>, 11.11.2023.

Figure 2 shows the synthetic indicator of the financial situation of the logistics sector in Poland from 2008 to 2020 and its pillars (financial liquidity, profitability, efficiency of operation and debt). The values of indicators vary. Financial liquidity and profitability indicators increase in the analyzed period, whereas the efficiency of operation and debt decrease. However, the synthetic indicator of the financial situation of the logistics sector in Poland from 2008 to 2020 characterizes a positive trend, which should be assessed as a favourable situation. Enterprises in the logistics sector have a relatively good financial situation.



**Figure 2.** The synthetic indicator of the financial situation and its pillars (2008-2020, the logistics sector)

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 11.11.2023.

Table 2 presents the descriptive statistics of the synthetic indicator of the financial situation of the logistics sector in Poland from 2008 to 2020 and its pillars (financial liquidity, profitability, efficiency of operation and debt). The average level and median of indicators are high during the analysis period. The maximum level majority of indicators was recorded in 2016, while the minimum level was recorded in various years (no connection).

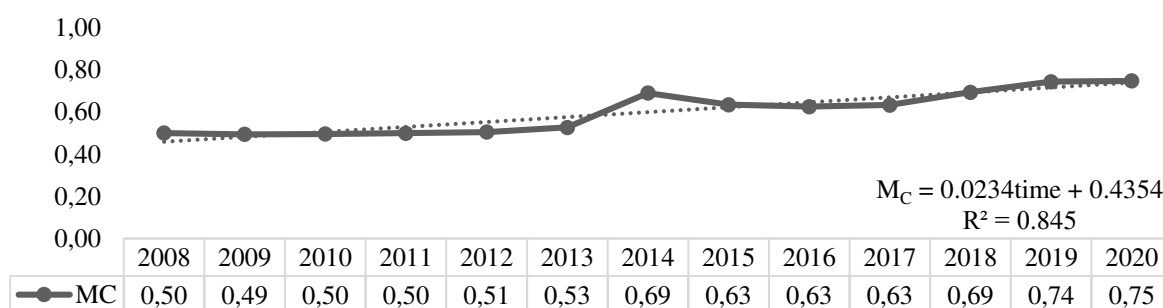
**Table 2.**

*The descriptive statistics of the synthetic indicator of the financial situation and its pillars (2008-2020, section H)*

Country	Sector	Variable	Descriptive statistics				
			Mean	SD	Median	Max	Min
Poland	Logistic	F <sub>L</sub>	0.88	0.07	0.88	1.00	0.76
		P	0.70	0.24	0.72	0.99	0.15
		E <sub>O</sub>	0.91	0.05	0.93	0.98	0.83
		D	0.84	0.09	0.80	0.99	0.72
		F <sub>S</sub>	0.83	0.05	0.84	0.89	0.71

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 11.11.2023.

Figure 3 shows the synthetic indicator of the macroeconomic conditions in Poland from 2008 to 2020. The indicator increases in the analyzed period, which should be assessed positively. It can be concluded that the macroeconomic situation in Poland improved during the period under review.

**Figure 3.** The synthetic indicator of the macroeconomic conditions (2008-2020, Poland)

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 11.11.2023.

Table 3 presents the descriptive statistics of the synthetic indicator of the macroeconomic conditions in Poland from 2008 to 2020. During the analysis period, the mean and median of the indicator are average. The maximum indicator level was recorded in 2020, and the minimum in 2009.

**Table 3.**

*The descriptive statistics of the synthetic indicator of macroeconomic conditions (2008-2020, Poland)*

Country	Variable	Descriptive statistics				
		Mean	SD	Median	Max	Min
Poland	M <sub>C</sub>	0.60	0.10	0.63	0.75	0.49

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, access: 11.11.2023.

Table 4 shows the results of the OLS regressions between explained variable (the synthetic indicator of the sustainable development of the logistics sector in Poland from 2008 to 2020) and explanatory variables (the synthetic indicator of macroeconomic conditions, the synthetic indicator of macroeconomic conditions  $(t-1)$  in Poland from 2008 to 2020, the synthetic indicator of macroeconomic conditions  $(t-2)$ , the synthetic indicator of the financial situation, the synthetic indicator of the financial situation  $(t-1)$ , the synthetic indicator of the financial situation  $(t-2)$ , the synthetic indicator of the sustainable development  $(t-1)$ , the synthetic indicator of the sustainable development  $(t-2)$  of the logistics sector in Poland from 2008 to 2020). The results



meet the OLS estimation conditions, including no collinearity, homoscedasticity, normal distribution of variables, and no autocorrelation. The synthetic indicator of macroeconomic conditions, the synthetic indicator of sustainable development ( $t-1$ ) and the synthetic indicator of sustainable development ( $t-2$ ) have a statistically significant impact on the synthetic indicator of sustainable development. The relationship between the examined variables is positive (without relation between the synthetic indicator of sustainable development ( $t-2$ ) and the synthetic indicator of sustainable development), with a different level of strength. The highest level of relationship is between the synthetic indicator of sustainable development ( $t-2$ ) and the synthetic indicator of sustainable development. The coefficient determination is 0.919, which means a very good fit of the data in the model.

**Table 4.**

*The Results of the OLS regressions (2008-2020, the logistics sector, ( $p < 0.05$ ))*

Country	Sector	Dependent variable	Independent variable	Coefficient	Std. error	p-value	R <sup>2</sup>
Poland	Logistic	S	Const	0.269	1.937	0.094	0.919
			M <sub>C</sub>	0.515	2.810	0.026	
			S <sub>(t-1)</sub>	0.872	3.363	0.012	
			S <sub>(t-2)</sub>	-0.639	-2.089	0.075	

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, access: 11.11.2023.

Table 5 presents the results of the SUR estimation between explained variables (the synthetic indicators of the economic, social and environmental development of the logistics sector in Poland from 2008 to 2020) and explanatory variables (the synthetic indicators of the economic, social and environmental development of the logistics sector in Poland from 2008 to 2020, the synthetic indicator of the financial situation, the synthetic indicator of the financial situation ( $t-1$ ) of the logistics sector in Poland from 2008 to 2020, the synthetic indicator of macroeconomic conditions, the synthetic indicator of macroeconomic conditions ( $t-1$ ) in Poland from 2008 to 2020). Models show different strengths and directions of relationships between variables. The estimation indicates a strong differentiation of the impact of individual variables on the economic, social, and environmental development of the logistics sector in Poland from 2008 to 2020.

**Table 5.**

*The results of SUR regressions (2008-2020, the logistics sector, ( $p < 0.05$ ))*

Country	Sector	Dependent variable	Independent variable	Coefficient	Std. error	p-value	R <sup>2</sup>
Poland	Logistic	E <sub>D</sub>	Const	-0.711	0.056	1.36E-06	0.994
			F <sub>S(t-1)</sub>	-0.382	0.097	0.004	
			S <sub>D</sub>	2.038	0.087	1.19E-08	
			Env <sub>D</sub>	0.159	0.040	0.004	
		S <sub>D</sub>	Const	0.349	0.030	8.65E-06	0.994
			F <sub>S(t-1)</sub>	0.188	0.044	0.004	
			E <sub>D</sub>	0.491	0.021	6.80E-08	
			Env <sub>D</sub>	-0.078	0.022	0.010	
		Env <sub>D</sub>	Const	0.163	0.174	0.377	0.665
			M <sub>C(t-1)</sub>	-0.972	0.427	0.052	
			E <sub>D</sub>	1.002	0.281	0.007	
			S <sub>D</sub>	0.613	0.243	0.036	

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 11.11.2023.

The indicator of economic development is influenced by the indicator of the financial situation ( $t-1$ ), the social development and environmental development of the logistics sector in Poland from 2008 to 2020 (the highest is between economic development and social development). The indicator of social development is influenced by the indicator of the financial situation ( $t-1$ ), the economic development and the environmental development of the logistics sector in Poland from 2008 to 2020 (the highest is between the social development and the economic development). The indicator of environmental development is influenced by the indicator of the macroeconomic conditions in Poland from 2008 to 2020, the economic development and social development of the logistics sector in Poland from 2008 to 2020 (the highest is between the environmental development and the economic development). The coefficient determination ranges from 0.665 (a satisfying fit of the data in the model) to 0.994 (a very good fit of the data in the model).

## 7. Discussion

The sustainable development of the logistics sector is important for Poland's stable and sustainable development; this is because this sector is important for developing other sectors and industries efficiently (Comporek et al., 2022; Martišius et al., 2022). Implementing the principle of sustainable development in logistics is important not only from the point of view of environmental protection but also for stable economic and social development (Jacyna et al., 2014; Brdulak et al., 2021; Przybylska et al., 2023).

The research results indicate that the central research hypothesis is true because macroeconomic conditions have a statistically significant impact on the sustainable development of logistics enterprises in Poland from 2008 to 2020. The OLS estimation results also indicate that the sustainable development of logistics is continuous, which means that the results obtained in previous periods impact current results.

Moreover, we did not record a statistically significant impact of the financial situation on the sustainable development of logistics enterprises. Therefore, this sector depends primarily on macroeconomic conditions and the situation in other sectors of the economy. The results thus confirm the results obtained by other researchers, indicating a positive relationship between macroeconomic conditions and the sustainable development of logistics (Czyżewski, 2017; Haldar, 2019; Comporek et al., 2022).

The first research sub-hypothesis is correct because, from 2008-2020, the sustainable development of logistics has a positive trend, which should be assessed positively, although it should be noted that the dynamics of development are low.

The second research hypothesis is true because the dynamics of economic development are higher compared to the dynamics of social and environmental development. Therefore, it should be noted that the logistics sector still prioritizes maximizing profits. Environmental development has the lowest growth dynamics. Therefore, it is necessary to implement new EU directives regarding environmental regulations and further reduce the sector's emission intensity.

The third sub-hypothesis is also true because the impact of macroeconomic conditions and the financial situation differ on the individual pillars of sustainable development. Therefore, economic, social and environmental development depends on financial and macroeconomic issues.

Sustainable development of enterprises requires analysis of macroeconomic conditions, ensuring correct balance sheet relations, and maintaining financial balance, which is crucial for stable operation and development.

The analysis has limitations related to the availability of data, the choice of normalization method and the choice of estimation method for both the one-equation model and the structural equation model.

## **8. Conclusion**

The sustainable development of logistics enterprises is important for sustainable socio-economic development and the protection of the natural environment in Poland. From the financial crisis to the COVID-19 pandemic, the dynamics of sustainable development and its economic, social and environmental pillars are positive, which should be assessed positively.

The OLS estimation results indicated that macroeconomic conditions determine sustainable development. In turn, economic and social development, following the SUR estimation, is influenced by the financial situation and environmental development by macroeconomic conditions.

The results indicate that managers of business entities should analyze both macroeconomic conditions and the financial and property situation of business entities on an ongoing basis.

Our further research will be devoted to analyzing the logistics sector in European Union countries. Our goal will be to identify a group of endo and exogenous factors important for the sector's sustainable development.

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## THE SUSTAINABLE DEVELOPMENT OF THE LOGISTICS SECTOR IN THE LARGEST EU ECONOMIES – COMPARATIVE ANALYSIS

Magdalena KOWALSKA<sup>1</sup>, Anna MISZTAL<sup>2</sup>, Agata GNIADKOWSKA-SZYMAŃSKA<sup>3\*</sup>

<sup>1</sup> Faculty of Economics and Sociology, University of Lodz; magdalena.kowalska@uni.lodz.pl,  
ORCID:0000-0002-5821-0305

<sup>2</sup> Faculty of Economics and Sociology, University of Lodz; anna.misztal@uni.lodz.pl,  
ORCID: 0000-0002-7455-5290

<sup>3</sup> Faculty of Economics and Sociology, University of Lodz; agata.gniadkowska@uni.lodz.pl,  
ORCID: 0000-0002-7321-3360

\* Correspondence author

**Purpose:** The main aim of this paper is to assess the level and dynamics of sustainable development of the logistics sector in the ten largest economies of the European Union from 2008 to 2020.

**Design/methodology/approach:** We normalize diagnostic variables into synthetic indicators to verify the hypothesis. We created a synthetic sustainable development index and indicators describing its economic, social, and environmental pillars.

**Findings:** The results indicate a positive trend in the sustainable development of the logistics sector in the largest EU economies from 2008 to 2020. Moreover, in most cases, countries with a higher GDP level also have a higher level of sustainable logistics development.

**Research limitations/implications:** The availability of data, the choice of normalization method and the choice of research sample.

**Practical implications:** Managing the sustainable development of enterprises takes place and requires analyzing the external situation, including macroeconomic conditions.

**Social implications:** The social development of the logistics sector is visible, and it is necessary to take further actions to improve working conditions and quality.

**Originality/value:** The novelty in the paper is the creation of sustainable development indicators. The paper addresses many recipients interested in developing the logistics sector.

**Keywords:** sustainable development, logistics sector, EU economies.

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

## 1. Introduction

Implementing the concept of sustainable development requires the participation of states, international institutions and organizations as well as whole communities (Bose, Khan, 2022; Szychta, 2022). A special place is occupied by enterprises that are widely recognized as the entities that have contributed the most to environmental degradation (Brzezinski, Pyza, 2021; D'Angelo et al., 2022). Therefore, it is necessary for them to take active measures to combat climate change and protect natural resources (Pishdar et al., 2022; Keshavarz-Ghorabae et al., 2022). However, current scientific research does not show a statistically significant impact of the implementation of an ESG strategy by a company on its market performance (Naffa, Fain, 2021). The literature has repeatedly examined the impact of implementing an ESG strategy on the value and growth potential of a company (Hong, Kacperczyk, 2009; Liston, Soydemir 2010) and, as summarized by Cunha et al. (2021) and Kumar et al. (2022), the nature of this compound is not homogeneous (Lins et al., 2017). Yu et al. (2018) and Wong et al. (2021), as one of the reasons for this phenomenon, show external determinants related to the operation of a specific enterprise, i.e., the country in which the company operates or the sector/industry to which it belongs (Adams, Jiang, 2016). The research gaps indicated by Baji and Yurtoglu (2018) emphasize that the analysis of the impact of the assessment of the implementation of the ESG strategy on the value of the company in a group of companies from many countries does not clearly say for which countries such a relationship is statistically significant. Egorova et al. (2022) and Friede et al. (2015) point out that so far no comparison has been made between different company groups or companies from different sectors that would show the relationship with the EGS strategy in these groups.

The main aim of this paper is to assess the level and dynamics of sustainable development of the logistics sector in the ten largest economies of the European Union from 2008 to 2020. We normalize diagnostic variables into synthetic indicators to verify the hypothesis. We created a synthetic sustainable development index and indicators describing its economic, social, and environmental pillars.

The study includes an introduction, literature review, research methodology, results, discussion, and conclusion. The review of scientific publications was based on the Scopus and Web of Science lists. The data for the analysis come from Eurostat databases.

Managing the sustainable development of enterprises takes place and requires analyzing the external situation, including macroeconomic conditions. The social development of the logistics sector is visible, and it is necessary to take further actions to improve working conditions and quality. The novelty in the paper is the creation of sustainable development indicators. The paper addresses many recipients interested in developing the logistics sector.

## 2. Sustainable development of enterprises

Sustainability in business refers to a company's strategy to reduce the negative environmental impact resulting from its operations in a particular market. An organisation's sustainability practices are typically analysed against environmental, social, and governance (ESG) metrics. Sustainable enterprise development is a multifaceted concept that involves integrating environmental, social, and economic considerations into business strategies to create long-term value while minimising negative impacts (Pererva et al., 2021; Ghauri, 2022; Diaz- Sarachaga, 2021). Here are key aspects and practices associated with the sustainable development of enterprises:

- Environmental sustainability - efficient use of resources, reduction of waste, and sustainable sourcing of materials; implementation of energy-saving practices and the adoption of renewable energy sources; strategies to minimize greenhouse gas emissions and contribute to climate change mitigation; Embracing circular economy principles, such as recycling, reuse, and reducing (Sribna et al., 2023; Hysa, 2020).
- Social Responsibility - ensuring fair wages, safe working conditions, and respecting workers' rights; promoting diversity within the workforce and fostering an inclusive workplace culture; Engaging with local communities, understanding their needs, and contributing positively to community development; Upholding human rights principles throughout the supply chain (Anh et al., 2022; Sribna et al., 2023).
- Economic viability - taking a long-term approach to business decisions rather than focussing solely on short-term profits; Embracing innovation to improve efficiency, create new products, and adapt to changing market conditions; Maintaining sound financial practices to ensure the company's resilience in the face of economic challenges (Mio et al., 2020; Teixeira et al., 2019).
- Transparency and Accountability - Provide transparent and comprehensive reporting on environmental, social, and governance (ESG) performance; Establishing mechanisms to ensure accountability for sustainable practices and continuous improvement (Hanaysha et al., 2022; Chege et al., 2020).
- Stakeholder Engagement - Working collaboratively with various stakeholders, including customers, suppliers, investors, and local communities; Actively seeking and considering the input of stakeholders in decision-making processes.
- Green Innovation and Technology - developing and promoting environmentally friendly products and services; Incorporating technologies that contribute to sustainability goals (Wojewnik-Filipkowska et al., 2019).
- Regulatory Compliance and Standards - ensuring compliance with environmental and social regulations in all areas of operation; Adhering to and, where possible, influencing industry standards that promote sustainability (Lu et al., 2019; Fotaki et al., 2020).

By incorporating these principles into their operations, companies can contribute to a more sustainable future, align with evolving social expectations, and build resilience in the face of global challenges. Sustainable development is not only a responsibility but also a source of innovation and competitive advantage in today's business landscape (Vuković et al., 2022; Jacyna et al., 2014; Przybylska et al., 2023).

Measurement of sustainable development poses several challenges due to the complex and multidimensional nature of the concept. There is no universally accepted definition or set of indicators for sustainable development (Brugmann, 2021). Different organisations, countries, and industries may use varying frameworks, making it challenging to compare and benchmark progress. Sustainable development encompasses economic, social, and environmental dimensions. Measuring progress in each of these areas and finding indicators that adequately capture their interactions is complex. Balancing and weighting these dimensions can be subjective. The benefits or negative impacts of sustainable practices may not be immediately evident. Long-term effects, especially in environmental sustainability, can take years or decades to manifest, making it difficult to assess the immediate success of sustainability initiatives (Miola et al., 2019; Hickel, 2020). Reliable and consistent data can be scarce on all dimensions of sustainable development. In some cases, the data may be incomplete, outdated, or difficult to obtain, hindering accurate assessments (Nilashi et al., 2023). The challenges and priorities vary significantly between regions and communities. Applying a uniform set of indicators may not capture the specific needs and nuances of different contexts. Stakeholders may have different views on what constitutes sustainable development. Perceptions of sustainability can vary between businesses, governments, NGOs, and the public, leading to subjective interpretations of progress (Attanasio et al., 2022; Gericke et al., 2019). Creating progress in one dimension of sustainability can have unintended consequences in another. For example, economic growth might lead to increased environmental impact. Balancing trade-offs and understanding complex interactions is challenging (van der Bom et al., 2020). Pressures for short-term results can conflict with the long-term nature of sustainable development. Companies may prioritise immediate economic gains over longer-term environmental or social benefits (Bandari et al., 2022). Inconsistent or evolving regulatory frameworks can impact measurement approaches. Changes in government policies or international agreements may influence the relevance and applicability of specific sustainability indicators (Glass et al., 2019; Breuer et al. 2019). Some organisations may engage in "greenwashing", where they present themselves as more sustainable than they actually are. This can mislead stakeholders and make it difficult to assess the true impact of sustainability efforts. Addressing these challenges requires ongoing collaboration among stakeholders, the development of standardised and universally accepted measurement frameworks, improved data collection and reporting mechanisms, and a commitment to transparency and accountability in sustainable development initiatives (Pizzetti et al., 2021; Kurpierz et al., 2020; Yang et al., 2020).

### **3. Sustainable development of enterprises in the countries TLS sector in the analysed**

The logistics sector plays a crucial role in the movement of goods and services throughout the supply chain. It encompasses various activities involved in planning, implementation, and control of the efficient and effective flow of goods, services, and information from the point of origin to the point of consumption. The logistics sector is dynamic and continually evolving, influenced by technological advancements, globalisation, and changing consumer expectations. Effective logistics management is essential for businesses to enhance competitiveness, reduce costs, and meet customer demands in an ever-changing market (Camporek et al., 2022; Danilevičius et al., 2023; Martišius et al., 2022).

The relationship between regional development and the logistics sector is crucial to fostering economic growth, improving connectivity, and improving overall efficiency in a given geographical area. Here are key points that highlight the connection between regional development and the logistics sector:

1. The logistics sector is heavily dependent on well-developed infrastructure, including roads, railways, airports, and seaports. Investment in logistics infrastructure is essential for improving connectivity within a region, facilitating the movement of goods, and supporting economic activities. This is especially visible in highly developed countries such as Germany, France, and Sweden (Vanpetch et al., 2020; Rodrigue et al., 2010; Kennedy et al., 2005).
2. A robust logistics sector facilitates trade by providing efficient transport and distribution networks. Regions with a well-connected logistics infrastructure are more attractive to businesses engaged in import and export activities, contributing to regional economic development. Furthermore, Central European countries (Poland, Austria) invest in their transport infrastructure to support the sector's expansion, making it an attractive destination for logistics companies and a critical gateway for goods in Europe (Brdulak et al., 2021; Camporek et al., 2021).
3. The logistics sector creates employment opportunities in areas such as transportation, warehousing, and distribution. A thriving logistics industry can contribute to the creation and skill development in the region (Chhetri et al., 2014). The logistics sector also plays a significant role in terms of the number of employees: In developed economies it is approximately 5-10% of all employees. The report "Logistics - Global HR Trends" by Gi Group Holding shows that the number of employees in the logistics sector is 17.8 million in China and 4.8 million in Brazil. Germany is the leader in Europe, with 1.8 million people working in logistics, followed by Great Britain (1.6 million), Italy (1.4 million) and Poland (1.1 million).

4. Efficient logistics processes contribute to a smooth and reliable supply chain. This, in turn, enhances the competitiveness of businesses within the region, attracting investment and promoting economic growth (Shahbaz et al., 2019; Illahi et al., 2021). In 2019, transport services contributed around 5% of the gross value added of the EU and 5.4% of all jobs. In 2019, the transport of goods in the EU-27 amounted to 3392 billion tkm, of which 52% was carried out by road (Statistical pocketbook, 2021).
5. The rise of e-Commerce has heightened the importance of efficient logistics networks. Regions with advanced last-mile delivery systems and well-connected transportation networks are better positioned to support the growth of online retail and contribute to the development of the local economy (Zennaro et al., 2022; Kalkha et al., 2023). At the end of 2022, the European logistics services market working for online trade was worth more than EUR 81.6 billion, of which domestic services are valued at more than PLN 69.9 billion, which constitutes 85.6% of the sector's value. Cross-border services accounted for the rest, i.e. PLN 11.7 billion. In a more balanced proportion, approximately 43 billion to approximately EUR 38.6 billion euros (52.7% to 47.3%), last-mile transport services remain compared to warehouse services (fulfilment). However, the value of individual markets in Europe differs significantly. Great Britain has clearly outperformed the rest of the countries (23.9 billion); much further behind are Germany (16.5 billion), France (12.1 billion), Spain (4.3 billion), Italy (3.6 billion), the Netherlands (2.8 billion) and Switzerland (2.1 billion). The Polish market, worth EUR 2.139 billion, ranks eighth in Europe. Behind us are Sweden (2 billion), Turkey (1.9 billion) and in 11th place Austria with a logistics sector worth nearly EUR 1.3 billion (Statistical release: BIS international banking statistics and global liquidity indicators at end-December 2022).
6. Logistics considerations play a role in spatial planning and urban development. Well-planned logistics infrastructure can guide the growth of urban areas and industrial zones, contributing to sustainable development. The first to pay attention to this aspect were the Germans, Italians, Dutch, and Belgians. The investments were individual in nature, but their success was determined by the participation of the public sector, which was not only actively involved in individual projects but was also often their initiator. The active attitude of the public sector consisted in the economic activation of selected regions and then in the creation of consortiums that initiated the construction of logistics centres and participated in companies implementing investments (Pultrone, 2021; Margherita et al., 2023; Alpkokin, 2012).
7. Integration of technology in logistics, such as GPS tracking, warehouse automation, and data analytics, can improve efficiency and reduce costs. Regions that adopt innovative logistics solutions are likely to attract businesses seeking modern and streamlined supply chain processes (Mathauer et al., 2019; Vilas-Boas et al., 2023).

8. Sustainable logistics practices, including green transportation and eco-friendly packaging, contribute to environmental conservation. Regions that promote sustainable logistics align with global trends and can attract environmentally conscious businesses (Munuhwa, 2023; Karaman et al., 2020). The European Union is a leader in the fight against climate change and wants to achieve complete climate neutrality by 2050. Malta, Luxembourg, Lithuania, Romania, and Italy are the countries with the highest dynamics of green economy development in 2011-2019. Poland ranks in the second half of the ranking (18th out of 27 countries). The so-called countries were characterised by a higher rate of green economy development. the "new" EU than the countries of the "old" EU (8th Cohesion Report: Cohesion in Europe towards 2050).

In summary, the logistics sector plays an important role in regional development by facilitating trade, improving connectivity, creating employment opportunities, and improving overall economic efficiency. A strategic focus on the development and optimisation of the logistics infrastructure is essential to promote sustainable regional development (Twrdy et al., 2020; Surya et al., 2021; Hernita et al., 2021)

The Global Logistics Industry includes all activities of the supply chain such as transportation, customer service, inventory management, information flow, and order processing. Other activities of the supply chain include warehousing, material handling, purchasing, packaging, information dissemination, and maintenance, among others (Adeitan et al., 2020). The logistics market in terms of revenue was valued at US\$ 8185.46 billion in 2015 and is expected to reach US \$15 522.02 billion by 2023, growing at a CAGR of 7.5% from 2015 to 2024. The volume market was valued at 54.69 billion tons in 2015 and is expected to reach 92.10 billion tons by 2024 growing at a CAGR of 6% between 2016 to 2024 (Transparency Market Research, 2016).

#### **4. Research methodology**

The research aims to assess the level and dynamics of sustainable development of the logistics sector in the ten largest economies of the European Union from 2008 to 2020. We want to show what the situation of logistics companies was like from the financial crisis to the Covid-19 pandemic.

The research sample covers the ten biggest economies in the European Union, including the following countries: Germany, France, Italy, Spain, Netherlands, Poland, Sweden, Belgium, Ireland, and Austria (Table 1).

**Table 1.**

*The GDP and main components in 2020 (output, expenditure and income)*

Germany	France	Italy	Spain	Netherlands	Poland	Sweden	Belgium	Austria	Ireland
3403730	2317832	1661240	1119010	796530	526147,2	480556,4	460747,7	380888,5	375249,6

Source: own study on the basis of Eurostat <https://ec.europa.eu/eurostat/>, 19.11.2023.

Due to our research goal, we have proposed the following hypothesis: “The dynamics of sustainable development of the logistics sector is the highest in countries with the highest level of GDP from 2008 to 2020”. This approach results from the fact that the logistics sector is largely dependent on macroeconomic conditions.

Additionally, we formulated the following sub-hypotheses:

- “The three pillars of sustainable development of the logistics sector economic, social and environmental, have a positive trend”;
- “The dynamics of the economic development of the logistics sector is higher than the dynamics of the social and environmental development of this sector”;
- “Sustainable development of logistics in the largest EU economies has positive dynamics”.

To verify our research hypothesis we created the synthetic indicators of sustainable development (S) based on its three pillars:

- economic (E<sub>D</sub>), including following stimulants: transport enterprises- number, turnover or gross premiums, production value, value added at factor cost, gross operating surplus, total purchases of goods and services, gross investment in tangible goods, investment rate;
- social (S<sub>D</sub>): stimulants: wages and salaries, social security costs, employee- number, turnover per person employed, apparent labour productivity, gross value added per employee, growth rate of employment, investment per person employed and destimulants: personnel costs - million euro, share of personnel costs in production – percentage;
- environmental development (Env<sub>D</sub>), based on destimulants: carbon dioxide, methane, nitrous oxide, sulphur oxides (SO<sub>2</sub> equivalent), ammonia (SO<sub>2</sub> equivalent);

Sustainable development indicators were determined by the variable standardization method based on the following formula:

- for the stimulants:

$$Z_{ij} = \frac{x_{ij}}{\max x_{ij}}, \quad Z_{ij} \in [0; 1] \quad (1)$$

- for the destimulants:

$$Z_{ij} = \frac{\min x_{ij}}{x_{ij}}, \quad Z_{ij} \in [0; 1] \quad (2)$$

where:

Z<sub>ij</sub> - the normalized value of the j-th variable in the i-th year,

x<sub>ij</sub> is the value of the j-th variable in the i-th year.



To calculate the indicator of sustainable development of the LOGISTICS sector ( $Sus_D$ ) and its components economic ( $E_D$ ), social ( $S_D$ ), and environmental ( $Env_D$ ) we use the formula:

$$Sus_D = \frac{\sum_{j=1}^n (E_{D\ ij} + S_{D\ ij} + Env_{D\ ij})}{n}, S_{D\ ij} \in [0; 1] \quad (3)$$

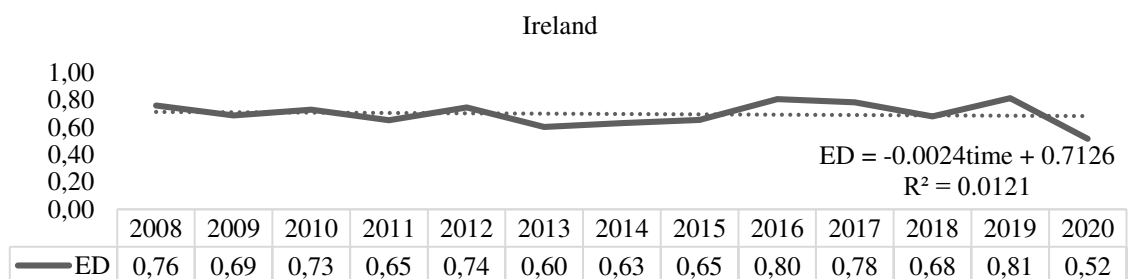
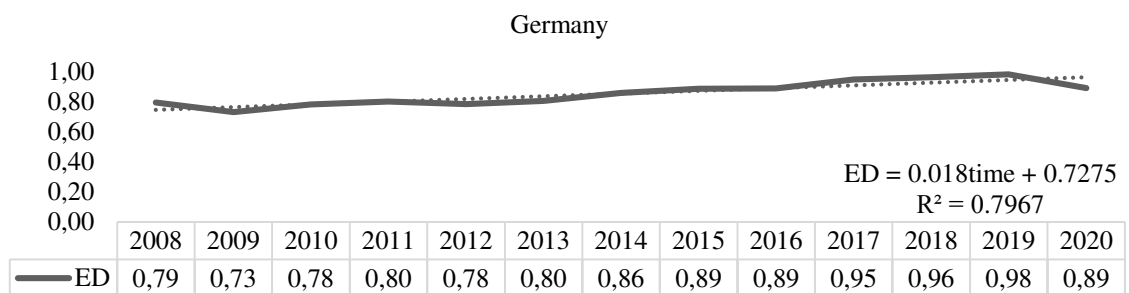
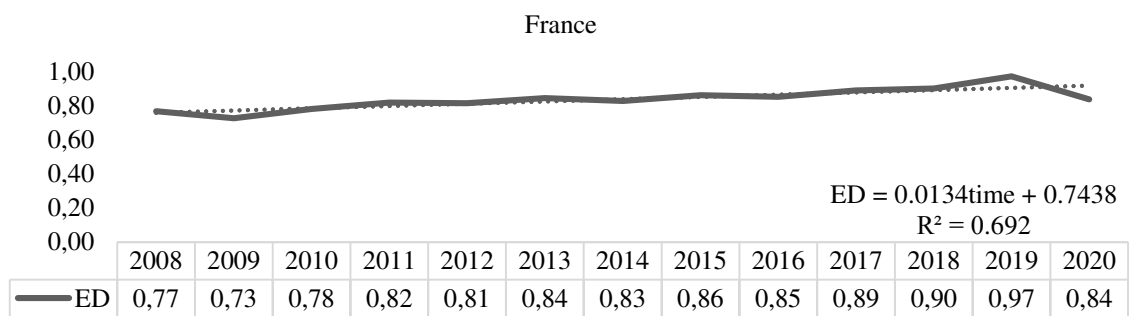
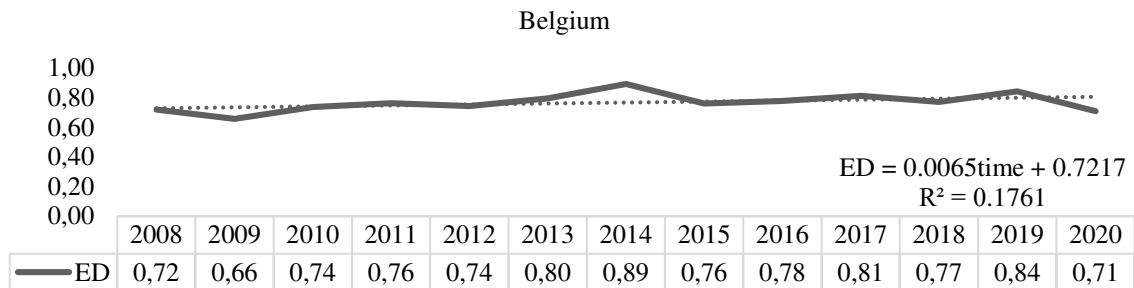
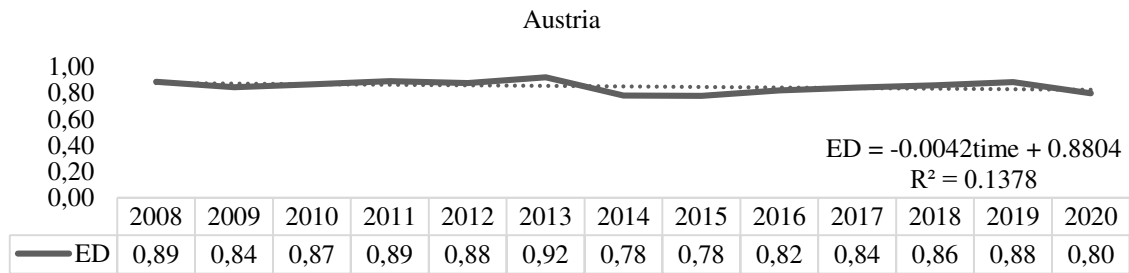
We created a linear equation, which we estimated using the classic least squares method, based on formula:

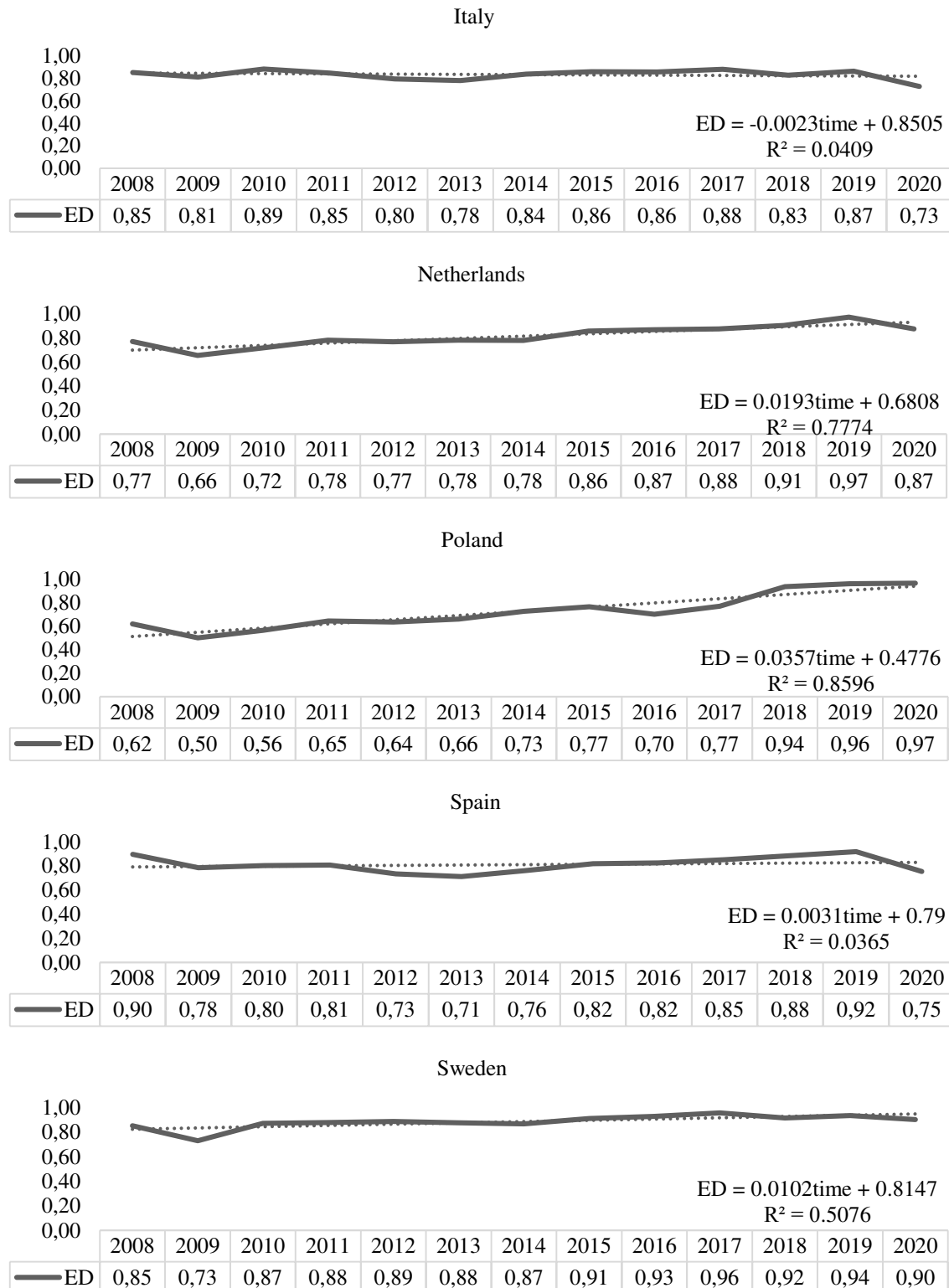
$$\begin{aligned} E_{D\ ij} &= \alpha_0 + \alpha_1 t + \varepsilon_i \\ S_{D\ ij} &= \alpha_0 + \alpha_1 t + \varepsilon_i; \\ Env_{D\ ij} &= \alpha_0 + \alpha_1 t + \varepsilon_i; \\ Sus_{D\ ij} &= \alpha_0 + \alpha_1 t + \varepsilon_i \end{aligned} \quad (4)$$

$$s(\hat{\alpha}_0, \dots, \hat{\alpha}_5) = \sum_{i=1}^n e_i^2 = \sum_{i=1}^n (Sus_{D\ i} - \hat{Sus}_{D\ i})^2 \rightarrow \min \quad \text{where } t\text{-time} \quad (5)$$

## 5. Research results

Figure 1 presents the synthetic indicator of the economic development of the logistics sector in the largest EU economies in the period from 2008 to 2020. The value of indicators in the analyzed period and countries is highly diversified. The indicator shows a positive trend in Belgium, France, Germany, the Netherlands, Poland, Spain and Sweden, which should be assessed as favourable. The enterprises from the logistics sector are highly involved in activities for economic development in these countries. The highest positive dynamics is in Poland ( $E_D = 0.0357 \text{ time} + 0.4776$ ,  $R^2 = 0.8596$ ). The lowest positive dynamics is in Belgium ( $E_D = 0.0065 \text{ time} + 0.7217$ ,  $R^2 = 0.1761$ ). In Austria, Ireland and Italy the indicator shows a negative trend. In these countries, logistics sector enterprises should pay special attention to their economic development. The highest negative dynamics is in Austria ( $E_D = -0.0042 \text{ time} + 0.8804$ ,  $R^2 = 0.1378$ ). The lowest negative dynamics is in Italy ( $E_D = -0.0023 \text{ time} + 0.850$ ,  $R^2 = 0.0409$ ).





**Figure 1.** The synthetic indicator of the economic development in the largest EU economies (2008-2020, the logistics sector).

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 21.11.2023.

Table 1 shows the descriptive statistics of the synthetic indicator of the economic development of the logistics sector in the largest EU economies in the period from 2008 to 2020. In the analyzed countries, the values of descriptive statistics of the indicator vary. The highest average level is in Sweden, 0.89 (SD = 0.05, median = 0.89). The lowest average level is in Ireland, 0.70 (SD = 0.08, median = 0.69). The maximum level is in Germany (0.98; 2019), and the minimum is in Poland (0.50; 2009).

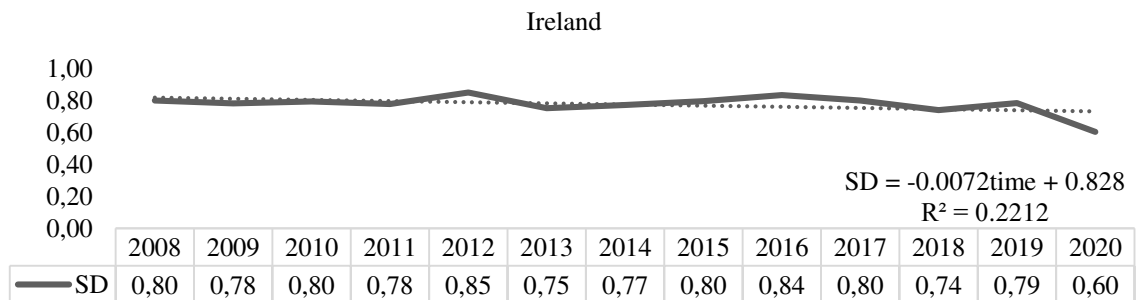
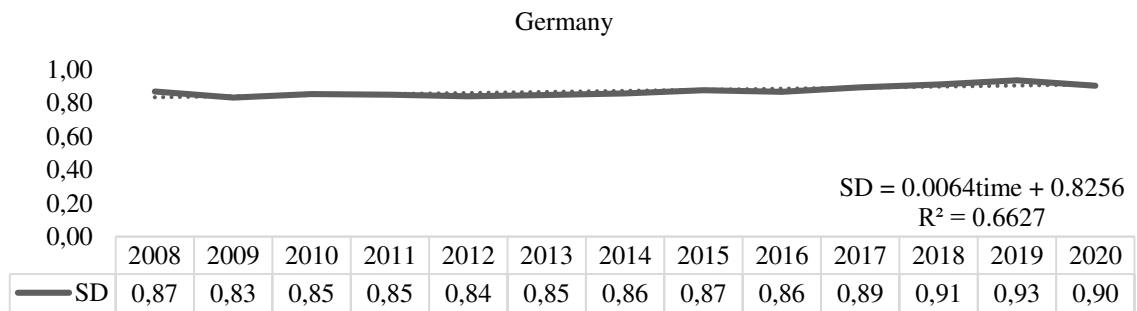
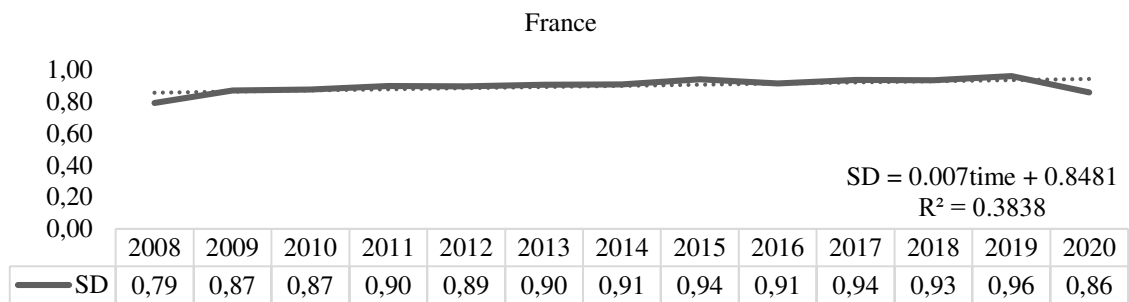
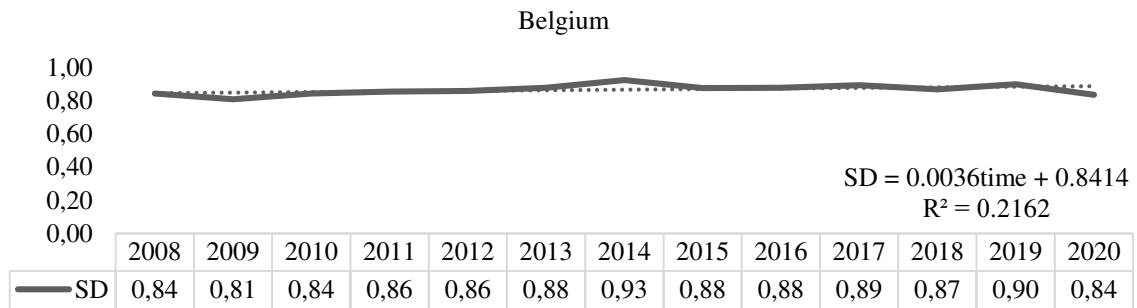
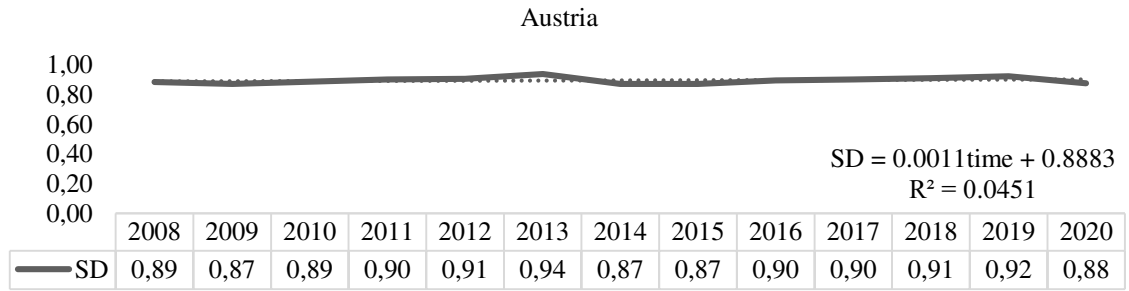
**Table 1.**

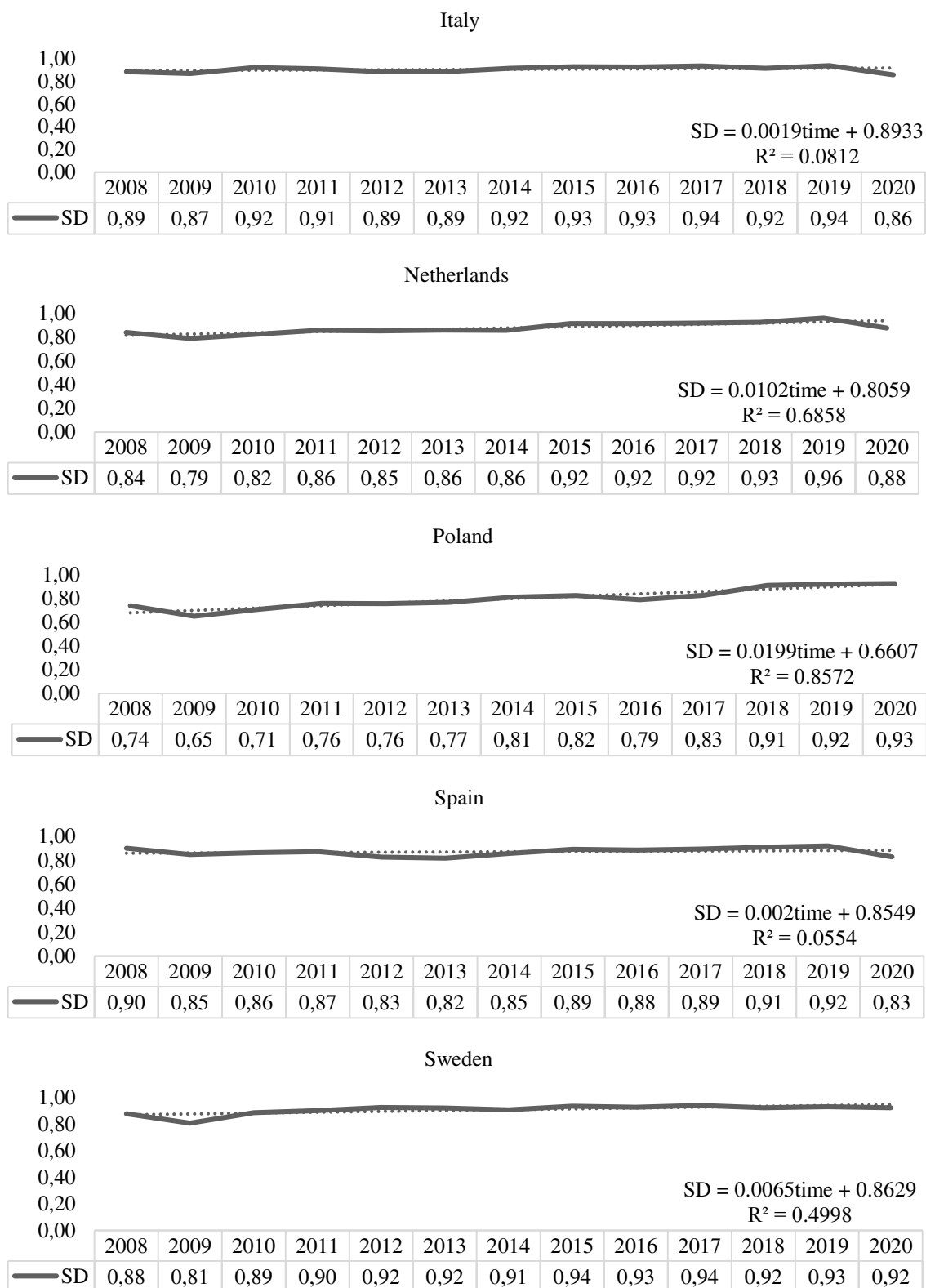
*The descriptive statistics of the synthetic indicator of the economic development in the largest EU economies (2008-2020, the logistics sector)*

Country	Sector	Variable	Mean	SD	Median	Max	Min
Austria	Logistics	E <sub>D</sub>	0.85	0.04	0.86	0.92	0.78
Belgium			0.77	0.06	0.76	0.89	0.66
France			0.84	0.06	0.84	0.97	0.73
Germany			0.85	0.08	0.86	0.98	0.73
Ireland			0.70	0.08	0.69	0.81	0.52
Italy			0.83	0.04	0.85	0.89	0.73
Netherlands			0.82	0.08	0.78	0.97	0.66
Poland			0.73	0.14	0.70	0.97	0.50
Spain			0.81	0.06	0.81	0.92	0.71
Sweden			0.89	0.05	0.89	0.96	0.73

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 21.11.2023.

Figure 2 presents the synthetic indicator of the social development of the logistics sector in the largest EU economies in the period from 2008 to 2020. The value of the indicator varies in the analyzed countries. The indicator shows a positive trend in all countries (except Ireland). It can be concluded that logistics enterprises in the surveyed countries pay special attention to social development, ensuring fair wages, safe working conditions, and respecting workers' rights. The highest positive dynamics is in Poland ( $S_D = 0.0199 \text{ time} + 0.6607$ ,  $R^2 = 0.8572$ ). The lowest positive dynamics is in Austria ( $S_D = 0.0011 \text{ time} + 0.8883$ ,  $R^2 = 0.0451$ ).





**Figure 2.** The synthetic indicator of the social development in the largest EU economies (2008-2020, the logistics sector).

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 21.11.2023.

Table 2 shows the descriptive statistics of the synthetic indicator of the social development of the logistics sector in the largest EU economies in the period from 2008 to 2020. In the analyzed countries, the values of descriptive statistics of the indicator vary. The highest average level is in Italy and Sweden, 0.91 (SD = 0.03, median = 0.92). The lowest average level is in Ireland, 0.78 (SD = 0.06, median = 0.79). The maximum level is in France and the Netherlands (0.96; 2019), and the minimum is in Ireland (0.60; 2020).

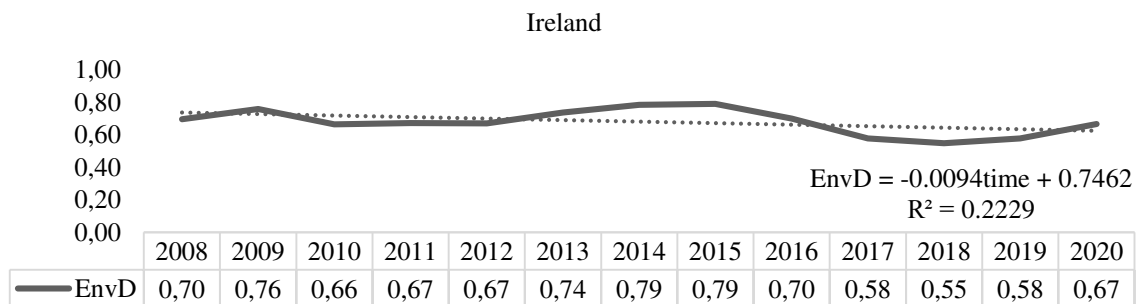
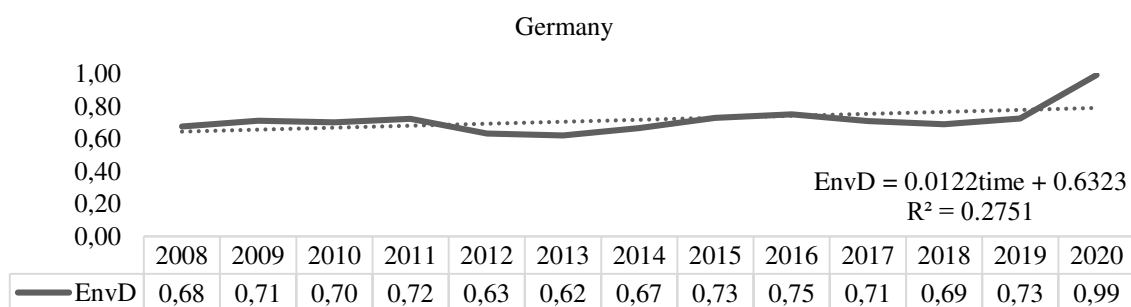
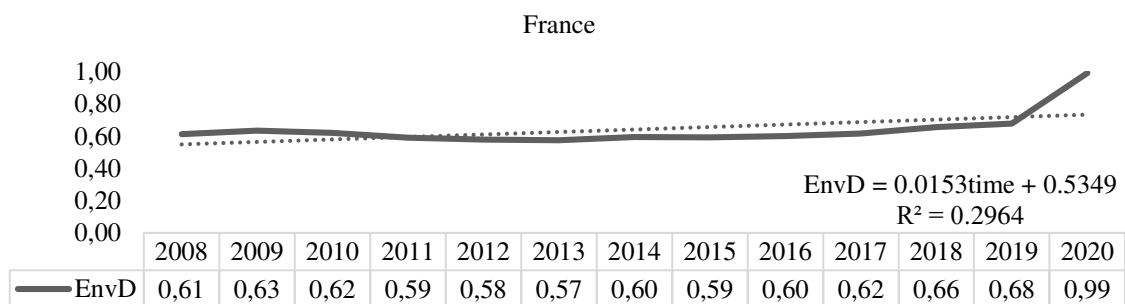
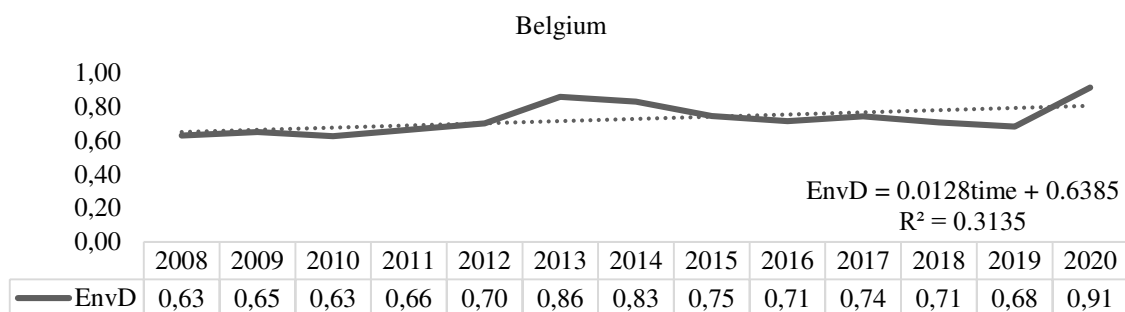
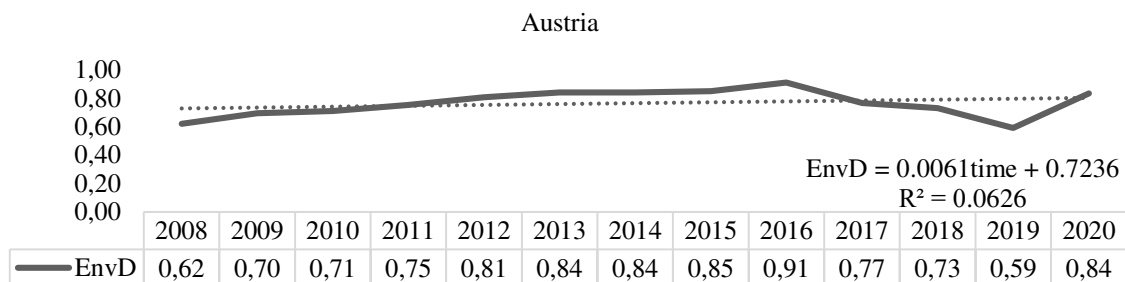
**Table 2.**

*The descriptive statistics of the synthetic indicator of the social development in the largest EU economies (2008-2020, the logistics sector)*

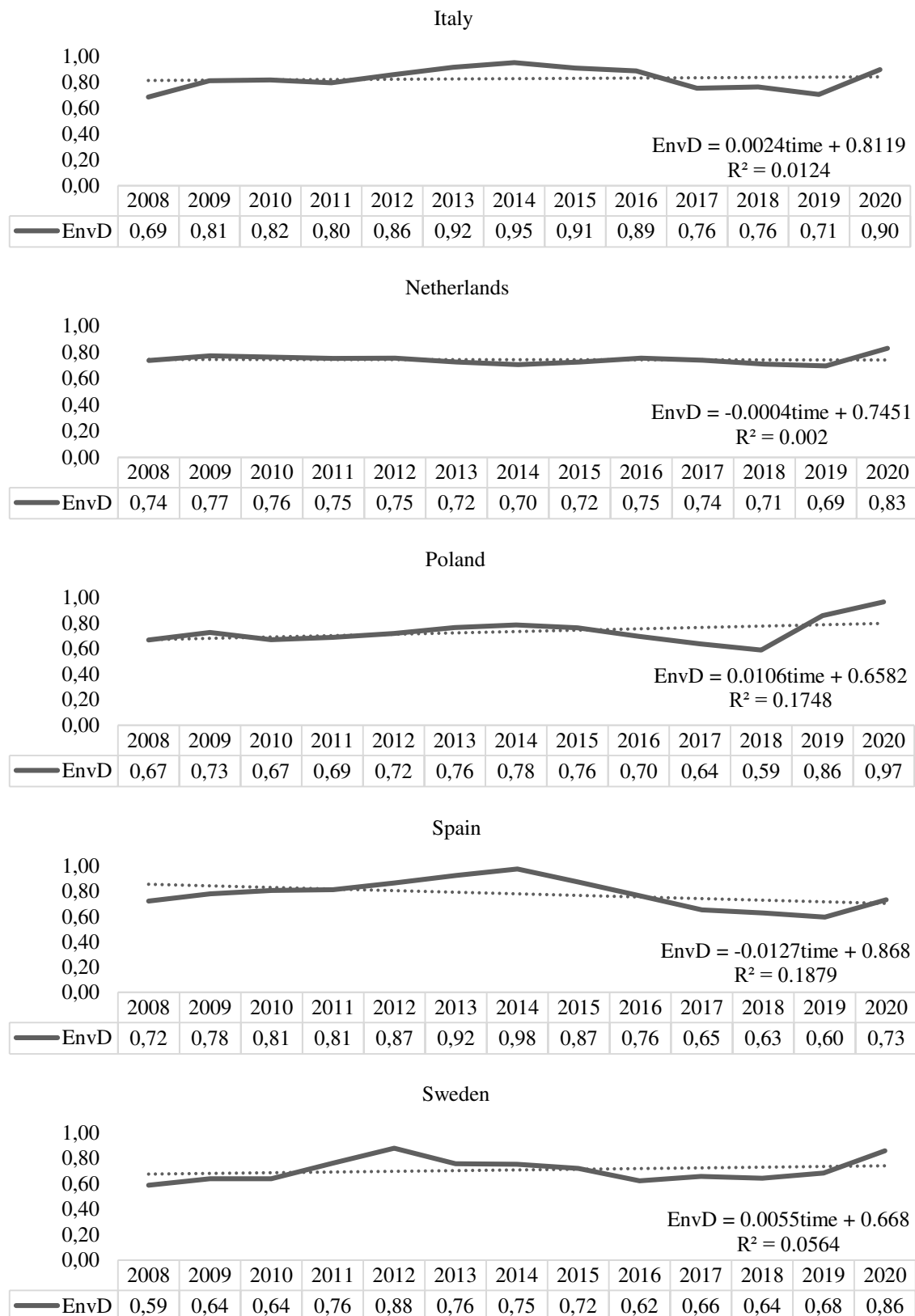
Country	Sector	Variable	Mean	SD	Median	Max	Min
Austria	Logistics	S <sub>D</sub>	0.90	0.02	0.90	0.94	0.87
Belgium			0.87	0.03	0.87	0.93	0.81
France			0.90	0.04	0.90	0.96	0.79
Germany			0.87	0.03	0.86	0.93	0.83
Ireland			0.78	0.06	0.79	0.85	0.60
Italy			0.91	0.03	0.92	0.94	0.86
Netherlands			0.88	0.05	0.86	0.96	0.79
Poland			0.80	0.08	0.79	0.93	0.65
Spain			0.87	0.03	0.87	0.92	0.82
Sweden			0.91	0.03	0.92	0.94	0.81

Source: own study on the basis of Eurostat <https://ec.europa.eu/eurostat>, 21.11.2023.

Figure 3 presents the synthetic indicator of the environmental development of the logistics sector in the largest EU economies in the period from 2008 to 2020. The value of indicators in the analyzed period and countries is highly diversified. The indicator shows a positive trend in Austria, Belgium, France, Germany, Italy, Poland, and Sweden, which should be assessed as very good. The enterprises from the logistics sector are highly involved in activities for environmental development in these countries and pay attention to the implementation of strategies to minimize greenhouse gas emissions, which contributes to climate change mitigation. The highest positive dynamics is in France ( $Env_D = 0.0153 \text{ time} + 0.5349$ ,  $R^2 = 0.2964$ ). The lowest positive dynamics is in Italy ( $Env_D = 0.0024 \text{ time} + 0.8119$ ,  $R^2 = 0.0124$ ). In Ireland, the Netherlands and Spain, the indicator shows a negative trend. In these countries, logistics sector enterprises should pay special attention to activities aimed at protecting the natural environment. The highest negative dynamics is in the Netherlands ( $Env_D = -0.0004 \text{ time} + 0.7451$ ,  $R^2 = 0.002$ ). The lowest negative dynamics is in Spain ( $Env_D = -0.0127 \text{ time} + 0.868$ ,  $R^2 = 0.1879$ ).







**Figure 3.** The synthetic indicator of the environmental development in the largest EU economies (2008-2020, the logistics sector).

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 21.11.2023.

Table 3 shows the descriptive statistics of the synthetic indicator of the environmental development of the logistics sector in the largest EU economies in the period from 2008 to 2020. In the analyzed countries, the values of descriptive statistics of the indicator vary. The highest average level is in Italy, 0.83 (SD = 0.08, median = 0.82). The lowest average level is in France, 0.64 (SD = 0.11, median = 0.61). The maximum level is in France and Germany (0.99; 2020), and the minimum is in Ireland (0.55; 2018).

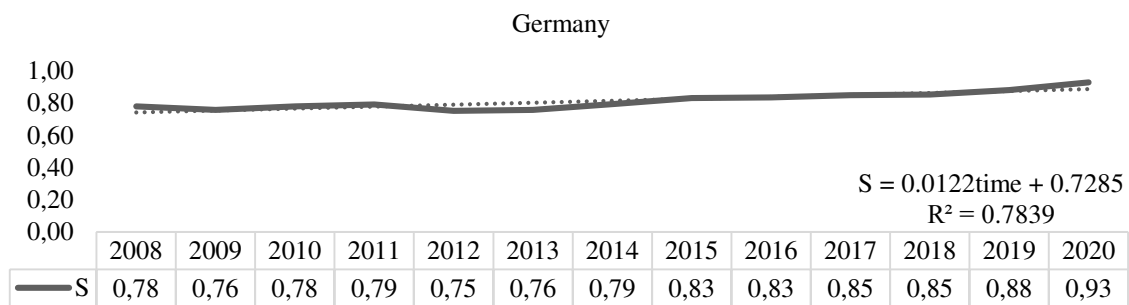
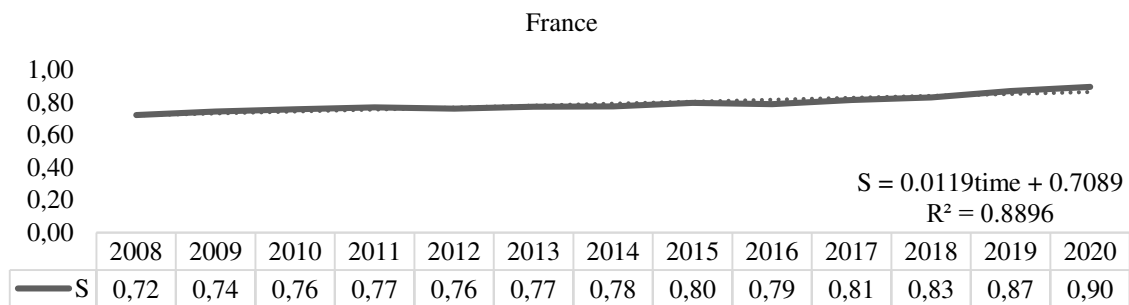
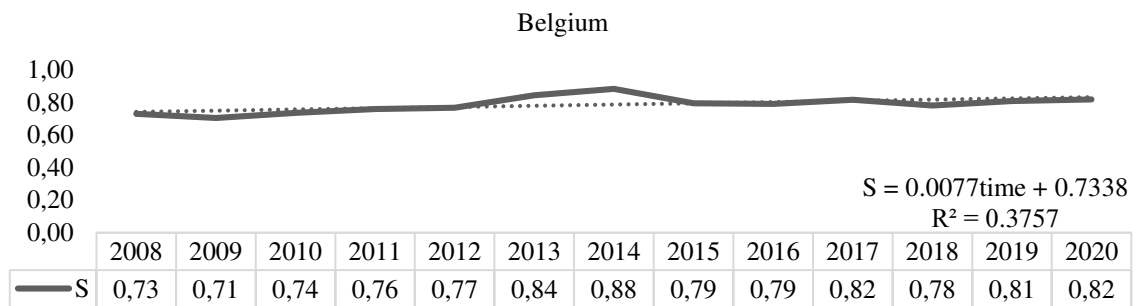
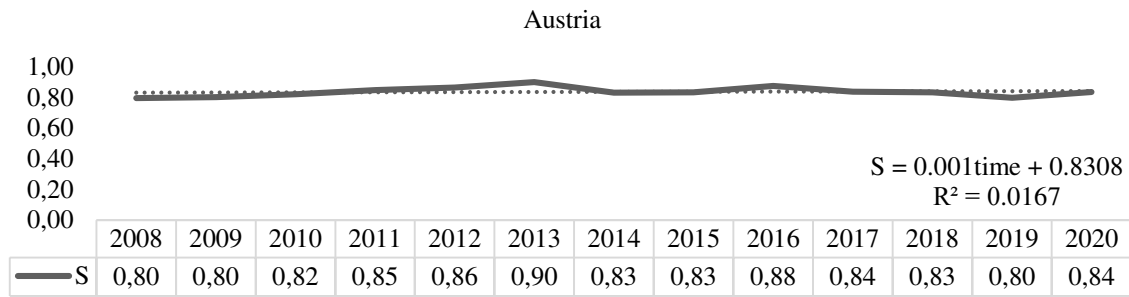
**Table 3.**

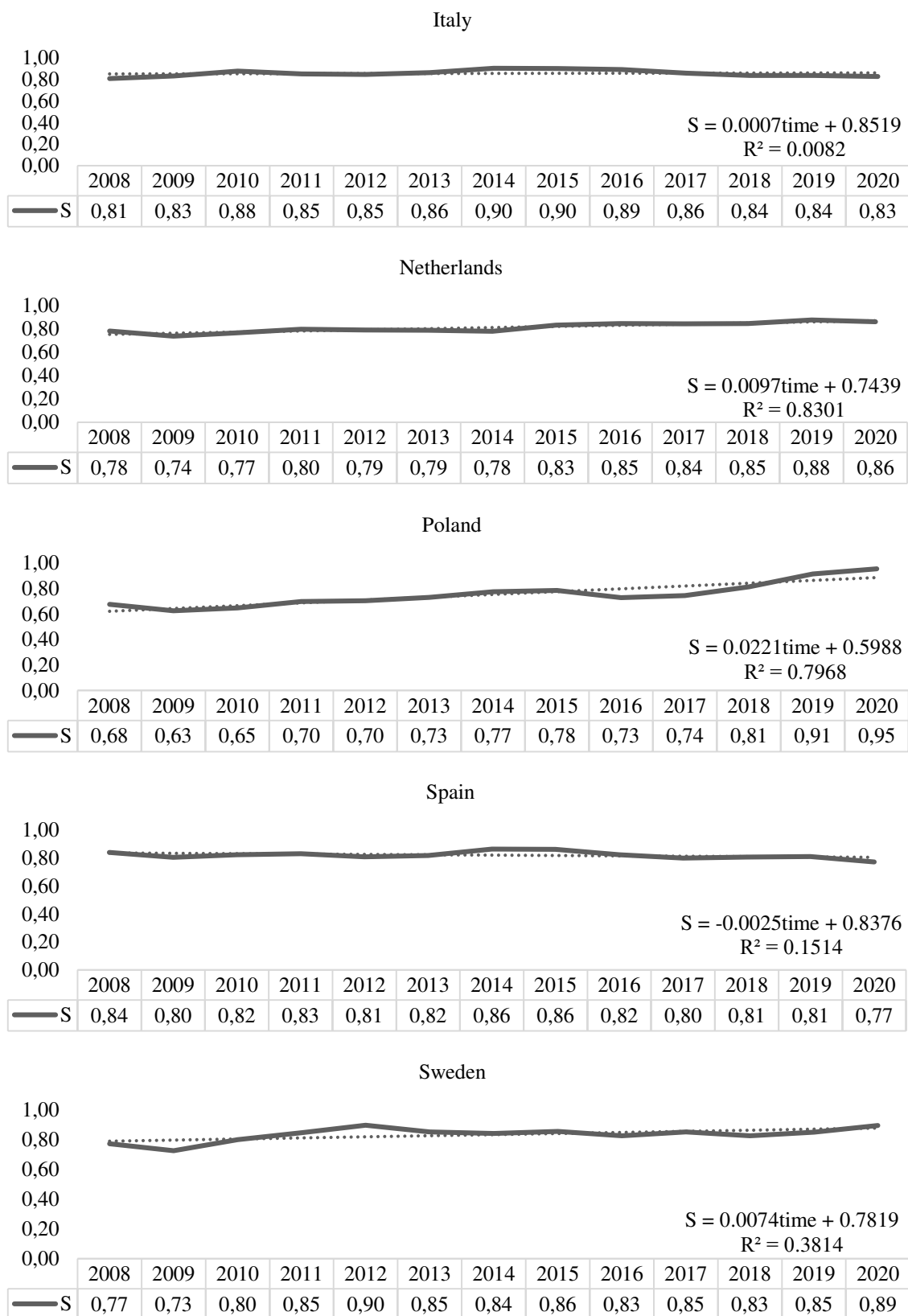
*The descriptive statistics of the synthetic indicator of the environmental development in the largest EU economies (2008-2020, the logistics sector)*

Country	Sector	Variable	Mean	SD	Median	Max	Min
Austria	Logistics	Env <sub>D</sub>	0.77	0.09	0.77	0.91	0.59
Belgium			0.73	0.09	0.71	0.91	0.63
France			0.64	0.11	0.61	0.99	0.57
Germany			0.72	0.09	0.71	0.99	0.62
Ireland			0.68	0.07	0.67	0.79	0.55
Italy			0.83	0.08	0.82	0.95	0.69
Netherlands			0.74	0.03	0.74	0.83	0.69
Poland			0.73	0.09	0.72	0.97	0.59
Spain			0.78	0.11	0.78	0.98	0.60
Sweden			0.71	0.09	0.68	0.88	0.59

Source: own study on the basis of Eurostat <https://ec.europa.eu/eurostat>, 21.11.2023.

Figure 4 presents the synthetic indicator of the sustainable development of the logistics sector in the largest EU economies in the period from 2008 to 2020. The value of the indicator varies in the analyzed countries. The indicator shows a positive trend in Austria, Belgium, France, Germany, Italy, the Netherlands, Poland, and Sweden, which should be assessed well. Logistics sector enterprises in these countries are concentrating on sustainable development from 2008 to 2020. The highest positive dynamics is in Poland ( $S = 0.0221 \text{ time} + 0.5988$ ,  $R^2 = 0.7968$ ). The lowest positive dynamics is in Italy ( $S = 0.0007 \text{ time} + 0.8519$ ,  $R^2 = 0.0082$ ). In Ireland and Spain, the indicator shows a negative trend, which is disturbing. In these countries, logistics sector enterprises should implement actions to improve sustainable development. The highest negative dynamics is in Ireland ( $S = -0.0063 \text{ time} + 0.7623$ ,  $R^2 = 0.2657$ ). The lowest negative dynamics is in Spain ( $S = -0.0025 \text{ time} + 0.8376$ ,  $R^2 = 0.1514$ ).





**Figure 4.** The synthetic indicator of the sustainable development in the largest EU economies (2008-2020, the logistics sector).

Source: own study on the basis of Eurostat <https://ec.europa.eu/Eurostat>, 21.11.2023.

Table 4 shows the descriptive statistics of the synthetic indicator of the sustainable development of the logistics sector in the largest EU economies in the period from 2008 to 2020.

**Table 4.**

*The descriptive statistics of the synthetic indicator of the sustainable development in the largest EU economies (2008-2020, the logistics sector)*

Country	Sector	Variable	Mean	SD	Median	Max	Min
Austria	Logistics	S	0.84	0.03	0.83	0.90	0.80
Belgium			0.79	0.05	0.79	0.88	0.71
France			0.79	0.05	0.78	0.90	0.72
Germany			0.81	0.05	0.79	0.93	0.75
Ireland			0.72	0.05	0.73	0.78	0.60
Italy			0.86	0.03	0.85	0.90	0.81
Netherlands			0.81	0.04	0.80	0.88	0.74
Poland			0.75	0.09	0.73	0.95	0.63
Spain			0.82	0.02	0.82	0.86	0.77
Sweden			0.83	0.04	0.85	0.90	0.73

Source: own study on the basis of Eurostat <https://ec.europa.eu/eurostat>, 21.11.2023.

In the analyzed countries, the values of descriptive statistics of the indicator vary. The highest average level is in Italy, 0.86 (SD = 0.03, median = 0.85). The lowest average level is in Ireland, 0.72 (SD = 0.05, median = 0.73). The maximum level is in Germany (0.93; 2020), and the minimum is in Ireland (0.60; 2020).

## 6. Discussion

The sustainable development of the logistics sector takes place in three pillars: economic, social and environmental (Breuer et al., 2021). Economic development means expanding the economic base, increasing the asset base, and improving the financial and property situation. Social development means improving working conditions and quality. Environmental development means improving eco-innovation and reducing the emission intensity of the sector (Comporek et al., 2022).

The sustainable development of the logistics sector in the ten largest economies in the European Union is diverse, although the vast majority of it has a positive trend, which is a positive phenomenon. It can be seen that in 2020, the level of economic development of the logistics sector decreased slightly, which was caused by the pandemic, but the level of social and environmental development increased. Therefore, it should be noted and agreed with researchers who point out that the pandemic has positively impacted the state of environmental protection (Brdulak, Brdulak, 2021; Comporek et al., 2021; Vilas-Boas et al., 2023; Danilevičius et al., 2023).

The main hypothesis is true because, in the most developed countries, the dynamics of sustainable development are also higher in most of the examined cases. This positive phenomenon proves that the sector is implementing good social changes and cares more about the natural environment.

The first research sub-hypothesis can be accepted because, in most economies, economic development has a positive trend (except Ireland), social development (except Ireland and the Netherlands), and environmental development (the exception is Ireland).

The second research sub-hypothesis should be rejected because only in a few cases is the level of economic development higher than social and environmental development; this could have been determined by the beginning of the COVID-19 pandemic.

The dynamics of sustainable development of the logistics sector are positive in all surveyed countries, which means that the directions of changes in the EU environmental protection policy and the fight for social development are going in the right direction.

The study has several limitations related to selecting analytical variables for the model, the research period and the availability of statistical data.

## **7. Conclusion**

Logistics sustainability has a significant impact on social development and the state of environmental protection in all EU countries. The sustainable development of the logistics sector shows a positive trend from 2008 to 2020. In the case of the pillars of this development, the situation is also similar, although it should be noted that the economic development index in most economies decreased in 2020. Sustainable development of the sector in the most developed economies is more noticeable, and its dynamics are higher.

In our further research, we will focus on a broader assessment of the impact of external and internal conditions on the sustainable development of the logistics sector in all economies of the European Union. We want to conduct a comparative analysis of highly developed and developing economies in the European Union.

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## SUSTAINABLE DEVELOPMENT AND SOCIAL ENTERPRISES: A BIBLIOMETRIC ANALYSIS

Łukasz Jarosław KOZAR

University of Lodz, Faculty of Economics and Sociology; lukasz.kozar@uni.lodz.pl,  
ORCID: 0000-0002-8426-8471

**Purpose:** The aim of the article is to identify the key research areas addressed in scientific discussions simultaneously addressing the issues of social enterprises and sustainable development.

**Design/methodology/approach:** To achieve the declared research aim, a structured literature review method was used to explore the Scopus database. As a result, through a Q1 query, 531 unique scientific papers from the period 2000-2022 were generated for bibliometric analysis in the VOSviewer software. The discussion was additionally supported by conclusions drawn from a classic literature review within the scientific papers identified for this study.

**Findings:** Social enterprises, like other business entities operating in the market, face the need to implement solutions aimed at sustainable development in their operations. Hence, the question of how such specific enterprises should implement the ideas of sustainable development while maintaining the continuity of their social mission, which is the process of inclusion of socially and professionally excluded people, is increasingly raised in the literature. The indicated analyses showed that the issue of social enterprises is discussed in the context of numerous areas related to the issue of sustainable development. In terms of these areas, a special place is given to the role of social enterprises in the process of striving to achieve certain sustainable development goals, or the issue of sustainable entrepreneurship. Based on the latter area, more and more researchers of the subject distinguish two new categories of social enterprises which are sustainable social enterprises and green social enterprises.

**Research limitations/implications:** The analyses were limited to the Scopus database. The Q1 query used is, however, of universal character, which means that it can be used in the scope of other databases after possible changes in the form of valid queries (primarily, after adjusting the characters formulating the query). The results obtained based on other bibliometric databases, despite the identical query, may be different, which is due to the issue of indexing individual scientific journals in them. Hence, the results obtained may be a source for other researchers to compare the research results obtained by them on an identical or similar bibliometric query.

**Practical implications:** The ongoing transformation of social enterprises under the impact of the idea of sustainable development is already being observed. This process is an inevitable direction for the development of social enterprises and, at the same time, may involve additional costs (depending, among other things, on the size and type of activities carried out by individual social enterprises), of which those managing these entities should be aware. Hence, already now those responsible for managing social enterprises should initiate changes in this direction,

which should take place gradually, so that this kind of transformation does not take place at the cost of the social services provided.

**Originality/value:** The article presents the results of the bibliometric analyses undertaken. Based on the author's keywords, the key research areas addressed in the analyzed scientific publications dealing simultaneously with the issues of social enterprises and sustainable development are indicated. Using overlay visualization, the change in interest over time in particular research areas in the context of the discussed issues from the researchers was highlighted. The performed classical literature review in terms of the author's keywords used, in turn, showed that one of the future directions of research in the context of transformation under the influence of the idea of sustainable development of social enterprises is the issue of the process of greening of such entities. The indicated observed direction of research, in the author's opinion, will play an increasingly important place in the literature on the subject. As a result, researchers will increasingly pay attention to at least the issue of green social enterprises. The article is addressed to all those interested in the issues of social enterprises and their gradual transformation under the influence of the idea of sustainable development.

**Keywords:** green jobs, green labor market, green social enterprise, social enterprise, sustainable development.

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

## 1. Introduction

Sustainable development is a very important and multidimensional direction of scientific considerations today. This concept is discussed, among other things, through the prism of solutions implemented in various sectors of the economy under the influence of the idea of sustainable development (e.g. Garetti, Taisch, 2012; Liu et al., 2023; Pouresmaieli et al., 2023), the set goals of sustainable development (e.g. Azmat et al., 2023; Heras-Saizarbitoria et al., 2022; Sinha et al., 2020), the development of various types of innovative solutions (e.g. Gibellato et al., 2021; Lorne, 2009; Ottosson et al., 2017), the adopted business models aimed at sustainable development (Bocken et al., 2014; Broccardo et al., 2023), or from the point of view of the functioning of various types of entities in the market and their interaction with stakeholders (Kozar, 2019; Presnyakova, Khryuchkina, 2020). The result of the scientific research undertaken in this area, as noted by the author of this article, is an increasing number of scientific studies that are aimed at indicating how the implementation of the idea of sustainable development in business entities contributes to the ongoing process of transformation of the economy towards sustainable development. Some of such scientific studies are based on the analysis of case studies (e.g. Evans et al., 2007; Hannah et al., 2023; Weissbrod, Bocken, 2017). It is then possible to observe a discourse on the implemented solutions, which are aimed at increasing resource efficiency, reducing the waste generated in the production process, as well as minimizing the emission of greenhouse gases and other types of pollution. Such solutions support the process of greening business entities (Oncioiu et al.,

2019; Shmatko et al., 2021). At the same time, it should be strongly emphasized that such changes implemented in individual business entities can, on a broader scale, lead to a gradual transition from the so-called "brown economy" to a green economy and are therefore aimed at the green transformation of the economy (e.g. Hirose, Matsumura, 2023; Kozar, Sulich, 2023b).

The process of implementing the idea of sustainable development is increasingly discussed by researchers in the context of the operation of social enterprises. Then, in scientific studies, for example, considerations are made on the issue of directing social enterprises on the path of sustainable development in such a way as not to upset the process of implementation by these entities of the adopted social goals (Kozar, 2023). The indicated transformation in the case of this type of entity is not easy, as it should be borne in mind that the purpose of the operation of social enterprises is primarily the implementation of the set social objectives, and not the maximization of the achieved profits. Hence, an important problem becomes how to finance the transformation of social enterprises towards sustainable development. At least some of the pro-environmental changes require significant investment in new equipment, which is characterized, for example, by a higher degree of resource efficiency of the raw materials used in the production process.

The issue of the cost of social enterprises entering the path of sustainable development occupies an important area in the current scientific discourse. However, more and more often from researchers of the subject it is pointed out that this process should be looked at more holistically, since the pace and quality of implemented solutions aimed at sustainable development does not depend solely on the financial capital held, but at least still on the intellectual capital held by the organization, among other things. In previous scientific studies, one can see various types of analyses aimed at discussing issues related to social enterprises in the context of sustainability issues (e.g. Galindo-Martín et al., 2020; Kamaludin, 2023; Kim, Lim, 2017; Picciotti, 2017). Some of this type of consideration is aimed simply at summarizing the current scientific output in this area. These are various types of bibliometric studies aimed at either classical or structured literature reviews (e.g. Diaz Gonzalez, Dentchev, 2021; Jayawardhana et al., 2022; Kah, Akenroye, 2020). These reviews include at least:

- indicating the number of identified scientific papers and their citation rate (especially indicating the most cited scientific publications) (e.g. Hisyam, Lin, 2023; Okano, 2019),
- extracting the key researchers dealing with the studied issues in the context of social enterprises with an indication of their affiliation (e.g. Gonçalves et al., 2016; Granados et al., 2011),
- listing of scientific journals with their ordering in terms of the number of scientific publications on the subject under discussion (e.g. Iswoyo, Narsa, 2023).

In bibliometric analyses of social enterprises, it is still possible to notice a certain lack of in-depth analyses focused on the identification of key research areas through the author's keywords (especially in the context of sustainable development, or the green economy). Attempts to delineate in terms of this type of analysis the future directions of scientific research are increasing, but they still, in the opinion of the author of this article, too narrowly address at least environmental and green issues in the field of social enterprises. Hence, recognizing the indicated research gap, as the aim of the article was set the identification of key research areas addressed in scientific discussions simultaneously addressing the issues of social enterprises and sustainable development. These areas will be identified based on a literature review of the subject with the support of the VOSviewer software (1.6.18 version), which is widely used in scientific research for various types of bibliometric analysis, including around the issue of social enterprises (e.g. Mardiani et al., 2023; Salqaura et al., 2022; Schlosser, Volkova, 2022).

In the article, four interrelated sections have been distinguished. They are oriented to the realization of the assumed purpose of the research. As part of the introduction, the importance of the research problem undertaken is presented. The purpose of the research is also indicated in this section. The second section of the article presents the various stages of the research, along with an indication of the research methods. In turn, the third section presents the results of the analyses obtained in the VOSviewer software in the form of bibliometric maps. A discussion is also conducted here while indicating probable future research directions. In turn, the last section contains a summary of the considerations made. Attention is drawn here, for example, to what methods researchers should use when directing their research toward environmental and green issues in the context of social enterprise issues.

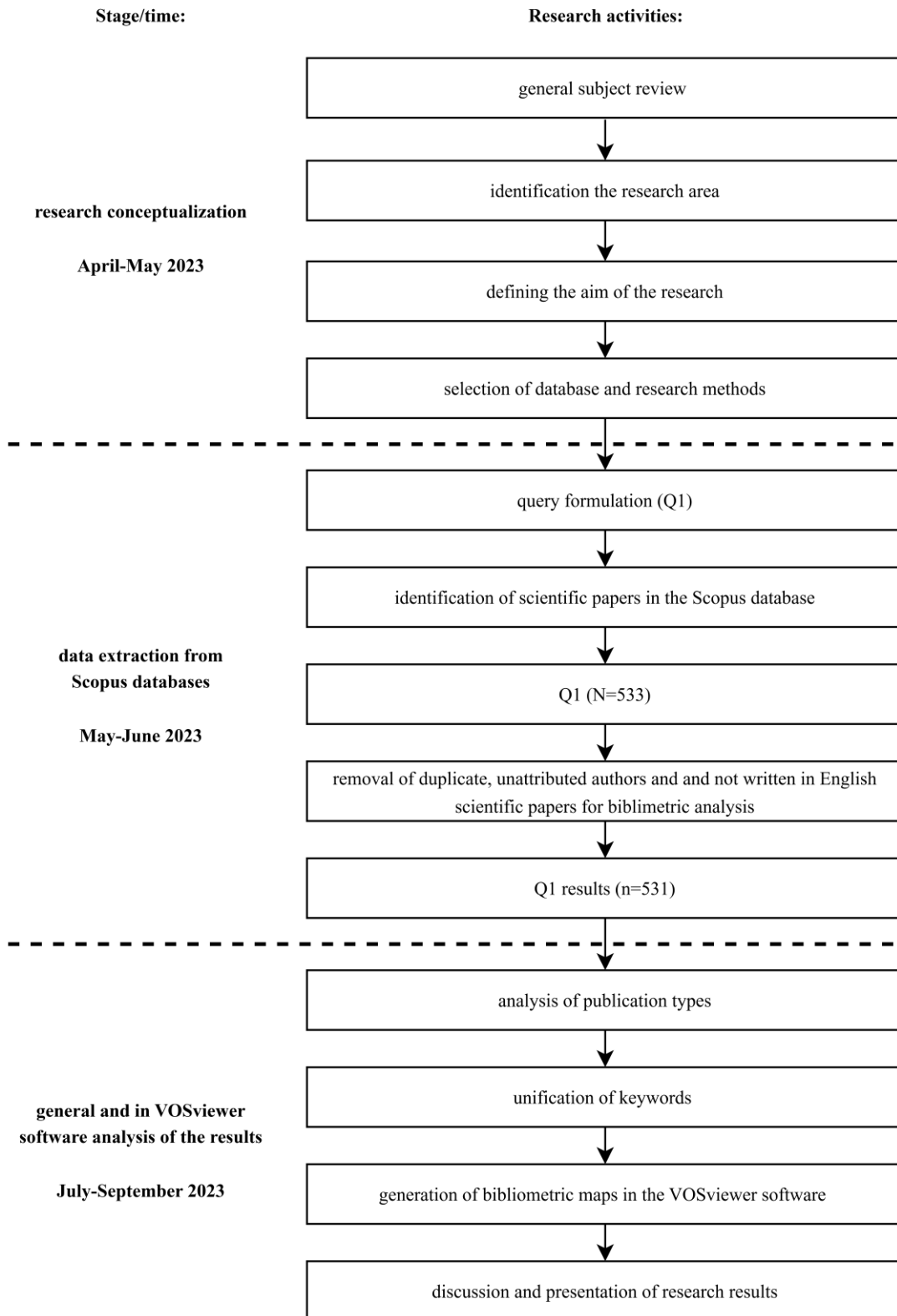
## **2. Research methodology**

The scientific considerations undertaken in this article were based on a three-stage research procedure (Figure 1). At each stage, strictly defined research activities were distinguished. At the first stage of the research, its conceptualization took place. During this stage of the research, a general review of scientific publications was carried out at the outset with a view to identifying considerations around the issue of social, economic, and environmental aspects of social enterprises in a sustainability-oriented economy. As a result of the review, the purpose of the research was defined, recognizing that the considerations undertaken by researchers related to the issue of social enterprises in the context of the issue of sustainable development require a synthetic summary if only in the context of identifying current research trends and determining future research directions. To implement such an outlined research direction, it was decided to carry out bibliometric research of scientific publications collected in the Scopus database. This database is recognized in the literature as a high-quality digital



bibliometric platform (e.g. Haba et al., 2023; Kozar, Sulich, 2023b). In addition, the Scopus database is widely used by researchers for bibliometric analysis around the issue of social enterprises (e.g. Chaudhuri et al., 2023; João-Roland, Granados, 2020; Kozar, 2023; Kulshrestha et al., 2022; Salido-Andres et al., 2022). At the same time, it should be noted that in the context of bibliometric research, limiting the analysis to a specific database (or databases) may lead to a situation in which a certain unspecified number of scientific articles related to the issue at hand will remain outside the scope of the analyses conducted. Nevertheless, due to the number of scientific databases, their diversity, and the fact that some scientific papers may not be indexed in any database, it is impossible to exclude and determine the degree of risk of not including scientific papers from a given research area in bibliometric analyses. At the same time, a Structured Literature Review (SLR) method was chosen, as it was assumed in the study that it should be reproducible for comparison with other similar or identical studies in the future, which will be conducted based on the Scopus database.

Process of extracting the data obtained was carried out at the second stage of the research. Based on the constructed research query Q1 (Table 1), the titles, abstracts and keywords of scientific papers indexed in the Scopus database were searched. Because it was assumed that at the third stage of the research the discussion of the obtained results would be additionally supported by analyses of the extracted database based on the Classical Literature Review (CLR) method, the research query was constructed to include only scientific studies (articles, reviews, and conference papers) written in English. In addition, to ensure that the indicated analyses can be compared by future researchers, the research query to the Scopus database was defined so that the period of the analyses undertaken did not include 2023. It should be emphasized at this point that it is a kind of good practice on the part of researchers not to include in bibliometric analyses scientific papers from the year in which the analyses are carried out. The constructed research inquiry initially made it possible to generate an inventory of 533 scientific studies for further analysis. In accordance with the established research procedure, these studies were subjected to verification aimed at removing repetitive scientific publications, or those that did not contain author attribution. Consequently, the qualitative review of the generated scientific publications thus undertaken resulted in a final database of 531 scientific publications, which were subjected to analysis in a VOSviewer software.



**Figure 1.** Research procedure stages and timeline.

Source: Authors' elaboration.

**Table 1.**  
*Search queries syntax details*

Database	Symbol	Query syntax	No. results
Scopus	Q1	TITLE-ABS-KEY ( "social enterprise*" AND ( sustainability OR "sustainable development" ) ) AND PUBYEAR > 1999 AND PUBYEAR < 2023 AND ( LIMIT-TO ( PUBSTAGE , "final" ) ) AND ( LIMIT-TO ( LANGUAGE , "English" ) ) AND ( LIMIT-TO ( SRCTYPE , "j" ) ) AND ( LIMIT-TO ( DOCTYPE , "re" ) OR LIMIT-TO ( DOCTYPE , "ar" ) OR LIMIT-TO ( DOCTYPE , "cp" ) )	533

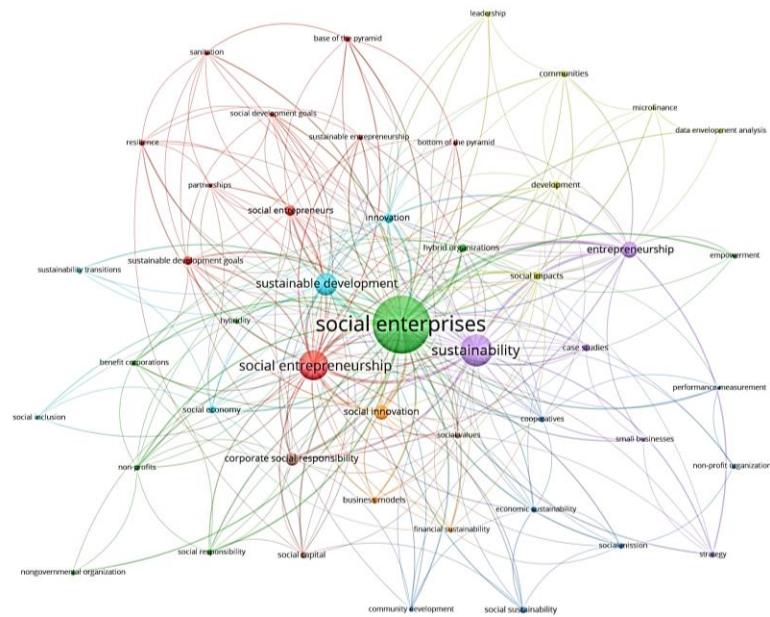
Source: Authors' elaboration.

The final stage of the research, presented in Figure 1, was geared towards a general and results-based analysis obtained in the VOSviewer software. It should be emphasized here that before generating bibliometric maps to be discussed in the context of the set research goal, a unification of the studied keywords was carried out (this process consisted of replacing with a single keyword the same words but appearing in the form of different types of acronyms, in different language versions, or plural and singular). The indicated procedure was aimed at obtaining better quality (more readable) bibliometric maps in in a VOSviewer software.

### 3. Results and discussion

As a result of the analysis of the identified 531 scientific publications meeting the methodological assumptions, it was found that 1469 author keywords were assigned. The identified set of author's keywords was subjected to a standardization procedure to standardize them in terms of the form of notation (e.g., due to differences in the linguistic notation of the same author's keywords - American English, British English, or the use of various abbreviations of individual words), which contributed to the final selection of 1387 unique author's keywords for analysis. The minimum number of co-occurrences of a keyword accepted for research was 5 (as indicated by the VOSviewer software). Of the selected unique authorial keywords participating in the analyses, 52 met the indicated research criterion. In the next step, those referring to geographic names or countries (India, South Africa, Vietnam) and gender were eliminated from the set of authoritative keywords. The measure aimed at eliminating such keywords in bibliometric analyses is a good practice in this type of research and is intended to increase the transparency of the data presented in bibliometric maps. As a result, at the next stage of the research, based on the remaining 48 author's keywords in the VOSviewer software, a visualization of their network of relationships was generated (Figure 2). The result was a bibliometric map of links consisting of eight clusters depicting the most frequently cited research issue based on the author's keywords related to the issue of social enterprises in the context of sustainability issues. The resulting visualization shows the author's keywords as nodes, with lines between them representing the

connections between them. The most frequent author keywords in the analyzed articles are distinguished on the bibliometric map by the size of the node.



**Figure 2.** Bibliometric map of author keywords co-occurrences results from Scopus based on original query (Q1).

Source: Author's elaboration in VOSviewer software (1.6.18 version).

The construction of each of the eight clusters is further presented in Table 2, where the color of a given cluster and the author keywords included in its scope are shown. The VOSviewer software assigned a given author keyword to only one cluster. The order of the listed author keywords in Table 2 is based solely on their alphabetical order. The number of links (L), total link strength (TLS) and number of occurrences (O), with each author keyword analyzed, which were calculated using VOSviewer software, are indicated in parentheses. The number of links indicates with how many of the 48 visualized author keywords have a connection (occurrence next to each other in the range of keywords listed by the author). TLS, in turn, indicates with how many keywords the studied author's keyword co-occurred within the studied 531 scientific publications. In turn, the measure of occurrences indicates in how many of the analyzed scientific papers the keyword was shown as an author keyword.

**Table 2.**

*Clusters of keywords co-occurrences are presented in Figure 2 for Scopus Q1*

Cluster	Color	Keywords
1	red	base of the pyramid (L = 9, TLS = 18, O = 8); bottom of the pyramid (L = 8, TLS = 12, O = 6); partnerships (L = 11, TLS = 13, O = 5); resilience (L = 10, TLS = 15, O = 7); sanitation (L = 9, TLS = 15, O = 6); social development goals (L = 13, TLS = 21, O = 6); social entrepreneurs (L = 17, TLS = 40, O = 19); social entrepreneurship (L = 38, TLS = 186, O = 104); sustainable development goals (L = 13, TLS = 28, O = 15); sustainable entrepreneurship (L = 9, TLS = 20, O = 6)
2	green	benefit corporations (L = 9, TLS = 16, O = 7); empowerment (L = 4, TLS = 10, O = 6); hybrid organizations (L = 9, TLS = 22, O = 14); hybridity (L = 8, TLS = 13, O = 6); non-profits (L = 12, TLS = 23, O = 8); nongovernmental organization (L = 3, TLS = 7, O = 6); social enterprises (L = 47, TLS = 438, O = 295); social responsibility (L = 9, TLS = 21, O = 8)
3	blue	communities (L = 9, TLS = 14, O = 10); data envelopment analysis (L = 3, TLS = 6, O = 6); development (L = 12, TLS = 23, O = 11); leadership (L = 6, TLS = 9, O = 7); microfinance (L = 7, TLS = 10, O = 5); scaling (L = 12, TLS = 19, O = 6); social impacts (L = 19, TLS = 34, O = 11)
4	yellow	community development (L = 9, TLS = 14, O = 5); cooperatives (L = 13, TLS = 18, O = 7); economic sustainability (L = 10, TLS = 13, O = 7); non-profit organizations (L = 4, TLS = 4, O = 6); performance measurement (L = 5, TLS = 8, O = 5); social mission (L = 8, TLS = 14, O = 8); social sustainability (L = 7, TLS = 12, O = 9)
5	purple	case studies (L = 10, TLS = 19, O = 11); entrepreneurship (L = 22, TLS = 97, O = 40); small businesses (L = 5, TLS = 11, O = 5); strategy (L = 7, TLS = 18, O = 7); sustainability (L = 41, TLS = 225, O = 116)
6	turquoise	innovation (L = 20, TLS = 48, O = 18); social economy (L = 15, TLS = 26, O = 12); social inclusion (L = 4, TLS = 6, O = 5); sustainability transitions (L = 4, TLS = 7, O = 6); sustainable development (L = 27, TLS = 122, O = 65)
7	orange	business models (L = 8, TLS = 22, O = 10); financial sustainability (L = 10, TLS = 15, O = 6); social innovation (L = 21, TLS = 59, O = 33)
8	brown	corporate social responsibility (L = 21, TLS = 62, O = 27); social capital (L = 11, TLS = 21, O = 10); social values (L = 8, TLS = 12, O = 8)

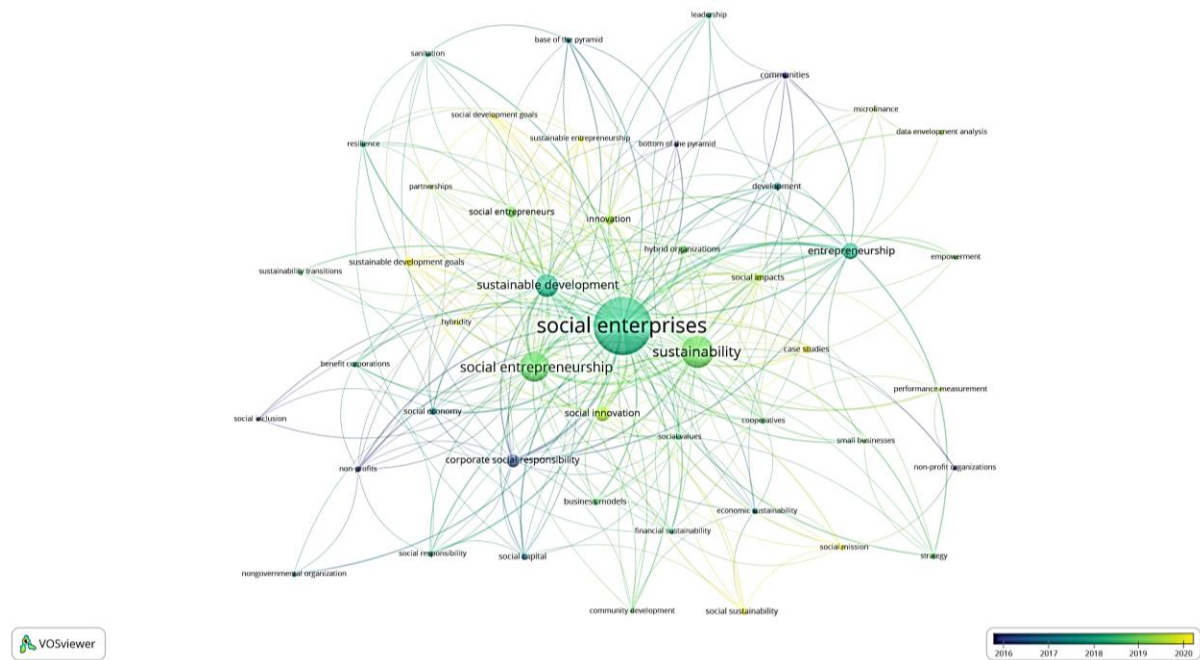
Symbols: O = number of occurrences, L = number of links, TLS = total link strength calculated in VOSviewer.

Source: Author's elaboration in VOSviewer software (1.6.18 version).

The information presented in Figure 2 and Table 2 indicates the multifaceted nature of the issues addressed in scientific deliberations simultaneously addressing the issues of social enterprises and sustainable development. In addition, in the light of the analysis carried out, it was noticed among the author's keywords quite a significant number of issues that in general for many years have been raised by researchers in the context of the problems of social enterprises. It is necessary to point out, for example, the issues of corporate social responsibility (Luo et al., 2020; Palakshappa, Grant, 2018; Qing, Jin, 2022), non-profit organizations (Arshad et al., 2016; Pitta, Kucher, 2009), social responsibility (Anh et al., 2022; Mysen, 2012), social entrepreneurs (Morrison et al., 2017; Ramadani et al., 2022; Satar, 2022; Sulphrey, Alkahtani, 2017), community development (Dahles et al., 2020; Wang et al., 2022), partnerships (Nguyen et al., 2021; Sanzo-Pérez, Álvarez-González, 2022), social inclusion (Baskaran et al., 2019; Machado et al., 2019), or social entrepreneurship (Duncan-Horner et al., 2022; Halberstadt et al., 2021; Rahdari et al., 2016; Stecker, 2014). At the same time, some of the author's keywords identified and shown in Figure 2 are directly related to the issue of sustainable development. For example, in as many as 116 of the scientific studies analyzed, sustainability

appeared in the author's keywords (e.g. Johannisova et al., 2013; Olofsson et al., 2018; Powell et al., 2019), and in 65 scientific studies a reference to sustainable development (e.g. Bilan et al., 2017; Oliński, Mioduszewski, 2022; Vázquez Maguirre et al., 2018).

It should be noted that in the scientific studies analyzed, some researchers directly referred to the issue of pursuing sustainability goals (Goyal et al., 2021; Vasconcellos et al., 2022), or to the issue of selected dimensions of sustainability (Javed et al., 2019; Rey-Martí et al., 2021). As a result, in Figure 2 it is possible to identify among the author's keywords at least social sustainability (Kajiita, Kang'ethe, 2020; Vluggen et al., 2020), or economic sustainability (Mswaka et al., 2016; Segovia-Vargas et al., 2021; Sodhi, Tang, 2011). Also a very important area of academic discussion undertaken was the issue of sustainability transitions (Hillman et al., 2018; Sunio et al., 2020; Vasquez-Delsolar, Merino, 2021). In the opinion of the author of this article, social enterprises occupy an important place in the context of the transformation of the current economy towards sustainable development. This is because it is impossible to completely exclude the possibility that the transformation towards sustainability will not contribute to the exclusion of some people from society (if only through the asymmetry of information on sustainability issues). Hence, social enterprises will increasingly be expected to contribute to the social and professional inclusion of those excluded for a sustainability-oriented economy. As a result, it will increasingly be observed that social enterprises, influenced by social expectations and the idea of sustainable development, will adjust their existing business model. The results of such changes are already discernible by researchers on the subject, who increasingly refer to sustainable entrepreneurship (Baraibar-Diez et al., 2019; Suriyankietkaew et al., 2022) and green entrepreneurship (Charles, 2021; Dixon, Clifford, 2007; Marjerison et al., 2021), and call social enterprises sustainable social enterprises (Dobson et al., 2018; Ketprapakorn, Kantabutra, 2019; Sabella, Eid, 2016) or green social enterprises (Descubes et al., 2018; Osti, 2012; van Gils, Horton, 2019). Green social enterprises will be expected to, among other things, bring socially and professionally excluded people back into the labor market by preparing them for professional roles in green jobs. These types of jobs are commonly discussed in the literature in the context of the operation of various types of business entities and economic sectors in the market (Kozar, 2019; Kozar, Sulich, 2023a), including the perspective of social enterprises (Carberry et al., 2019; Simatele, Dlamini, 2019; Smith-Nonini, 2016). Within the scope of the analyses carried out, a bibliometric map was also generated to indicate the changes occurring in the field of the discussed issues over time (Figure 3).



**Figure 3.** Bibliometric map of author keywords newest results from Scopus based on original query (Q1).

Source: Author's elaboration in VOSviewer software (1.6.18 version).

The analyses carried out, illustrated in Figure 3, indicate the change over time of the addressed research areas in scientific discussions simultaneously addressing the issues of social enterprise and sustainable development (the brighter the color, the more current the issue is in scientific inquiry). The range of issues currently being addressed includes the already mentioned issue of sustainable development goals, social sustainability, or sustainable entrepreneurship. The social mission of social enterprises is also being emphasized on the part of researchers of the subject (Lambooy et al., 2020; Leung et al., 2019; McDonald et al., 2015; Sun, Sohn, 2021). This aspect is understandable given the specific nature of the activities of social enterprises and, above all, their mission in the context of undertaken activities of an inclusive nature aimed at socially and professionally excluded people. In this way, social enterprises can contribute to building sustainability in terms of the social and economic dimensions of sustainable development. In the case of sustainable entrepreneurship, on the other hand, it should be noted that research is often directed at citing specific case studies (Baraibar-Diez et al., 2019).

In the bibliometric maps presented here, there are no explicit references to environmental or green issues, which may also be due to the degree of occurrences of author's keywords. Nonetheless, these areas are emphasized by some scholars of the subject in their scientific reflections on social enterprises, which was also noticed during the procedure of standardization of author's keywords. In the case of environmental issues, references to the following issues were identified in the light of the analysis, among others: environmental awareness (Elnokaly, Thomas, 2019), environmental education (Adhariani, Dewi, 2022), environmental entrepreneurship (York et al., 2016), environmental leadership (Biedenkopf et al., 2019),

environmental management strategy (Tolba, Khatcherian, 2022), or environmental sustainability (Ambati, 2019; Javed et al., 2019; Parris, McInnis-Bowers, 2014; Shah, Naghi Ganji, 2019). On the other hand, in terms of green issues, references have been spotted to such issues as green economy (Davies, Mullin, 2011), green industry (Withisuphakorn, 2017), green information systems (Carberry et al., 2019), greentech companies (Scaffidi, 2022), greenwashing (Stecker, 2016), and the aforementioned green jobs (Smith-Nonini, 2016), among others. In the future, in the opinion of the author of this article, the topic of green will be increasingly exposed through author keywords, which will be primarily due to the expectations placed by various types of stakeholders on social enterprises to embark on the path of sustainable development just like other entities. In addition, such entities, especially green social enterprises, are expected to be an important pillar in building the so-called green labor market (Kozar, 2023).

#### **4. Summary**

The bibliometric analyses carried out allowed, through the identified authorial keywords, to identify the key research areas addressed by researchers who simultaneously address the issues of social enterprises and sustainable development in their scientific deliberations. In addition, based on bibliometric maps, the network of connections of the diagnosed authorial keywords was demonstrated. At the same time, the occurring changes over time within the research themes addressed by the scientists were highlighted. The analyses undertaken made it possible to see that only slowly in the context of authorial keywords appear references to environmental issues or directly green in the context of social enterprises. Thus, authors wishing to explore the indicated research area should combine SLR and CLR methods in their research, with the latter analyzing the entire content of scientific papers, and not just titles, abstracts, or keywords, as Kozar (2023) shows through his research. The observation indicated makes it still too early in the context of research on green issues to carry out at least using a software such as VOSviewer.

In the coming years, considering the analyses and discussions presented, we can expect an increasing number of scientific studies aimed at analyzing specific case studies of individual business models adopted by social enterprises in the context of the implementation of sustainable development by such entities. It can be assumed that part of such studies will be aimed at analyzing the interactions taking place between the stakeholders of social enterprises. At the same time, it will be increasingly possible to see references to green issues in scientific considerations, because, as the author of this article sees it, some social enterprises will become green social enterprises, in which the creation of green competencies among socially and professionally excluded people will take place, so that they can take up employment in green



jobs. It can be pointed out that this is one of the expected directions of change in the existing operation of enterprises on the part of the economy undergoing a gradual green transformation. Hence, the issue of various types of partnerships for the greening of social enterprises may also become an important research thread to be developed in the future.

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## REMOTE EDUCATION ACCORDING TO STUDENTS OF POLAND'S PUBLIC UNIVERSITIES OF ECONOMICS: LIMITATIONS AND EXPECTATIONS

Michał KRÓL<sup>1\*</sup>, Marcin ZAWICKI<sup>2</sup>

<sup>1</sup> Department of Public Economics, Krakow University of Economics; krolm@uek.krakow.pl,  
ORCID: 0000-0001-9648-3139

<sup>2</sup> Department of Public Policy, Krakow University of Economics; zawickim@uek.krakow.pl,  
ORCID: 0000-0002-3724-2658

\*Corresponding author

**Purpose:** The aim of this article is to discuss the results of a study on the limitations of remote education during the COVID-19 pandemic in the opinion of students of Poland's universities of economics and their expectations for this form of education in the future.

**Design/methodology/approach:** The article is based on a survey of 614 students at four public universities of economics in Poland.

**Results:** Remote teaching was considered to be of inferior quality in comparison with face-to-face instruction before the pandemic. Too much time spent at the computer was the primary reported problem. The most popular synchronous teaching method was the lecture. Students' expectations for post-pandemic distance education vary considerably and depend on the level and mode of study, but according to more than 40% of those surveyed, online classes should make up at least 50% of the total teaching load.

**Research limitations/implications:** Since the survey was conducted at four public universities of economics in Poland, its results cannot be generalised to all Polish universities. In the future, similar studies should be undertaken in order to assess the long-term consequences of emergency remote teaching during the COVID-19 outbreak on graduate outcomes and long-term changes in the proportion of distance education in the curricula.

**Practical implications:** The findings of the study can be used to inform teaching development strategies adopted by higher education institutions and to modify educational programs.

**Originality/value:** The article discusses the results of a unique study on the limitations of remote education and students' expectations for its long-term incorporation in the educational process at Poland's universities of economics. The findings offer valuable insights for both higher education managers and scholars.

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**Keywords:** higher education, remote education, emergency remote teaching, education policy, didactic management, education quality evaluation.

**Category of paper:** research paper.

## 1. Introduction

Coronavirus disease 2019 (COVID-19), caused by a new virus strain known as SARS-CoV-2, affected many countries on all the inhabited continents and due to its high incidence was declared a global pandemic (Chahrour et al., 2020) by the World Health Organisation on 12 March 2020 (WHO, 2020). As of 12 March 2020, the Regulation of Poland's Minister of Science and Higher Education of 11 March 2020 on the temporary restriction of the operation of certain entities of the higher education and science system in connection with the prevention, counteraction, and eradication of COVID-19 (Ministry of Science and Higher Education, 2020), introduced the option to deliver classes in higher education institutions using remote learning methods and techniques. Public universities of economics in Poland immediately responded to the emergency. In the days that followed, their authorities issued pertinent regulations and guidelines for delivering classes, holding examinations, and graduating online.

The aim of this article is to discuss the results of a study on the limitations of remote teaching encountered by students of Poland's universities of economics during the COVID-19 pandemic and their expectations for this form of education in the future.

## 2. Evaluation of remote education in the COVID-19 setting in the light of international research

Remote teaching can be divided into synchronous and asynchronous. The former takes place in real time and requires participants to use appropriate technology (Wierzbik-Strońska, Ostopolets, 2021), whereas in the latter, students access materials at their own pace and at different times (Witkowski, 2011). Common forms of remote education include problem-based activities (e.g. problem solving using a discussion board), curriculum-based ones (e.g. online courses), practical ones (e.g. assignments to be completed emailed by the teacher), edutainment (e.g. showing a film), expository methods (e.g. an informative lecture), and activation (e.g. teaching games or discussions) (Grzybowska, 2020). Based on a study of 30,383 students from 62 countries, Aristovnik et al. (2020) found that remote education in crisis situations was usually delivered using synchronous techniques and tools, as reported by nearly 60% of survey participants. Asynchronous techniques and tools, such as posting presentations (15.2%), accessing videos (11.6%), communicating via forums and chat rooms (9.1%), and audio recordings (4.7%) were substantially less prevalent. Synchronous online activities and, for asynchronous technologies, accessing presentations were rated as the most satisfying at the research sample level.

Individual motivation, classroom interaction, course structure, and the teachers' skills and competence are the most important aspects influencing students' reception of remote classes. (Baber, 2020). However, according to a study conducted by Meletiou-Mavrotheris et al. (2022) among 1,051 Cypriot students, the number of factors that may affect the perception of remote classes and, as a result, the teaching quality ratings, is more comprehensive and includes: 1) technology access and accessibility issues; 2) speed/quality of the broadband internet connection; 3) increased workload/work-life balance; 4) lack of digital skills/unpreparedness for at-distance learning; 5) limited teacher-student and student-student interaction; 6) limited engagement, participation and motivation; 7) lack of hands-on and practical training; 8) instructors' lack of familiarity with online learning; 9) field of study; 10) students' technology background and self-rated preparedness for emergency remote learning; 11) level of study; and 12) access and accessibility of technology. Each of the above factors and their various configurations affect the quality of remote teaching and, consequently, may translate into its positive or negative perception.

The quality of remote education implemented from 2020 onwards in response to the epidemic crisis has been the subject of numerous international studies. Overall, the data indicate that both students and academics consider in-person instruction to be considerably superior to its remote counterpart. It should be mentioned that all studies on online education during the pandemic actually refer to emergency remote teaching (ERT; cf. Hodges et al., 2020). ERT is a branch of remote or distance teaching (Bozkurt et al., 2020; Hodges et al., 2020), and its characteristic feature is that it occurs in an unplanned manner (Bond et al., 2021). Remote education implemented by Poland's universities of economics in the pandemic setting, which is the focus of the empirical research discussed in this article, is also classified as emergency remote teaching (ERT).

Tinjić and Halilić (2020), in order to investigate the impact of the sudden transition from face-to-face to remote teaching on educational outcomes, compared the final grades obtained by students from the Swedish Jönköping International Business School during the 2018/2019 and 2019/2020 academic years. They found that the outcomes of students participating in the former were significantly higher than those achieved once remote teaching had been introduced. In a study conducted on a sample of 289 students at the Worcester Polytechnic Institute in the United States, Boggiano et al. (2020) also observed a decline in the quality of remotely delivered lessons in comparison with on-site classes. As many as 83% of the surveyed students opined that the quality of remote teaching was lower than that of face-to-face instruction prior to the COVID-19 outbreak. The vast majority of the 1011-strong sample of students from the Isparta University of Applied Sciences in Turkey felt that remotely held classes were significantly less effective and satisfying than face-to-face ones (Ebru et al., 2020). Aguilera-Hermida (2020) showed that the implementation of remote education resulted in a decline in the quality of instruction for a sample of 270 students at Penn State Harrisburg in the United States. Remote teaching was also judged to be more work-intensive, significantly more

tiresome, and more cumbersome in terms of maintaining contact with academics than on-site education.

Cranfield et al. (2021) noted that a factor that affects the ratings of remote education is the nature and scale of support provided to students by the state or their home university. This conclusion emerged from a survey of students from three universities in Hungary, Wales, and South Africa. Before the COVID-19 pandemic, most South African students had access to a computer with internet connection only on campus. Once remote classes began, the university purchased laptops and limited data packages for students requiring assistance; moreover, mobile phone operators in South Africa provided students with free access to university websites.

Research indicates that the way synchronous and asynchronous teaching tools and methodologies are configured has an impact on the perception of remote education as a whole. An interesting conclusion comes from a survey conducted in the first term following the COVID-19 outbreak on a sample of 3056 students and 396 lecturers from Goethe University Frankfurt in an effort to obtain their opinions on remote education. It turns out that compared with students taking classes based on asynchronous learning techniques and tools, those who participated in classes primarily using synchronous learning methods and tools reported more opportunities for feedback and interactions with peers. Moreover, during the term when instruction was provided remotely, students using synchronous learning methods and tools received more psychological support and felt a greater sense of satisfaction with their classes compared with students taught mainly in the asynchronous mode (Fabriz et al., 2021). This demonstrates that students' perceptions of the quality of remote instruction are influenced by the choice and extent to which different teaching methods are used.

Let us now focus on the limitations of remote education that emerged during the pandemic. Based on a study of 604 students at the Politehnica University of Timișoara, Gherheș et al. (2021) concluded that the main disadvantage of remote education is the absence of interaction, particularly the lack of opportunities to socialize with peers. On the other hand, one of the most significant psychological challenges that students reported when learning remotely was the difficulty in maintaining concentration during online sessions. According to Le (2021), many teachers struggle to keep students interested. The main causes of poor concentration are students' lack of interest in the course contents and syllabus design.

Low digital skills and soft skills, such as self-reliance and self-organisation, also hinder participation in remote education, yet these are essential if its full potential is to be realised (Meletiou-Mavrotheris et al., 2022).

It appears that students who prefer the traditional teaching model have greater problems adapting to remote learning (Aguilera-Hermida, 2020). Ignaciuk and Gutowski (2022), in a study conducted on 489 students at the University of Gdansk, showed that only 17% of the sample reported active engagement during class time. In a similar study, a survey of 152 students at Peter the Great St. Petersburg Polytechnic University identified students'

problems with concentration and inability to focus during online sessions. Shortening synchronous online sessions from 90 to 60 minutes was offered as one recommended solution to this problem (Rubtsova et al., 2023). Le and Truong (2021) report that students prefer face-to-face teaching, i.e. in the classroom and with a teacher present, over remote teaching. Their findings are based on a survey of 255 students from Ho Chi Minh City University in Vietnam.

Despite all of the disadvantages and criticisms levelled at remote learning, when used properly, it can be a valuable supplementary teaching tool. For instance, Meulenbroeks (2020) emphasizes the importance of hybrid teaching and believes it to be the most effective type of instruction. Since according to Cranfield et al. (2021) younger students find it more difficult to adjust to remote instruction, the authors recommend that they be taught exclusively in a face-to-face setting. These researchers also claim that hybrid education is more suitable for senior students, who are better adapted to this mode of teaching.

Remote education has great potential, particularly on courses tailored to specific categories of students, such as individuals in full-time employment who cannot attend on-site classes or those unable to study away from their place of residence. However, remote education cannot be regarded as a long-term solution for all types of courses. For example, engineering degrees require direct interaction between students and instructors to ensure adequate transfer of knowledge and practical skills (Gherheş et al., 2021).

A review of the literature shows that the issues of limitations of remote teaching encountered by students of Poland's universities of economics during the COVID-19 pandemic and their expectations for this form of education in the future. For this reason, we consider these issues to be original and a research gap that deserves in-depth research and analysis.

### **3. Research methodology**

The aim of the study was to identify the limitations of remote education encountered by students at Poland's universities of economics during the COVID-19 pandemic and their expectations from this form of education for the future. The study draws on the experiences of students participating in remote classes over two terms – from March to June 2020 (summer term of the 2019/20 academic year) and from October 2020 to February 2021 (winter term of the 2020/21 academic year). The survey was conducted from March to June 2021 among the students of four universities of economics – in Katowice, Krakow, Poznan, and Wroclaw.

The aim of the study was operationalised into four research questions, which also determined its focus, namely:

- 1) What was the quality of remote teaching delivered from October 2020 to February 2021 in comparison with traditional teaching before the COVID-19 outbreak?
- 2) What issues hindered remote teaching in the crisis situation?
- 3) What do students expect from remote education?
- 4) What changes should be made to improve the quality of remote education?

To answer these research questions, a questionnaire was designed, which included an introductory demographics section that identified the respondents' form, type, and year of study, as well as two identical groups of specific questions that addressed different aspects of remote education at universities during the summer term of the 2019/20 academic year and the winter term of the 2020/21 academic year.

With the permission of university authorities, the questionnaire was made available on their websites and circulated to students via social media platforms. Prior to submitting the official questionnaire, a pilot was done on 10 Kraków University of Economics students to check for accuracy and comprehension. In response to feedback from pilot participants, minor changes were made to the survey.

The research sample included 614 full-time and part-time students who took online courses during both periods of interest. Specifically, the survey was conducted among second- and third-year full-time and part-time first cycle (bachelor's and engineering) students and second- and third-year full-time and part-time uniform master's students, as well as first- and second-year full-time and part-time second cycle (master's) students and fourth- and fifth-year full-time and part-time uniform master's students. The breakdown of the research sample is shown in Table 1.

**Table 1.**  
*Breakdown of the research sample*

	<b>Full-time</b>	<b>Part-time</b>	<b>Total</b>
Students in the 2 <sup>nd</sup> and 3 <sup>rd</sup> year of bachelor's and engineer's degree programmes and the 2 <sup>nd</sup> and 3 <sup>rd</sup> year of uniform master's degree programmes.	286	89	375
Students in the 1 <sup>st</sup> and 2 <sup>nd</sup> year of second-cycle (master's) studies and 4 <sup>th</sup> and 5 <sup>th</sup> year of uniform master's studies	160	79	239
<b>Total</b>	446	168	614

Source: own study.

For the sake of clarity, the following acronyms are used to refer to each of the groups in the study sample:

- 1FT – second- and third-year students of full-time first-cycle programmes (bachelor's and engineering) and second- and third-year students of full-time uniform master's programmes;
- 1PT – second- and third-year students of part-time first-cycle programmes (bachelor's and engineering) and second- and third-year students of part-time uniform master's programmes;



- 2FT – first- and second-year students of full-time second-cycle programmes (master's) and fourth- and fifth-year students of full-time uniform master's programmes;
- 2PT – first- and second-year students of part-time second-cycle programmes (master's) and fourth- and fifth-year students of part-time uniform master's programmes.

As requested by the authorities of some of the universities included in the survey, the breakdown of the research sample and the survey results are presented in a generalised manner, without indicating the disparities between individual institutions with regard to the issues addressed.

#### 4. Research results and discussion

The study's results are organized by research topic and addressed in the following order: (1) The quality of remote teaching in a crisis situation compared with traditional on-site teaching; (2) Limitations of remote education; (3) Expectations of remote education; and (4) Suggested changes to remote education.

##### **Research question 1: What was the quality of remote teaching delivered from October 2020 to February 2021 in comparison with traditional teaching before the COVID-19 outbreak?**

The first part of the study sought to collect students' perceptions of the quality of teaching between October 2020 and February 2021 compared with the period before the COVID-19 outbreak. The period October 2020 – February 2021 is the second term of emergency remote teaching, during which universities had already taken a number of measures to address the organisational and technological issues encountered in March–June 2020, or the first term of compulsory remote teaching following the outbreak of the pandemic. The results of the survey are shown in Table 2.

**Table 2.**

*Quality of education in October 2020 – February 2021 compared with the period before the COVID-19 outbreak (percentages of responses given; n = 614)*

Quality comparison	1FT	1PT	2FT	2PT	Total
Much lower quality	19.9	11.2	15.6	22.8	17.9
Lower quality	30.1	36.0	31.9	25.3	30.8
Comparable quality	30.8	31.4	30.6	32.9	31.1
Higher quality	15.0	18.0	14.4	10.1	14.7
Much higher quality	4.2	3.4	7.5	8.9	5.5

Source: own study.

The data show that despite the implementation of numerous improvements in remote teaching introduced by Poland's economics universities in the 2020/2021 winter term compared with the 2019/2020 summer term, the quality of education did not match its pre-pandemic

levels. In fact, as many as 48.7% of the surveyed students said that the quality of remote teaching in the second term in question was lower than in typical on-site education. This figure comprises 30.8% of students who found the quality of remote teaching to be lower than its on-site counterpart and 17.9% of students who considered it to be much lower. Full-time first-cycle (1FT) students expressed the most dissatisfaction with remote teaching, with 50% of them having unfavourable opinions about its quality. Thirteen percent of the students who took part in the survey felt that remote classes offered during the 2020-2021 winter term were on par with those delivered prior to the pandemic. On the other hand, only 20.2% of respondents thought that the quality of remote teaching during the October 2020 – February 2021 term was either higher or much higher than that provided prior to April 2020.

### **Research question 2: What issues hindered remote teaching in the crisis situation?**

The second issue was to identify the problems with remote education encountered by students at Poland's universities of economics during the COVID-19 pandemic. Students were asked to select up to five out of 16 responses, which were based on the literature review, suggestions from the pilot participants, and personal experience of the researchers. The results of this part of the survey are shown in Table 3.

**Table 3.**

*Issues encountered in remote education (percentages of responses given; n = 614; multiple choice)*

<b>Issue</b>	<b>1FT</b>	<b>1PT</b>	<b>2FT</b>	<b>2PT</b>	<b>Total</b>
Unstable or slow internet connection during class	59.1	55.1	47.5	43.0	53.4
Technical problems with remote teaching applications	24.5	24.7	28.1	11.4	23.8
Lack of direct contact with the tutor and other course participants	46.5	43.8	46.9	46.8	46.3
Lack of suitable conditions at home (e.g. presence of other household members)	34.3	30.3	35.0	40.5	34.7
Excessive amount of material to be covered	24.1	29.2	28.1	20.3	25.4
Inappropriate choice of online teaching methods and/or tools by tutors	14.7	20.2	18.1	17.7	16.8
Lack of tutor involvement	11.9	19.1	11.9	20.3	14.0
Too much time spent in front of the computer screen	60.5	55.1	62.5	62.0	60.4
Difficulty in concentration due to wanting to do other activities during class	43.7	27.0	40.0	32.9	38.9
Difficulty in finding appropriate self-study materials	16.8	12.4	10.6	5.1	13.0
Difficulty in consultations with tutors	0.3	3.4	2.5	3.8	1.8
Difficulty in asking questions during class	5.6	3.4	5.6	10.1	5.9
Feelings of burnout and fatigue after a long period of remote teaching	44.8	30.3	37.5	32.9	39.3
Insufficient time to complete examination tasks	37.4	37.1	41.3	36.7	38.3
Lack of opportunity to review answers after the examination or receive feedback	15.7	18.0	18.8	16.5	16.9
Too strict rules imposed during examinations	25.2	23.6	18.8	16.5	22.1

Source: own study.

According to 60.4% of students participating in the survey, the most onerous issue affecting the perception of classes delivered remotely was the excessive amount of time spent at the computer. Other significant problems identified by students included: unstable or slow internet connection during class (53.4%); lack of direct contact with the tutor and other course

participants (46.3%); a sense of burnout and fatigue after a prolonged period of remote learning (39.3%); difficulty in concentration due to a desire to do other things during class (38.9%); too little time to sit examinations (38.3%); and lack of suitable conditions at home (e.g. presence of other household members; 34.7%).

It is worth noting that difficulties in concentration due to the desire to do other things during class were reported far more frequently by full-time students (1FT and 2FT) than by part-time ones (1PT and 2PT), who, in turn, were more likely than the former to mention their tutors' lack of commitment. In contrast, first-cycle students (1PT and 1FT) were more prone than second-cycle students (2PT and 2FT) to complain about excessively strict examination rules and internet connection problems. Full-time students (1FT and 2FT) expressed symptoms of burnout and exhaustion more frequently after prolonged periods of remote learning. The latter opinion appears entirely justified, since full-time students are required to attend more classes than part-time ones, who have a greater obligation to study independently.

It is also worth noting that a relatively small proportion of the surveyed students reported difficulties in consulting their tutors (1.8%); difficulties in asking questions during class (5.9%); problems in finding appropriate self-study materials (13.0%), and a lack of involvement on the part of tutors (14%).

### **Research question 3: What do students expect from remote education?**

The third topic studied involved students' expectations from remote education features such as synchronous vs. asynchronous teaching techniques and tools, as well as different types of remote tutorials. To make it easier for respondents to specify their preferences, they were given the opportunity to choose a maximum of three options.

#### **Expected synchronous teaching methods**

Table 4 shows the results of the part of the survey devoted to the expectations of students regarding synchronous teaching methods applied in remote teaching.

**Table 4.**

*Expected synchronous teaching methods (percentages of answers given; n = 614; multiple choice)*

<b>Method</b>	<b>1FT</b>	<b>1PT</b>	<b>2FT</b>	<b>2PT</b>	<b>Total</b>
Case study analysis	36.4	41.6	41.9	46.8	39.9
Discussion	46.5	55.1	46.9	49.4	48.2
Educational film	19.9	14.6	16.9	15.2	17.8
Group work	49.0	48.3	50.6	43.0	48.5
Lecture	75.2	78.7	77.5	81.0	77.0
Presentation of group projects	22.4	16.9	24.4	20.3	21.8
Teaching games	19.9	18.0	15.6	27.8	19.5

Source: own study.

By far the most popular synchronous teaching method among students is the lecture. As many as 77.0% of the survey participants agreed that it should be used again in the future should the need for remote teaching arise again. It proved to be particularly attractive for part-

time second-cycle (2PT) students. The benefits of group work are acknowledged by 48.5% of the respondents, with full-time students (FT), particularly second-cycle students (2FT), showing slightly more interest in this method than part-time ones (1PT and 2PT). The third most popular synchronous teaching method is discussion, which was slightly more popular with part-time students (PT), particularly first-cycle students (1PT), than with full-time ones (FT). According to 39.9% of survey participants, case studies are also considered to be a successful synchronous teaching method, with the provision that first-cycle full-time students (1FT; 36.4%) find it less satisfactory than second-cycle part-time ones (2PT; 46.8%). The least popular synchronous teaching methods are educational films, instructional games, and group project presentations, which are helpful according to 17.8%, 19.5%, and 21.8% of respondents, respectively.

### Expected synchronous teaching tools

Table 5 summarizes the survey results on students' expectations about the synchronous teaching tools used in remote teaching.

**Table 5.**

*Expected synchronous teaching tools (percentages of answers given; n = 614; multiple choice)*

Tool	1FT	1PT	2FT	2PT	Total
Blackboard Collaborate	2.1	0.0	2.5	1.3	1.8
Cisco WebEx	1.4	1.1	0.0	5.1	1.5
Discord	14.3	21.3	8.8	5.1	12.7
Facebook Messenger	2.4	0.0	1.3	5.1	2.1
Google Meet (Classroom)	15.4	19.1	18.1	11.4	16.1
Microsoft Skype	3.1	3.4	3.1	1.3	2.9
Microsoft Teams	82.2	68.5	85.6	75.9	80.3
Zoom	72.7	68.5	67.5	68.4	70.2

Source: own study.

Microsoft Teams and Zoom are the most popular synchronous teaching tools. As many as 80.3% and 70.2% of the students surveyed said they expect these two software packages to be used in remote instruction. Full-time students (1FT and 2FT) regard Microsoft Teams to be marginally more user-friendly than part-time students (PT), although Zoom is more popular among first-cycle students (1FT and 1PT) than second-cycle ones (2FT and 2PT). Students expressed a lot less interest in using Google Meet and Discord with only 16.1% and 12.7% of respondents anticipating to use them in the future, respectively. Discord is substantially more popular among first-cycle students (1FT and 1PT) than second-cycle ones (2FT and 2PT). In each case, no more than 3% of survey respondents said that they expected to use platforms like Microsoft Skype, Cisco WebEx, or Blackboard Collaborate for remote teaching in the future.

### Expected asynchronous teaching methods and tools

Table 6 shows the survey results on students' expectations about the asynchronous teaching methods and tools used in remote teaching.

**Table 6.**

*Expected asynchronous teaching methods and tools (percentages of responses given; n = 614; multiple choice)*

Methods and tools	1FT	1PT	2FT	2PT	Total
Assignments posted online by tutors – completed projects, papers, presentations, etc. uploaded by students	33.2	36.0	40.6	36.7	36.0
Group work (e.g. joint projects, compiling glossaries and databases of terms)	39.5	38.2	30.6	32.9	36.2
Online courses developed using e-learning platforms	69.2	69.7	64.4	65.8	67.6
Online forum discussions	11.5	6.7	7.5	8.9	9.4
Sharing materials	9.8	5.6	12.5	17.7	10.9
Quizzes	42.0	50.6	37.5	41.8	42.0
Accessing recorded lectures and/or multimedia presentations	54.2	57.3	57.5	59.5	56.2
Use of internet-based resources (YouTube videos and others; total)	17.1	7.9	18.1	16.5	16.0

Source: own study.

Online courses created using e-learning platforms and accessing pre-recorded lectures and/or multimedia presentations are students' preferred asynchronous teaching methods and tools. These should be utilized in remotely delivered classes, according to 67.6% and 56.2% of the respondents. The next most popular group includes quizzes, group work, and assignments posted by tutors, which are found useful by 42.0%, 36.2% and 36% of the students surveyed, respectively. Remarkably, first-cycle students (1FT and 1PT) show more interest in group work under remote instruction than do second-cycle students (2FT and 2PT). Internet-based resources, sharing materials, and online forum discussions are the least favoured asynchronous teaching techniques and tools. Of the students surveyed, 16.0%, 10.9%, and 9.4% expect them to be used in remote teaching.

### Expected methods of remote communication during tutorials

The results of the survey on the methods of remote communication during tutorials expected by students are presented in Table 7.

**Table 7.**

*Expected methods of remote communication during tutorials (percentages of answers given; n = 614; multiple choice)*

Remote communication method	1FT	1PT	2FT	2PT	Total
Synchronous tool (e.g. Zoom) at times designated by the tutor	90.9	80.9	85.0	91.1	87.9
Social media (e.g. Facebook)	7.0	9.0	6.9	5.1	7.0
University's e-learning platform	45.8	49.4	35.6	39.2	42.8
Email	92.7	88.8	88.1	91.1	90.7
Telephone at times designated by the tutor	11.5	19.1	15.0	17.7	14.3

Source: own study.

Email and synchronous tools at times specified by the tutor are by far the most popular methods of remote communication during tutorials, chosen by 90.7% and 87.9% of students, respectively. Remote tutorials using the university's e-learning platform are preferred by 42.8% of all the respondents and are slightly more popular with first-cycle students (1FT and 1PT) than with second-cycle ones (2FT and 2PT). Telephone communication and social media contact are the least favoured (chosen by 14.3% and 7.0% of students, respectively). Part-time (1PT and 2PT) students appreciate phone communication at times designated by the tutor more than full-time (1FT and 2FT) students.

#### **Research question 4: What changes should be made to improve the quality of remote education?**

The fourth issue of interest involved the modifications that should be implemented to improve the quality of remote teaching and students' preferred participation in remotely held classes in the post-pandemic setting.

#### **Expected changes in remote education**

A total of 296 responses were collected from 205 survey participants ( $n = 205$ ) to the open-ended question on expected changes in remote education. The responses were classified into 21 categories based on similarity analysis, as shown in Table 8.

**Table 8.**

*Expected changes in remote education (percentages of responses given;  $n = 205$ )*

<b>Response category</b>	<b>1FT</b>	<b>1PT</b>	<b>2FT</b>	<b>2PT</b>	<b>Total</b>
Discontinue remote classes immediately after the pandemic	12.4	6.7	14.5	9.7	11.7
Extend the allotted time for online examinations	20.2	26.7	7.3	16.1	17.1
Change the examination method – abandon test-based examinations	4.5	3.3	5.5	6.5	4.9
Shorten online classes	4.5	0.0	0.0	3.2	2.4
Introduce longer breaks between classes	7.9	16.7	0.0	0.0	5.9
Move away from lectures as the predominant form of teaching	12.4	10.0	9.1	3.2	9.8
Reduce the number of onerous assignments and the amount of content to be covered	9.0	20.0	12.7	3.2	10.7
Improve the methodological skills of teachers in online education	7.9	13.3	3.6	6.5	7.3
Improve the technical skills of teachers	3.4	3.3	0.0	0.0	2.0
Introduce interactive and engaging teaching methods	18.0	23.3	16.4	25.8	19.5
Increase the involvement of teachers during class	4.5	20.0	1.8	22.6	8.8
Improve communication between students and teachers	4.5	0.0	7.3	3.2	4.4
Enable recording of classes	4.5	6.7	9.1	9.7	6.8
Introduce the obligation to turn on the camera	4.5	0.0	0.0	0.0	2.0
Abolish the obligation to turn on the camera	4.5	6.7	1.8	3.2	3.9
No change (teaching quality is sufficient)	6.7	0.0	7.3	6.5	5.9
Teachers should be more understanding of their students	4.5	0.0	1.8	0.0	2.4
Share all materials	2.2	6.7	0.0	0.0	2.0
Invest in educational software	1.1	0.0	7.3	6.5	3.4
Replace group work with individual assignments	0.0	0.0	5.5	9.7	2.9
Other	7.9	13.3	7.3	22.6	10.7

Source: own study.

The most common wish is for more interactive and engaging teaching methods, expressed by 19.5% of respondents and more often by part-time than full-time students. A somewhat smaller percentage (17.1%) stated that there is a need to lengthen the time allotted for online examinations; first-cycle students (1FT and 1PT) expressed this expectation significantly more frequently than second-cycle ones (2FT and 2PT). According to 11.7% of respondents, universities should discontinue remote instruction immediately after the end of the pandemic. The need to reduce the number of onerous assignments, cut down on excess content, and move away from lectures was indicated by 10.7 and 9.8%, respectively.

Second-cycle students (2FT and 2PT) signal a greater need to invest in teacher support software and reduce group work in favour of individual assignments than first-cycle ones (1FT and 1PT). However, first-cycle students (1FT and 1PT) are far more inclined to demand that teachers' methodological and technical skills in online instruction be improved. It is also worth noting that part-time students (1PT and 2PT) significantly more frequently than full-time ones (1FT and 2FT) want teachers to be more involved in class.

### Expected proportion of online classes in total teaching time

The last factor to be studied was the expectations of students about the proportion of remotely delivered to in-person classes on courses offered after the pandemic. Table 9 summarizes the survey results on this topic.

**Table 9.**

*Expected proportion of online classes in total course time (percentages of responses given; n = 614)*

Proportion of remote teaching	1FT	1PT	2FT	2PT	Total
Up to 10%	16.4	14.6	11.3	10.1	14.0
10–19%	13.7	5.6	8.8	10.1	10.7
20–29%	14.4	11.2	12.5	8.9	12.7
30–49%	19.9	24.7	25.0	22.8	22.3
50–79%	20.6	22.5	23.7	21.5	21.9
Over 80%	15.0	21.4	18.7	26.6	18.4

Source: own study.

Despite the criticism of the quality of remote teaching, students generally express positive opinions about classes delivered after the pandemic using online teaching methods and resources. Differences in this regard are related to the preferred proportion of online classes in the educational programs offered by Poland's universities of economics. The distribution of responses, however, does not provide a clear answer on this issue. A little more than 40% of those surveyed feel that distance instruction should account for at least 50% of the total teaching time, whereas 59.7% disagree with this view. Only 14.0% of students believe that online classes should not exceed 10% of the total course time. According to 10.7% of respondents, the ideal percentage of online classes would be 10-19%, while 12.7% expect 20-29% of all classes to be conducted online. According to the largest group of respondents (22.3%), 30-49% of classes should be taught remotely. Lastly, a much higher proportion of online education – more than

80% – is supported by 18.4% of respondents. In comparison with part-time students (1PT and 2PT), full-time ones (1FT and 2FT) report the least preference for the widespread use of distance teaching.

## 5. Conclusions and recommendations

The most important findings from the study, organised by research question, are presented below.

1. Despite numerous improvements in remote teaching, the quality of education at the surveyed universities of economics in Poland was considered lower in the 2020/2021 winter term in comparison with the time before the outbreak of the pandemic. During the study period, nearly half of the respondents said that in-person instruction was superior to online instruction. Only a little more than 20% of those surveyed believe that teaching quality has actually improved during this period.
2. The major downside of remote teaching, according to students, is spending too much time at the computer. Over 60% of all respondents agreed with this statement. There were slightly fewer reports of internet connection problems during class (53.4%) as well as the lack of direct contact with the teacher and other course participants (46.3%). It should be noted that such issues are inherent in online education and are not difficult to resolve. Other significant disadvantages of remote education include: insufficient time to complete examinations online (38.3% of responses), excessive amount of material to cover (25.4%), technical problems with remote learning applications (23.8%), strict rules applied during exams (22.1%), as well as the inability to review the answers after the exam or obtain feedback (16.9%). The above problems can be addressed by universities, among other things, by implementing appropriate online teaching procedures and training-up academic staff.
3. By far, the most preferred method of synchronous teaching is the lecture, which was chosen by 77% of all students participating in the survey, followed by group work and discussion (approx. 48% of responses in each case). According to nearly 80% of students, the MS Teams platform should be used for synchronous classes. On the other hand, the most popular asynchronous teaching methods and tools are online courses developed using e-learning platforms (67.6% of respondents) and accessing pre-recorded lectures and/or multimedia presentations (56.2%). Students most commonly expect tutorials by e-mail (90.7%) and communication via synchronous tools at times specified by the teacher (87.9%).



4. More than 40% of the surveyed students think that after the pandemic, online teaching should account for at least 50% of the total course time. However, as many as 14% of them would prefer the percentage to be less than 10%. Students believe that longer online exams and the introduction of interactive, engaging online teaching techniques are essential for raising the standard of instruction. First-cycle students anticipate less content being covered, longer breaks between sessions, more time for exams, and a shift from traditional lectures. Second-cycle students, on the other hand, emphasize the need of investing in teacher support software and reducing group work in favour of individual assignments. Part-time students are more likely to favour continuing classes remotely.

Despite its many drawbacks, remote education has enormous potential. According to the research findings discussed in this paper, students at Poland's public universities of economics prefer on-site classes, because they believe they help them achieve better learning outcomes; they are, nevertheless, receptive to a variety of distance teaching alternatives that supplement traditional face-to-face instruction.

The research also demonstrates opportunities for improvement in the teaching process. Their input identifies that teaching methods and materials should be tailored to the requirements of the specialty, as well as reflect the degree (first-cycle vs. second-cycle), and the mode of study (full-time vs. part-time).

The findings of the study can be used to inform teaching development strategies adopted by higher education institutions and to modify educational programs. The findings may also be valuable for university e-learning centers responsible for developing educational technologies and strengthening the technical and methodological competencies of academic teachers involved in distance education.

Since the survey was conducted at four public universities of economics in Poland, its results cannot be generalised to all Polish universities. In the future, similar studies should be undertaken in order to assess the long-term consequences of emergency remote teaching during the COVID-19 outbreak on graduate outcomes and long-term changes in the proportion of distance education in the curricula.

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## PREMISES AND POTENTIALS FOR REDUCING GENERATION OF PACKAGING WASTE BY THE E-COMMERCE INDUSTRY

Dariusz KRZYWDA

Faculty of Management, Częstochowa University of Technology; [dariusz.krzywda@pcz.pl](mailto:dariusz.krzywda@pcz.pl),  
ORCID: 0000-0001-9234-1686

**Purpose of the study:** This study attempts to answer the question whether it is possible to reduce the quantity of packaging waste generated by online stores through modification of the ways they operate. Due to the dynamic development of e-commerce, the problem of packaging waste is becoming increasingly visible – its overall quantity has increased significantly in recent years. Daily observations of online shoppers and review of websites of packaging manufacturers, for e-commerce demonstrate that problems such as empty space in boxes or the use of various types of fillers or too much plastic are important for both buyers and sellers. Given these phenomena and expected growth trends – both in terms of the packaging waste generated by e-commerce and the need to pursue the principles of sustainable development – actions should be taken to implement the first goal of the waste hierarchy: reduction of the quantities of waste.

**Methodology/approach:** In order to answer this question, a survey was conducted among consumer electronics store employees responsible for shipping products. The survey questionnaire contained questions and responses arranged on a Likert scale.

**Limitations:** The study touched upon the issue of reducing the quantity of waste generated by e-commerce and focused mainly on changing the approach in stores at the operational level. Meanwhile, it would be possible to introduce changes already at the stage of packaging production. It is known that new materials and products are being developed which could be used for shipments, as they are greener. It is certainly possible to make changes at the packaging design stage.

**Implications:** The conclusions of the following study are primarily applicable at the operational management level. On their basis, guidelines and tips for packaging in e-commerce shops can be formulated.

**Value:** The study shows a great potential for online store staff in terms of reducing empty spaces and fillers, and also confirms the existence of a trend in perceiving “green” stores as more competitive.

**Keywords:** e-commerce, packaging, packaging industry.

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

## 1. Introduction

Packaging waste, defined as post-consumer packaging, withdrawn from use and constituting waste within the meaning of waste regulations, is an important issue from the point of view of the protection of the environment and natural resources. Between 2009 and 2019, the quantity of this type of waste increased by 20.5% in the European Union (Ochrona środowiska, 2022). And although it is possible, at least in Poland, to achieve the desired levels of recovering and recycling, waste management remains a very important subject and a problem because it is not possible to implement the principles of waste hierarchy in this area, according to which, in the first instance, the production of waste should be avoided in general.

E-commerce is one of the sources of particularly large quantities of packaging waste. According to the Polish Central Statistical Office, 64.6% of people aged 16-74 made purchases online in Poland in 2022 (compared to 61.2% in 2021) (Społeczeństwo informacyjne w Polsce, 2022) and this is the result of a long-standing trend. Therefore, the e-commerce industry, as online trade is also called, can be considered one of the main culprits of the increase in the quantity of packaging waste. The increase in the amount of waste generated in e-commerce is, of course, due to the growth of the industry, but this increase is disproportionate. It seems that packaging is undergoing the next stage of evolution in online trade. While they previously played the role of a marketing and communication instrument, in e-commerce they return to their most original role, i.e. product protection, this time in transport over longer distances. Thus, the quantities of smaller and larger cardboard boxes, various types of plastic film, paper and plastic materials, which are intended to protect products purchased online on their way to the customer, are growing. The question inevitably arises about the possibility of reducing this waste stream.

## 2. Literature review

As consumers' purchasing preferences shift from traditional retail channels towards e-commerce, the harmful impact of e-commerce is readily apparent. For example, it is estimated that online shopping generates 4.8 times more packaging waste than offline shopping for the same amount of spending (Tokar et al., 2021). Some see the need to change policy in this area to prevent further environmental damage caused by packaging waste from online shopping (Kim et al., 2022), and it is also recognized that this is a task for managers and planners (Adibfar et al., 2022). Online shopping has brought convenience to customers, retailers are constantly making efforts to improve the online shopping experience, and packaging must cope with the rapid growth of the industry.

One of the most important threads in packaging research is that of packaging design, which should take into account issues related to the packaging waste generated (Yin et al., 2023; Spruit, 2021, Kazancoglu et al., 2023). Escursell et al. (2021) note that packaging materials and technologies evolved rapidly until the 1990s, but thereafter it became increasingly difficult to further reduce their costs and environmental impact. Furthermore, some packaging products are still manufactured from non-renewable materials and there is a need for further research to make new packaging from renewable sources, such as cellulose-containing materials that are widely available in nature, or from recycled cellulosic materials, such as cardboard. Streamlining distribution processes with new and more effective tools could further help mitigate the environmental impact of packaging. Similarly, new manufacturing processes such as additive manufacturing and 3D printing can help optimize packaging volume and shape, thereby facilitating more sustainable manufacture, for example by reducing CO<sub>2</sub> emissions. The technology currently available could be useful in rethinking the entire e-commerce packaging paradigm, which has changed very little over the last few decades (Escursell et al., 2021).

The growth of e-commerce and, therefore, the increase in the quantity of waste it generates was also influenced by the CoViD-19 pandemic (Kim, 2020; Nath et al., 2023; Yang et al., 2023), as well as the expansion of express delivery services (Pinos et al., 2022). Another reason is the overpackaging found, for example, in the electronics industry and resulting from the tendency of vendors to protect the product from damage in transport (Lu et al., 2020) or in food industry (Lin, 2022) but also in e-commerce in general (Xie et al., 2021). As an upward trend is expected, questions arise about recycling costs and whether producers of packaging waste are charged appropriately (Cruz et al., 2014) and the issue of packaging in the context of the circular economy has long been emerging (Novakovic et al., 2023; Nielsen, Hakala, 2023; Palazzo et al., 2023).

In the research on e-commerce packaging there is also a thread related to competitiveness of enterprises. Some studies confirm that there is a relationship between pro-environmental, or “green”, solutions used by companies and customer satisfaction and loyalty. This means that the more attention online retailers pay to eco-friendly delivery (parcel lockers, collection points, click & collect), packaging (responsible materials and packaging sizes) and post-consumer returns (returnable packaging, return of end-of-life products), the more are consumers satisfied, loyal and willing to make repeat purchases (Kawa, Pierański, 2021). Studies that have shown this were carried out, for example, in the UK. According to them, one third (33%) of consumers currently decide to buy from brands that, in their opinion, do something good for society or the environment (Unilever, 2017) and rational packaging management in e-commerce adds to its competitiveness (Kim et al., 2021).

The last thread in research on e-commerce packaging concerns the next levels of the waste management hierarchy, after avoiding generation, i.e. waste recovery and recycling. Research conducted on this suggests that there are great opportunities to reduce the consumption of packaging materials and then mitigate their impact on the environment (Su et al., 2020) both in

the technological and management spheres. With regard to packaging used for online shopping, there is a need to create conditions for full recycling and/or reusability. Thus, e-commerce companies, and therefore also customers who would be responsible for returning packaging, face a challenge – the use of reusable packaging (Bukowska-Piastrzyńska, Górnjak, 2023).

### **3. Research hypotheses and methodology**

The analysis of existing threads in the literature regarding e-commerce packaging made it possible to ask several practical questions regarding the business of mail-order stores in the context of reducing the packaging waste they generate. According to the main hypothesis of this study, it is possible to reduce the quantity of packaging waste generated by online stores right now – by modifying their methods of working. Based on this main hypothesis, four secondary hypotheses were formulated, which resulted from observations of everyday practices of this type of stores. These hypotheses are as follows:

- (h1) There is potential for more eco-friendly packaging for shipping goods in online stores.
- (h2) The “greenness” of packaging benefits the company’s competitiveness.
- (h3) Voids in packaging can be reduced and fillers and plastic elements can be eliminated.
- (h4) Managers are ready to take action to make packaging more environment-friendly.

The research tool was an anonymous survey conducted among employees of online stores. The questionnaire consisted of 13 questions in which respondents were asked directly about the phenomena under study and asked to rate them using a Likert scale. The questions in the survey were designed to verify the hypotheses set at the beginning of the study. Some of the respondents spontaneously shared their opinions on the topics discussed in the survey, which was taken into account in the interpretation of the results.

### **4. Research results**

Responses were received from 47 persons – managers from the e-commerce industry and employees of online stores responsible for shipping goods to customers, preceded by packaging. The research sample consisted of 35 men and 12 women. The mean age of the respondents was 38 years.

The questionnaire contained 13 questions, in the grammatical form of affirmative statements, with responses using a 5-point Likert scale intended to verify the hypotheses formulated based on the identified research gap. For each statement, respondents could choose from among 5 responses consisting of a verbal and numerical description, arranged in order from 100% denial to 100% agreement:



- 1 – I strongly disagree.  
 2 – I tend to disagree.  
 3 – Neither yes nor no.  
 4 – I tend to agree.  
 5 – I strongly agree.

On this basis, a weighted average was calculated for each statement, providing information about the side and strength of the attitude towards each statement. The answers are presented in Table 1.

**Table 1.**  
*Questions (affirmative statements), responses and weighted averages*

N°	Question/Response	I strongly agree	I tend to agree	Neither yes nor no	I tend to agree	I strongly disagree	Weighted average
		% of responses					
Q1	The issue of packaging waste from mail order sales worries me.	59.57	31.91	8.5	0	0	4.51
Q2	Packaging and environmental issues related to it are becoming more and more important to consumers.	63.82	29.78	0	4.25	2.12	4.48
Q3	Online stores that respect the principles of ecology and sustainable development have a competitive advantage over other online stores.	95.74	2.12	2.12	0	0	4.93
Q4	Shipping packaging in an online store could be “greener”.	93.61	4.25	2.12	0	0	4.91
Q5	When shipping from an online store, the quantity of plastic ancillary materials (adhesive tapes, fastening tapes) could be reduced.	6.38	10.63	42.55	40.42	0	2.82
Q6	When shipping from an online store, it would be possible to reduce empty space in packages.	91.48	4.25	4.25	0	0	4.87
Q7	Reducing the empty space in a parcel shipped by an online store would reduce logistics costs.	91.48	6.38	2.12	0	0	4.89
Q8	It is possible to reduce the quantity of “fillers” in shipments from online stores (stretch foil, bubble wrap).	74	17.02	8.5	0	0	4.65
Q9	It is possible to reduce the use of other “fillers” in packaging used for shipping by online stores.	14.89	19.14	19.14	31.91	14.89	2.87
Q10	Most parcels are packed in such a way that they are difficult to open and are frustrating for the consumer.	74.46	19.14	6.38	0	0	4.61
Q11	Packaging that is difficult to open or is unsustainable may effectively discourage a consumer from purchasing a product of the same brand again.	6.38	10.63	19.14	36.17	27.65	2.31
Q12	I am ready to diversify my approach in my work and put more effort into making the packaging more “eco” (so that it is not a source of much waste).	42.55	31.91	23.4	2.12	0	4.14
Q13	Most packaging could be designed slightly differently to generate less waste.	80.85	10.63	4.25	4.25	0	4.68

Source: The author’s own study.

The first three questions/statements concerned the general perception of the issue of waste generation by the e-commerce industry. The first statement (Q1), according to which the issue of packaging waste from mail order sales is worrying, has an average weight of 4.51. This means that the respondents considered the phenomenon, as well as the threats resulting from it to be noticeable: 91.48% of respondents believed so. The respondents also believed that “packaging and environmental issues related to it are increasingly important to consumers” – this statement (Q2) has an average weight of 4.48 and 93.6% of respondents agreed with it. In the next statement (Q3), this observation was confirmed and supplemented with the aspect of competitiveness. 97.86% of the respondents agreed with the statement that online stores that respect the principles of ecology and sustainable development have a competitive advantage over other online stores – the result is the highest weighted average (4.93) and this is the strongest statement in the entire survey.

The next six questions concerned the method of packing as such itself and the possibility of reducing the quantity of waste in e-commerce stores. The results of this part of the study are inconclusive. The respondents agreed that shipping packaging in an online store could be more “eco” (Q4 – 4.91, 97.86%), that empty space in parcels could be reduced (Q6 – 4.87, 99.98 %) and that it would reduce logistics costs (Q7 – 4.89; 99.98%). Slightly narrower acceptance, although still quite wide, was noted for the statement that the number of “fillers” in shipments from online stores (stretch foil, bubble wrap) could be reduced (Q8 – 4.65; 91.02%). The weighted average agreement to statement that the quantity of plastic ancillary materials (adhesive tapes, fastening tapes) could be reduced when shipping in an online store (Q5 – 2.82; 42.55%). To an even lesser extent, the respondents agreed with the statement the use of other “fillers” in packaging used for shipping by online stores can be limited (Q9 – 2.87; 34.03%).

The last four questions of the survey concerned the consumers’ reaction to non-green packaging and the possibility of more ecological packing of parcels in online stores and designing packaging in such a way that it generates less waste. First of all, the majority of the respondents (63%) did not agree with the statement that non-ecological packaging can effectively discourage repeated purchases (Q11 – 2.31), but at the same time the respondents confirmed that most parcels are packed in such a way that they are difficult to open and that opening them is frustrating for the consumer (Q10 – 4.61; 93.6%). In response to question Q12, a majority of respondents (74.46%) declared their readiness to diversify their approach in their work to make the packaging more ecological (4.14). In the last statement, the respondents confirmed that most packaging could be designed slightly differently to generate less waste (Q13 – 4.68; 91.48%).

## 5. Discussion

Hypotheses (h1), according to which there is a potential for more ecological packaging for shipping goods in online stores, and (h2), according to which the “ecological” nature of packaging benefits competitiveness should be considered positively verified. The study has confirmed that the issues of packaging waste from mail order sales are worrying for representatives of the e-commerce industry, and environmental issues related to them are becoming increasingly important for consumers. The statement that online stores that respect ecological principles are perceived as more competitive has also been confirmed. This state of affairs confirms the research hypothesis formulated based on the existing research. Employees in the e-commerce sector notice the problem of waste from their industry. In the general view of both employees and customers of online stores, ecological issues are gaining on importance, and competitiveness of e-commerce stores is correlated with whether they respect the principles of ecology and sustainable development. It should be noted that the term “ecology”, or “greenness”, was not defined in detail in the study – on purpose. While the adjective “ecological” is commonly used in very different contexts and areas of life, it seems that most people use it to mean “related to environmental protection” – and the term was used in this sense in the study. It is also commonly believed that one of the aspects of “environmental protection” is the reduction of the quantity of waste generated, including packaging waste, and that it is in this sense that the word “ecological” is used. The study has shown that the ecological approach of e-commerce stores in terms of the packaging used by them may be a factor improving their competitiveness. There are many strategies to ensure that stores – not only e-commerce ones – remain competitive on the market, and the subject of their effectiveness is extremely comprehensive. Undoubtedly, however, “being eco” is gaining on importance as a factor of competitiveness due to growing awareness of environmental issues in societies. Therefore, it is a reason to take measures aimed at cultivating the image of e-commerce enterprises as “greener”. The respondents also said that shipping packaging in an online store could be more “eco”. This is an important statement because it comes from employees themselves who, as those closest to the packaging process, notice the lack of optimization in the selection of packaging. In additional comments on this topic, the respondents emphasized that there was a great potential to improve packaging. The employees surveyed admitted that packing is primarily aimed at securing the goods for transport. Some emphasized that their priority was to deliver shipments as quickly as possible and that that was the main goal of shipping companies, and the most important expectation of customers. As the respondents admitted, given such goals, the subject of adjusting the packaging in terms of size to the dimensions of the product becomes less important and it is much easier to use larger packaging in which voids are closed with additional materials (fillers).

Thus, hypothesis (h3) has been partially confirmed, according to which “air gaps” in packaging can be reduced and fillers and plastic elements can be eliminated. This hypothesis was verified using 7 questions, and the answers are not entirely clear. The low average weight comes to the fore when it comes to the statement that packaging that is difficult to open or is non-green may effectively discourage a consumer from purchasing a product of the same brand again. This is a very important suggestion for the market. While the respondents agreed with the very general statement that environmental friendliness promotes competitiveness, they tended to disagree with the more specific statement that a brand would lose popularity due to the fact that its products are packaged in a non-green manner. This is, of course, relatively simple to explain by the fact that brand loyalty is something different than the perception of an online store and shipping.

The respondents moderately agreed with the statement that the number of plastic packaging elements could be reduced in online store shipping (Q5). In additional comments, they justified this by the fact that currently these materials and their use are often already reduced to the necessary minimum. Plastics in mail order stores are used primarily in the form of ancillary packaging materials, such as adhesive or fastening tapes and bubble wrap to protect the product in transport against damage. The respondents declared that plastics were used less and less often as fillers of voids, for which purpose they increasingly used paper, among others. Next, they agreed that the quantity of “fillers” in online shipping, such as stretch film and bubble wrap, could be reduced (Q8) and, at the same time, they were less likely to agree with the statement that other “fillers” used in shipping packaging could be reduced. It turns out that it is necessary to use fillers, even paper ones, and the trend of moving away from plastic is already noticeable.

The statement about the possibility of reducing overall empty space in parcels sent as part of online sales (Q6) and the related possibility of reducing logistics costs (Q7) also met with strong acceptance. This issue also provoked many additional spontaneous comments from the respondents, which they shared in the survey. They confirmed that the phenomenon of empty space in boxes delivered after online shopping is extremely common and even has a name: the “empty space economy” consisting in “carrying air and fillers” is perceived very critically by the respondents. They noticed a number of negative consequences associated with this phenomenon: ranging from increased transport costs if packages take up more space than the size of the product, through generating unnecessary waste, to customer disappointment and frustration resulting in adverse publicity. One of the respondents drew attention to marketing aspects: There are popular videos on YouTube channels in which customers review products purchased online, also commenting on the packaging and often expressing unfavorable opinions about brands that use excessive quantities of fillers. This comment was reflected in the survey in response to the question about consumers’ frustration with opening a package that is difficult to unpack (Q10).

The last two questions of the questionnaire were used to verify hypothesis (h4), according to which managers are ready to take action to make packaging greener and to examine the possibility of changing the approach to packaging in online stores in such a way that packaging from this type of sales does not generate so much waste. Representatives of the e-commerce industry are willing to diversify their approach at work and make more efforts to make packaging more environment-friendly. As many as 80% of the respondents fully agreed with the statement that most packaging could be designed in a slightly different way to generate less waste.

## 6. Conclusions

The research can offer both general conclusions, regarding the situation of waste management in the online sales industry, and conclusions regarding management issues. First of all, it should be noted that the problem of too much waste generated by the industry is so great that it has not escaped the attention of its employees and customers, and this problem could be solved. This would bring benefits not only for the environment, but also for e-commerce which must treat ecology as an element of their competitive strategy in times of growing environmental awareness of society. Secondly, online store employees are willing to modify their procedures to make packaging greener. Empty space in parcels should certainly be reduced – there is potential for this. This can be achieved by purchasing a wider range of box sizes which should be matched to products. Thirdly, we must not forget that the process of packing goods in online stores is primarily intended to protect products in transport. However, it is still not a factor determining the brand's popularity.

The study described in this paper had its limitations. Thus, it touched upon the issue of reducing the quantity of waste generated by e-commerce and focused mainly on changing the approach in stores at the operational level. Meanwhile, it would be possible to introduce changes already at the stage of packaging production. It is known that new materials and products are being developed which could be used for shipments, as they are greener. It is certainly possible to make changes at the packaging design stage. The study only highlights issues related to existing and marketed packaging: their recycling and upcycling, as well as their reintroduction into economic circulation. These matters should certainly be investigated in future research and economic practice.

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## IMPLEMENTATION OF ELECTRIC ROAD TRANSPORT – POLAND IN COMPARISON WITH EUROPEAN COUNTRIES

Adam KUCHARSKI<sup>1\*</sup>, Iлона LEKKA-PORĘBSKA<sup>2</sup>

<sup>1</sup> University of Lodz; adam.kucharski@uni.lodz.pl, ORCID: 0000-0001-8699-7566

<sup>2</sup> University of Lodz; ilona.lekka@uni.lodz.pl, ORCID: 0000-0002-0504-9124

\* Correspondence author

**Purpose:** Electromobility significantly changes the approach to road transport. Therefore, we decided to evaluate the implementation of electric vehicles in road transport in selected countries and compare Poland with the leaders in the transformation taking place in Europe.

**Design/methodology/approach:** Statistics on electromobility and national energy systems were obtained from Eurostat. We used statistical measures to measure the extent of progress of the introduced electric mobility solutions. We identified leaders in road transport transformation using the TOPSIS method.

**Findings:** The successful implementation of electromobility solutions in road transport across Europe is limited to a handful of countries that we have identified. Most countries do not have sufficiently developed grid infrastructure and charging stations. Poland compares very unfavourably with the leaders in road transport transformation and occupies roughly the same distant position in the rankings.

**Research limitations/implications:** The most recent data available are from 2021. In addition, some countries did not provide Eurostat with complete data on road transport and energy policy. It would be worthwhile to re-examine the study with completed data to understand the impact of the disrupted supply chains and the war in Ukraine that occurred in 2022.

**Originality/value:** This interdisciplinary study combines green logistics, statistical analysis of energy policy and multi-criteria optimisation. We propose a new way of evaluating consumer interest in electric vehicles. In addition, our set of criteria in the TOPSIS method includes an assessment of a country's energy security.

**Keywords:** electromobility, TOPSIS, energy transformation, energy policy.

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

### 1. Introduction

Logistics serves as the circulatory system of the modern economy. One of the key forms of logistics activity is road transport, where the impact of electromobility is increasingly evident. This is part of a "green logistics," aimed at reducing the negative environmental impact of

logistics (Lee, 2012). This trend is unlikely to change, given the emphasis on implementing sustainable socio-economic development in the European Union (EU).

However, the concept of electromobility does not yet have a universally accepted definition. For instance, the Polish Act from 11th January 2018, on electromobility and alternative fuels does not provide such definition. Most publications also refrain from explicitly defining this term, although a recurring set of concepts and ideas describing electromobility can be identified. Koszowska and Rokicki (2021) noticed this.

We will consider electromobility to encompass issues arising from the use of electric vehicles (EV), including the technologies used in EVs, charging infrastructure, legal frameworks, and the social, economic, and environmental consequences. Electromobility significantly changes the approach to road transport, leading to transformations worthy of investigation (Reid et al., 2011). Therefore, our study has two main objectives:

1. Evaluate the extent of electromobility solutions implementation in road transport across selected European countries, expressed not only by changes in the structure of the existing car fleet but also by the manner it is fuelled.
2. Identify a group of countries leading the transformation of road transport and examine how Poland compares to them to assess the distance separating Poland from these leaders.

The article is structured as follows. The second section describes EU regulations related to reducing CO<sub>2</sub> emissions, increasing the use of renewable energy and introducing electromobility affecting road transport. In the third section, we have included a literature review. The fourth section describes the algorithms of the TOPSIS method and the Shannon's entropy method. The fifth section presents the results of our study. The sixth section contains a discussion of the results of section five. The article concludes with a summary.

## **2. The impact of energy policy on road transport in Europe**

Electricity nowadays is the basis for the functioning of virtually every area of life. Most daily-use equipment and machines are powered by it. Prolonged power outages pose a serious problem and threat, destabilising the economy (Schossig T., Schossig W., 2014). Naturally, electricity is exported and imported, but with current consumption we cannot rely solely on imports. In addition, advances in technology and civilisation are increasing the need for it (Samuel, Jan, 2020).

Renewable energy sources (RES) play a crucial role in the energy economy of European countries (Buonocore et al., 2019). The European Union, through European Commission directives, emphasizes the need to increase the share of RES in the energy mix. One of the most important documents is the Directive of the European Parliament and of the Council on the

promotion of the use of energy from renewable sources. There, we find a definition of energy from renewable sources: it is energy from non-fossil sources, namely wind energy, solar energy (thermal and photovoltaic), aerothermal, geothermal, and hydrothermal energy, ambient heat, tidal, wave and other ocean energy, hydropower, energy from biomass, gas from landfills, sewage treatment plants and from biological sources (biogas). The EU's energy policy aims to fulfil the 2015 Paris Agreement on climate change by promoting renewable energy sources. This directive establishes a common framework for promoting energy from renewable sources in various sectors. Specifically, it:

- sets a binding EU target for the share of such energy in the energy mix by 2030,
- regulates self-consumption for the first time,
- establishes a common set of rules for the use of renewable energy in the electricity, heating and cooling, and transport sectors in the EU.

Increased use of renewable energy will significantly counteract climate change, support environmental protection, and reduce energy dependence. It will contribute to the EU's technological and industrial leadership, create new jobs, and promote growth, especially in rural and isolated areas. The directive mandates an overarching EU target for 2030 whereby a minimum of 32% of electricity generated in a Member State must originate from RES. From our perspective, the goals set in the transport sector are important, particularly the target of a 14% share of energy from renewable sources (Amin et al., 2020).

The law created by the European Commission compels vehicle manufacturers to implement new technical solutions leading to lower emissions. Regulations are also emerging mandating the recycling of lithium used in battery construction. Legislation is also being developed to mandate the recycling of lithium used in batteries. Therefore, we will commence this chapter with a brief discussion of the legal regulations introduced in the EU and Poland in recent years.

Firstly, we will mention the White Paper on Transport published by the EC in 2011. It outlines a plan for a unified European transport area and establishes several goals of EU transport policy, such as:

- A 60% reduction in GHG emissions from transportation by 2050 compared to 1990 levels. This will primarily require changes in vehicle propulsion and restrictions on the use of conventional vehicles in densely populated areas.
- Reduction of dependence on fossil fuels.
- Introduction of electromobility in transport following the principles of sustainable development (SD).

These goals should be achieved in harmony with maintaining the efficiency of road transport without limiting the mobility of its users. The set of strategies, recommendations, and initiatives from the White Paper continues to influence the transformation of road transport in Europe.

Another notable European legal act is the Directive on the Development of Alternative Fuel Infrastructure from 22th October 2014. It imposes obligations on member countries, including:

- The development of national policy frameworks for alternative fuel markets in the transport sector.
- The development of appropriate infrastructure for the production and supply of alternative fuels along with specified deadlines.
- The assumption that the average number of publicly accessible EVSE (Electric Vehicle Supply Equipment) points in 2020 should be at least one charging point per 10 EVs.

The implementation of this regulation will have an impact on the country's energy demand and security of supply, as electricity will be needed to operate the charging stations.

In 2016, the European Commission published the European Strategy for Low-Emission Mobility. In this document it addressed actions to achieve a reduction of at least 60% in GHG from the transport sector by 2050 compared to 1990 levels, progressively reducing these emissions to zero. The strategy includes actions such as optimising the transport system, promoting multimodality, increasing the use of low-emission alternative energy sources in transport, building infrastructure for alternative fuels, and transitioning to zero-emission transport.

In 2019, the European Green Deal was published, emphasising the commitment to achieve climate neutrality by 2050. It incorporates the "green transformation" into key cross-cutting programs and sectoral policies. The authors of the document identified infrastructure development as one of the strategic elements of the transition to a "clean", safe, and intelligent transport network.

Another document worth mentioning is the Strategy for Sustainable and Intelligent Mobility from 9th December 2020. It includes 82 initiatives in 10 key areas and specific actions to significantly reduce the current dependence on fossil fuels. Priorities include the development of affordable alternative solutions to increase demand for zero-emission vehicles, greater use of digital technologies supporting the functioning of an integrated multimodal transport network, and 'green' financing to increase the resilience of transport infrastructure.

The most recent European document is the Fit for 55% package, which took the form of a communication of the European Commission Communication in 2021. In essence, it is a set of interrelated proposals aimed at collectively ensuring the implementation of the ambitious climate policy of the EU. It is named after the plan to reduce GHG emissions by at least 55% by 2030 compared to 1990 levels. The document aims to achieve climate neutrality by 2050. The plan outlined in the document for the development of alternative fuels and infrastructure is important from a road transport perspective.

Laws adopted at the EU level influence regulations in member countries, including Poland. In response to the aforementioned legal acts, the Polish government and the Sejm (Polish Parliament) have developed and implemented a series of plans and regulations. Firstly, we mention the Development Plan for Electromobility in Poland 2016-2025 announced

in 2016. It outlines three phases of development: (preparatory phase - 2016-2018, pilot projects phase - 2019-2020, implementation phase - 2020-2025). The plan complements a set of instruments aimed at contributing to the development of the electromobility industry, the modernisation and stabilisation of the power grid, and the creation of demand for electric vehicles. Within the second phase, projects such as e-Bus and e-Car were initiated. ElectroMobility Poland SA, a company created as part of the second project to design a modern electric city car.

A year later, the National Framework for the Development of Alternative Infrastructure was published. Among other things, it contains general and specific goals for the development of charging infrastructure. According to these goals, by the end of 2020, 6000 normal power and 400 high power charging points were to be deployed in 32 selected agglomerations in Poland. The pandemic and subsequent events hindered the implementation of this plan.

A crucial legal act is the Law from 11th January 2018, on Electromobility and Alternative Fuels with subsequent amendments. It defines the principles of development and functioning of the infrastructure necessary for using alternative fuels in transport. It aims to encourage drivers to choose electric vehicles and those powered by alternative fuels. Interestingly, there is no definition of electromobility as such in the Act. Instead, it defines many other concepts, e.g., an electric vehicle is a motor vehicle under road traffic law that uses exclusively electric energy accumulated by connecting to an external power source. The law allows municipalities to create clean transport zones, which are designated and appropriately marked areas where only vehicles meeting specific emission requirements can operate.

### **3. Literature review**

While many publications on energy management focus on technical issues, we will highlight a few that consider the economic aspect. Many authors describe case studies. Dergiades, Martinopoulos, and Tsoulfidis (2013) focused on energy consumption and economic growth in Greece. The conclusion from their research provides valuable information for a more effective energy policy regarding both energy consumption and environmental protection. Energy-related analyses are very often addressed in relation to Asian countries. Rehman et al. (2023) investigated the impact of digitalisation on renewable electricity generation and identified both positive and negative effects of globalisation on renewable energy production in specific South Asian countries.

Aszódi et al. (2023) focused on the future impact of nuclear energy on decarbonisation and continuous electricity supply in the EU. They analysed the energy strategies of 15 European countries and then compared the impact of nuclear power plants on the mix of electricity production, carbon dioxide emissions, natural gas demand, and supply security in 2030 and

2040. Their results indicate that scenarios involving nuclear energy provide the lowest CO<sub>2</sub> emissions. Closing such power plants, despite using solar and wind energy, increases CO<sub>2</sub> emissions, limits supply, and requires larger energy storage. These findings have significant implications for the EU's energy policy, which advocates for a greater use of RES while simultaneously reducing reliance on nuclear and coal power.

Tansel Tugcu and Menegaki (2023) have a different perspective on the energy situation in Europe. They considered energy security as the most important one and examined the relationship between renewable energy generation and energy security in G7 countries between 1980 and 2018. They used several methods for this purpose. The results show a one-way causal relationship between renewable energy and energy security in the short term, while renewable energy generation significantly reduces the risk that threaten energy security in the long term. Tansel Tugcu and Menegaki suggested that due to the current energy crisis in Europe, there is an urgent need to increase the share of renewable energy generation to mitigate threats to energy security. The presented publications offer different perspectives and potential consequences of increasing the share of RES in the energy mix. There is an increasing interest in literature on the energy economy concerning the potential repercussions and impact of energy policy on technological advancement, predominantly reliant on electricity.

DeRosa et al. (2022) also consider energy security to be important. Their study shows a stable evolution of fuel mix diversification and a relatively low concentration in the European energy market over the period considered. They found that import dependence reduces energy security by about 30% due to the high share of imports from a limited number of countries.

One of the threats to Europe's energy security is the war in Ukraine. Osička and Černoch (2022) analysed this influence. They expect that the main objectives of EU policy will be to reduce energy vulnerability and accelerate decarbonisation, probably at the expense of the further development of the EU's integrated energy market in its current form. They concluded that the EU has the resources, knowledge base, and determination to turn the crisis into an opportunity.

We will discuss publications on electromobility from two points of view: general and multi-criteria optimisation.

Brdulak and Pawlak (2022) point out the challenges associated with the electrification of road transport, with a particular focus on transformations related to urban logistics. Many inaccuracies, terminological confusion and even deliberate marketing manipulation are currently slipping into the discussion on the transformation of car transport. We also noted the problem with terminology. The article also addresses the cost and infrastructure-related conditions associated with the implementation of electromobility in Polish road transport. Similar issues considered Drábik and Krnáčová (2018) in Slovakia, with a strong emphasis on the preferences of potential buyers of electric vehicles. Ehrler and Camilleri (2021) conducted a survey in Germany and France to assess the attractiveness of electric vehicles for users. Igliński (2018) performed a comparative analysis of the level of electromobility development

in Poland compared to 10 countries in the region. Kłos et al. (2019) assessed the impact of developing electromobility on the Polish electricity system. They pointed out that the distribution subsector is most exposed to negative interactions with the expanding electric vehicle power grid infrastructure. Tamba et al. (2022) conducted an extensive analysis of the impact of electrification in the EU on road transport. They measured these impacts using a Computable General Equilibrium (CGE) model that combines techno-economic assumptions about electric vehicles with deployment scenarios derived from energy models.

Bednarczyk and Bielski (2021) aimed to determine if electromobility in the supply chain enhances its innovativeness. They identified the lack of a sufficiently developed charging network as a primary obstacle to the transformation of transportation. Cempírek et al. (2019) focused on electric freight transport, drawing on experiences from trolleybus operations. According to them, regardless of the type of power supply considered, the ecological efficiency of electric freight transport depends on the main method of energy generation, which varies between countries. Jedliński and Nürnberg (2022) focused on electric delivery vehicles for courier services, conducting simulations of deliveries for the Szczecin Metropolitan Area. Malladi et al. (2022) addressed a somewhat similar issue. They studied the problem of optimising the size and mix of a mixed fleet of electric and conventional vehicles owned by urban freight companies. Malladi et al. formulated a two-stage stochastic program and proposed a heuristic method based on sample-average approximation for its solution.

Charging infrastructure returns repeatedly in articles. Several publications discuss the selection of charging point locations, including (Szterlik-Grzybek, Kucharski, 2023) - the case of the city of Lodz (Poland), or (Guler, Yomralioglu, 2010) – Istanbul (Turkey). Both articles employed discrete multi-criteria optimisation. In (Philipsen et al., 2015) preferred locations for charging stations are indicated by users who participated in a special survey.

In the second part of the study, we used the TOPSIS method, which belongs to the group of multi-criteria optimization methods. The TOPSIS method is frequently encountered in research related to energy production and consumption, RES, and electromobility. Let's delve into the literature on this topic from the last few years.

To begin with, let us turn our attention to research on the role of various energy sources in sustainable economic development. Many authors opted for a fuzzy version of TOPSIS (FTOPSIS) due to difficulties in linguistically determining the importance of individual criteria. Afsordegan et al. (2016) highlighted the problem of uncertainty in determining precise evaluations of decision variants if the decision-maker uses a descriptive approach. Their study aimed to identify sustainable alternative energy sources that best align with decision-makers' preferences. They utilised their own modification of the TOPSIS, converting verbal descriptions provided by decision-makers into sets of labels. Bilgili et al. (2022) employed fuzzy TOPSIS to assess RES that were expected to ensure the sustainability of Turkey. They proposed the Intuitionistic Fuzzy TOPSIS (IF-TOPSIS), which they believed performs better for problems with numerous criteria and fluctuating decision-maker preferences.

Ervural et al. (2018) also focused on RES in Turkey, integrating multicriteria optimisation with SWOT analysis.

Publications on sustainability and energy transition from countries like Turkey make frequent appearances, which is not unexpected due to their efforts to swiftly catch up with more advanced economies. Şengül et al. (2015) created a ranking of RES available in the Turkey using FTOPSIS. They determined the criterion weights using Shannon's entropy. Li et al. (2022) analysed a set of criteria for assessing the suitability of land for geothermal energy use in a province of China. They applied not only the classical TOPSIS method but also weights obtained by the entropy method. This approach made it possible to create maps of areas particularly suitable for this type of energy source. Yuan and Luo (2019) used 14 criteria to analyse China's energy security by province. Objective weights were determined by using the Mahalanobis-Taguchi Gram-Schmidt system and were then included in the SPA-TOPSIS (Set Pair Analysis TOPSIS) model.

Iqbal et al. (2021) explored Pakistan's challenges in adopting sustainable energy technologies in the industry. They combined two multicriteria optimisation methods: AHP and TOPSIS. A similar methodological approach but for Iran can be found in Sadat (2021). Sadat focused solely on barriers to photovoltaic development. Again, Pakistan is covered in a study by Solangi et al. (2019). They prepared ranking of 13 energy strategies for sustainable electricity supply planning. They also used AHP and SWOT. Rani et al. (2020) proposed an extensive algorithm for selecting RES, incorporating fuzzy TOPSIS and testing it on data from India.

Kay and Kahraman (2011) introduced a modified fuzzy TOPSIS to select among alternative energy sources. They concentrated on depicting technical, economic, environmental, and social aspects of energy production and consumption. Leng and Zhang (2023) conducted a study evaluating the progress of RES in selected countries on several continents. They used the classical TOPSIS method and proposed some ideas to promote the development of RES, including improving the efficiency of energy use, improving the renewable energy distribution system, and optimising the industrial structure.

In our research, we assess European countries using a set of predetermined criteria which outline, among other factors, their energy policies. Vavrek and Chovancová (2019) used seven indicators and the CV-TOPSIS (Coefficient of Variance TOPSIS) method. Their article aimed to provide a quantitative assessment of results of ongoing energy management and environmental measures in EU countries. While this study partially differs from ours, some criteria overlap. Wang et al. (2021) conducted an analysis covering 42 countries from all continents. They used the DEA technique to determine the most effective countries regarding producing renewable energy. They subsequently used fuzzy TOPSIS to highlight three countries with the highest capacity for renewable energy production.



The TOPSIS method also emerges in research on electromobility. Wątróbski et al. (2017) applied multicriteria optimisation to aid the selection of an electric vehicle for urban deliveries. The set of alternatives consisted of vans, and the criteria were divided into four groups, mainly focusing on technical parameters of vehicles. In addition to fuzzy TOPSIS, the authors used the PROMETHEE II method and placed the entire analysis in the context of urban logistics. Urban logistics also interested Wołek et al. (2021). Their analysis concerns the selection of bus lines on which diesel vehicles would be replaced with electric ones. Ziemba (2020) combined PROMETHEE with Monte Carlo simulation to give a tool to support the selection of electric vehicles for SD of local government units and state administration in Poland.

An interesting application of classical TOPSIS can be found in (Yildiz, 2021). Yildiz assessed the performance of batteries used in electric vehicles. Battery performance directly affects vehicle efficiency. The author examined six types of batteries by taking their technical parameters. Zhang et al. (2020) evaluated the quality of public chargers in China. They used TOPSIS and concluded that decision-makers in their country underestimate the importance of charger's availability. Zirganos et al. (2022) focused on promoting electromobility. They developed a methodology to assess a set of good practices based on predefined criteria. Combining expert knowledge and the AHP method, they determined weights for the criteria.

#### 4. The TOPSIS Method

The transition of road transportation to electromobility solutions is a complex process. To describe and assess it correctly, a whole set of criteria should be used. Our goal is to determine the distance that separates Poland from the leaders in the transformation of road transportation. Therefore, we opted for multi-criteria optimisation. We have chosen the TOPSIS method, which in our opinion is best suited to achieving the stated goal.

The TOPSIS method (Technique for Order Preference by Similarity to Ideal Solution) was developed by Hwang and Yoon (Hwang, Yoon, 1981; Cheng, Hwang, 1992). It falls under deterministic methods for multi-criteria optimisation. Its primary concept is to apply the principle of selecting decision variant that is closest to the ideal solution while simultaneously being the farthest from the anti-ideal solution.

Let's assume that the set of decision alternatives  $A = \{\mathbf{a}_1, \dots, \mathbf{a}_n\}$  is evaluated with respect to the set of criteria  $F = \{f_1, \dots, f_m\}$ . Each criterion is assigned a weight  $w_k$  and  $\sum_{k=1}^n w_k = 1$ . We will now outline the successive steps of the TOPSIS method algorithm.

**Step 1.** Create the normalised matrix  $\mathbf{N}$ . Calculate its elements using the formula:

$$x_{ik} = \frac{f_k(\mathbf{a}_i)}{\sqrt{\sum_{i=1}^m f_k(\mathbf{a}_i)^2}} \quad (1)$$

where:  $f_k(\mathbf{a}_i)$  – evaluating variant  $\mathbf{a}_i$  by criterion  $f_k$ ,  $i = 1, \dots, m$ ,  $k = 1, \dots, n$

**Step 2.** Calculate the elements of the weighted normalised decision matrix:

$$v_{ik} = w_k x_{ik} \quad (2)$$

**Step 3.** Determine the weighted ideal solution:

$$v_k^+ = \begin{cases} \max_i v_{ik} & k \in K^+ \\ \min_i v_{ik} & k \in K^- \end{cases} \quad (3)$$

and the anti-ideal solution:

$$v_k^- = \begin{cases} \min_i v_{ik} & k \in K^+ \\ \max_i v_{ik} & k \in K^- \end{cases} \quad (4)$$

where  $K^+$  represents the set of stimulant criteria, and  $K^-$  the set of destimulant criteria.

**Step 4.** Calculate the Euclidean distances separating the alternatives from the weighted ideal solution:

$$d_i^+ = \sqrt{\sum_{i=1}^m (v_{ik} - v_k^+)^2} \quad (5)$$

and the anti-ideal solution:

$$d_i^- = \sqrt{\sum_{i=1}^m (v_{ik} - v_k^-)^2} \quad (6)$$

**Step 5.** For each  $\mathbf{a}_i$  calculate the relative distance from the weighted ideal solution:

$$s_i = \frac{d_i^-}{d_i^+ + d_i^-} \quad (7)$$

The  $s_i$  belongs to the interval  $(0,1)$ . The closer the  $\mathbf{a}_i$  is to the ideal solution, the greater the value of  $s_i$  becomes. In its final step the algorithm produces a ranking of decision alternatives based on the decreasing values of  $s_i$ .

The weights from formula (2) are relevant to the results. The classical approach assumes that ratings of the decision alternatives against criteria and the weights of criteria are known and expressed using real numbers. Experts can provide weights, but in real decision problems, decision-makers have difficulty in determining their preferences and judgments. If reliable weights cannot be determined, objective weights can be used. Abbreviations for technical terms will be explained upon first use. The Shannon's entropy method is one such procedure.

Our study employed this method, and the following description of the calculations is based on (Kacprzak, 2018; Lotfi, Fallahnejad, 2010; Kobryn, 2014).

The algorithm for determining weights in the Shannon's entropy method proceeds in the following steps:

**Step 1.** Construct matrix  $\mathbf{Y}$ , where all criteria are of the stimulant type:

$$y_{ik} = \begin{cases} f_k(\mathbf{a}_i) & k \in K^+ \\ \frac{1}{f_k(\mathbf{a}_i)} & k \in K^- \end{cases} \quad (8)$$

**Step 2.** Create the normalised matrix  $\mathbf{Z}$  with elements:

$$z_{ik} = \frac{y_{ik}}{\sum_{i=1}^m y_{ik}} \quad (9)$$

**Step 3.** Calculate the entropy vector  $\mathbf{e}$ :

$$e_k = -\frac{1}{\ln m} \sum_{i=1}^m z_{ik} \ln z_{ik} \quad (10)$$

In the case where  $z_{ik} = 0$  for a certain  $i$ , the value of the component  $z_{ik} \ln z_{ik}$  equals to zero.

**Step 4.** Calculate the variability level vector  $\mathbf{d}$  for each criterion:

$$d_k = 1 - e_k \quad (11)$$

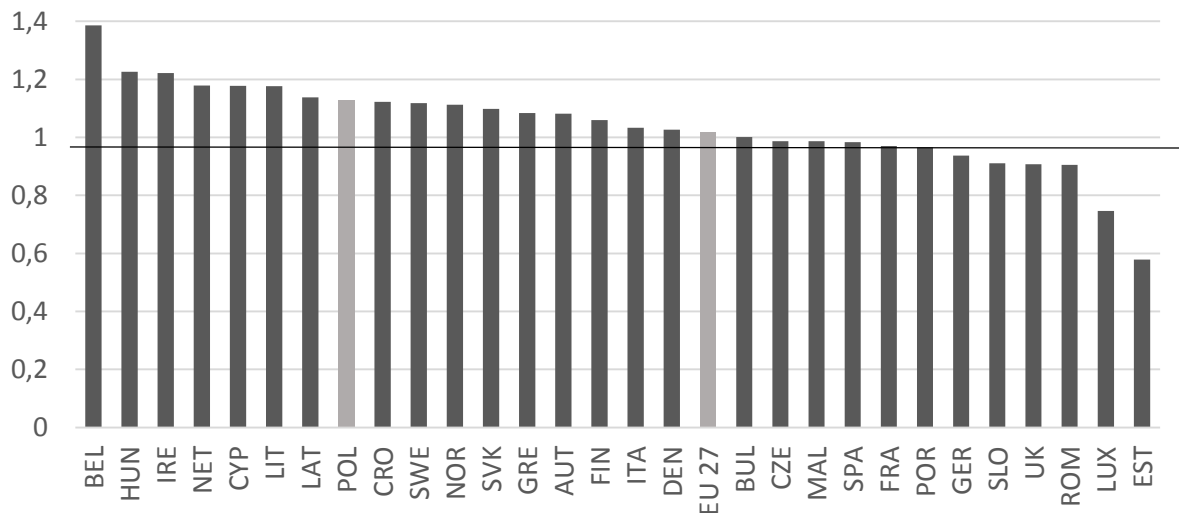
**Step 5.** Calculate the criteria weight vector:

$$w_k = \frac{d_k}{\sum_{k=1}^n d_k} \quad (12)$$

## 5. Results

### 5.1. Dynamics of electricity production for chosen European countries

We will start by presenting the analysis of the production dynamics and the balance of electricity export and import in selected European countries. The data is sourced from Eurostat database. Figure 1 depicts the dynamics of electricity production in 2021 compared to 2014. With a different shade of grey we have marked the results for Poland and the EU. Poland performs well in this comparison. We chose 2014 as the base because, in May of that year, the European Commission and the Council published a communication about the EU's strategy for energy security. This was a response to concerns about the EU's energy dependence and disruptions in supply, aiming to ensure stable and ample energy supplies for the citizens and economy of Europe.



**Figure 1.** Dynamics of electricity production 2021/2014.

Source: own calculations.

Overall, the EU recorded a modest (2%) increase in electricity production, which is positive. However, current technology development significantly increases electricity consumption. The actions of Priority Axis I of the Operational Programme Infrastructure and Environment in Poland for the years 2014-2020 aimed to improve energy efficiency and increase the share of energy from RES. Hence, the 13% increase in electricity production in Poland.

**Table 1.**

*Balance (Export - Import) of Electricity (GWh)*

	2018	2019	2020	2021		2018	2019	2020	2021
<b>AUT</b>	-8946.8	-3128.6	-2195.8	-7543.2	<b>IRE</b>	27.73	-644.54	151.9	-1587.6
<b>BEL</b>	-17327.5	1854.6	332.9	7876.5	<b>ITA</b>	-43898.8	-38141.2	-32200.4	-42789.8
<b>BUL</b>	7807.3	5810.2	3408.1	8778.3	<b>LAT</b>	-908.9	-1118.08	-1625.6	-1772.6
<b>CRO</b>	-5387.6	-6133	-4639.3	-3961	<b>LIT</b>	-9632.5	-9343.6	-7908.5	-9043.7
<b>CZE</b>	13907.1	13096.6	10152.9	11075.3	<b>NET</b>	-7969.9	-855.235	2659.5	-252.9
<b>DEN</b>	-5224.3	-5810.9	-6882.6	-4868.8	<b>NOR</b>	10149.2	-44	20472.1	17583.8
<b>EST</b>	1897	-2157	-3644	-2629	<b>POL</b>	-5694.5	-10623	-13267	-887.8
<b>EU 27</b>	-8850.5	-2944.7	-13962.3	-7317.4	<b>POR</b>	2657	-3399.17	-1456.3	-4753
<b>FIN</b>	-19936	-20042	-15104	-17768	<b>ROM</b>	2544.4	-1518.02	-2792.3	-2199
<b>FRA</b>	62966.7	57667.1	45039.2	44892.3	<b>SLO</b>	502.2	318.556	2003.1	270.4
<b>GER</b>	48736	32667	19029	18575	<b>SPA</b>	-11102	-6862.3	-3279.6	-852.4
<b>GRE</b>	-6278	-9944	-8864	-3684	<b>SVK</b>	-3682	-1700	-319	-774
<b>HUN</b>	-14348	-12584	-11677	-12754	<b>SWE</b>	17223	26161	24997	25568

Source: own calculations.

Belgium leads this ranking with a growth of 39%, attributed to the maintenance of nuclear power plants and the construction of modern offshore wind farms (located at sea). Additionally, Belgium gradually increased the use of gas in its energy mix. Estonia closes the ranking. Its low electricity production dynamics (below 60%) is related to the closure of four oil shale energy blocks. The country has thus reduced its greenhouse gas emissions (GHG).

In Table 1, we present the electricity balance (in GWh) for selected European countries for the period 2018-2021. It is the difference between electricity exports and imports. Countries with a positive annual electricity balance produce more electricity than their demand.

Countries with a favourable geographical location, such as the Scandinavian countries, take advantage of the natural conditions to produce larger amounts of electricity. They are thus becoming the leading suppliers in Europe. Countries utilising nuclear energy also exhibit a positive balance in the examined years. An example is France, which has the most nuclear reactors in Europe with a total capacity of more than 63,000 megawatts. Nuclear power plants alone make it possible to meet about 75% of French electricity demand. There have been fluctuations in Poland's balance value, however, it has consistently remained negative. Despite Poland possessing natural coal deposits, the EU climate policy is pushing the country to abandon this fuel.

## 5.2. Status of electromobility road transport implementation in Europe

To assess and compare the degree of implementation of electromobility solutions in selected European countries, we calculated an index giving the number of electric vehicles per 1000 internal combustion engine vehicles. We present this index separately for passenger cars, buses and coaches, and trucks for the period 2018-2021. Our index measures consumer interest in electric vehicles. A higher value indicates a greater significance of electromobility in the transportation sector of a given country.

In Table 2, we presented the number of passenger electric cars per 1000 of their combustion engines counterparts. We have not taken hybrids or plug-in hybrids into account. The denominator includes cars powered exclusively by petrol and diesel engines.

**Table 2.**

*Number of electric cars per 1,000 equivalent internal combustion engine vehicles*

Country	2018	2019	2020	2021	Country	2018	2019	2020	2021
AUT	4.24	5.96	8.98	15.57	LAT	0.67	0.97	1.74	2.95
BEL	1.62	2.68	4.24	7.33	LIT	0.74	1.02	1.74	3.32
CRO	0.29	0.44	0.78	1.74	NET	5.57	13.08	21.36	30.66
DEN	3.89	5.90	11.98	25.20	NOR	82.54	112.69	148.51	211.04
EST	1.70	1.77	2.24	3.07	POL	0.15	0.25	0.46	0.84
FIN	0.73	1.40	2.88	6.89	POR	1.93	3.42	5.00	8.02
FRA	2.84	3.77	6.58	10.94	ROM	0.17	0.41	0.81	1.66
GER	1.80	2.93	6.65	13.49	SLO	1.16	1.74	3.20	4.67
HUN	1.07	1.77	2.90	4.88	SPA	1.10	1.64	2.36	2.74
IRE	2.16	3.94	5.79	9.88	SWE	3.74	6.85	12.77	26.01
ITA	0.34	0.64	1.50	3.38					

Source: own calculations.

Norway has the highest ratio values in all years. It ranges from around 83 to more than 200 electric cars per thousand combustion cars. Norway surpasses other European countries in this regard. Only in 2021 do some countries, such as the Netherlands or Sweden, reach a level of EV saturation that deems electromobility significant. However, this is still around 25-30

electric cars per 1000 combustion cars. At the other end of the scale is Poland, which performs the worst of all the countries. It loses even to countries with theoretically weaker economies.

In all countries, the ratio of the number of electric to combustion cars is increasing over time. These changes range from tens to over a hundred percent year-on-year. Italy, for instance, recorded growth of 86%, 135%, and 116%, respectively. On the other hand, the growth rate slowed down in 2021 for almost all countries, which may be related to the prevailing COVID-19 pandemic at that time.

Diesel buses, vans, etc. (see Table 3) had only diesel engines due to the lack of data on petrol engines for this category. The number of countries slightly decreased due to the unavailability of data from Estonia and Ireland.

The values shown in Table 3 are not as straightforward as those for passenger cars. One reason is that a higher number of countries have electric buses compared to diesel ones, mainly because local authorities regulate public transport and can more readily introduce electromobility solutions. The EU's Strategy for Sustainable and Smart Mobility has backed the adoption of these greener buses which have replaced their older counterparts.

**Table 3.**

*Number of electric buses per 1,000 equivalent internal combustion engine vehicles*

Country	2018	2019	2020	2021	Country	2018	2019	2020	2021
<b>AUT</b>	16.01	16.50	17.93	18.06	<b>LIT</b>	61.06	71.16	62.18	60.46
<b>BEL</b>	1.22	2.85	4.51	6.03	<b>NET</b>	45.75	91.53	164.95	208.56
<b>CRO</b>	0.52	0.51	0.59	1.19	<b>NOR</b>	2.92	13.78	31.32	39.21
<b>DEN</b>	0.56	6.94	7.86	28.04	<b>POL</b>	5.35	3.47	5.47	7.56
<b>FIN</b>	1.31	3.40	4.80	14.79	<b>POR</b>	2.54	4.44	6.66	8.74
<b>FRA</b>	5.16	8.07	9.64	17.53	<b>ROM</b>	0.27	1.29	2.97	4.74
<b>GER</b>	2.91	4.89	10.17	17.32	<b>SLO</b>	1.46	2.17	2.71	2.38
<b>HUN</b>	1.29	1.16	2.60	5.34	<b>SPA</b>	4.20	6.72	7.87	5.50
<b>ITA</b>	5.15	5.72	5.47	7.95	<b>SWE</b>	9.95	26.19	57.71	81.21
<b>LAT</b>	56.15	59.25	70.34	81.29					

Source: own calculations.

The Netherlands performed exceptionally well in Table 3, surpassing even Norway, the leader in Table 2. It has the most favourable ratio of electric to combustion vehicles. Croatia achieved the weakest results. Poland ranked in the second ten, surpassing Belgium but lagging behind Portugal.

The dynamics of the indicator also proved to be much more diverse. Over the first three years, we mainly observe increases in the number of electric buses per 1000 combustion equivalents. However, in 2021, some countries experienced a decrease. This was the case in Spain (30% drop) or Slovenia (12% decrease). In other countries, the indicator continued to grow compared to 2020 but much less.

Table 4 presents the number of electric heavy-duty vehicles per 1000 combustion equivalents. It includes the fewest number of countries, as only a few have published relevant data. This is partly due to the importance of the transport sector in their economies and partly due to the practice of collecting statistical data.

**Table 4.**

*Number of electric heavy-duty vehicles per 1000 equivalent internal combustion engine vehicles*

Country	2018	2019	2020	2021	Country	2018	2019	2020	2021
AUT	4.56	5.34	6.59	10.50	NET	3.36	4.57	6.14	9.12
FIN	0.54	0.62	0.83	1.35	NOR	9.69	13.19	17.58	17.73
FRA	6.25	7.19	8.19	9.46	POL	0.58	0.74	0.57	0.76
GER	5.67	7.57	9.63	12.62	POR	0.46	0.69	0.92	1.22
HUN	0.79	0.98	1.36	2.03	SPA	1.16	1.49	1.84	2.17
ITA	1.40	1.30	1.46	2.24	SWE	4.25	6.20	9.11	12.94

Source: own calculations.

Once again, Norway stands out the most, although its advantage over countries like Sweden or Germany is not as significant. Poland performs the weakest in 2020 and 2021, although even before its index was low. As a country located at the crossroads of trade routes, Poland has a transport sector that is significant for Europe. However, it is highly fragmented, with small companies responsible for most transportation. Until now, they have invested in car fleets powered by combustion engines. Due to frozen capital in these vehicles, leasing agreements, etc., they cannot quickly switch to electric vehicles. Limited charging infrastructure, especially along international and national roads, is also an important factor.

Polish companies often undertake long-distance cargo transport, so combustion engines still lack competition. Nevertheless, over four years, the indicator increased in all surveyed countries each year. Even in 2021, these increases reached tens of percent, except for Norway, where it was only 1%.

### 5.3. Multi-criteria ranking of countries using the TOPSIS method

Fuzzy methods require each decision option to be described by a certain set of numbers (e.g., three for triangular fuzzy numbers) instead of one. This approach is employed when decision-makers may struggle to unambiguously determine the value of available options. We chose the classical TOPSIS method because our study relied on annual macro data, sourced from reliable government institutions. The greater challenge was the selection of criteria themselves due to data gaps than the values available for decision variants, i.e., countries. Below, we present our set of criteria:

1. Share of electricity import (C1).
2. Share of renewable electricity in total energy consumption in the transport sector (C2).
3. Newly registered electric passenger cars [units] (C3a).
4. Newly registered electric commercial vehicles [units] (C3b).
5. Final electricity consumption in the road transport sector [kt of oil equivalent] (C4).

We divided the study into two parts according to criterion C3. One set of rankings was based on criteria C1, C2, C3a, and C4, while the other used C1, C2, C3b, and C4. This enabled us to analyse the implementation of electromobility regarding both personal passenger transport (private cars) and heavy road transport, independently. Trucks in the study are the sum of

vehicles up to 3.5 tons and those above. The first study covered 19 European countries (not only from EU) for the years 2014-2021. In the second, we included data from 16 countries for the years 2017-2021. There are two reasons behind this: to separate commercial road transport from private passenger transport and to address the lack of data, as some countries did not publish data on commercial transport required for our study. We therefore had to limit the time horizon to ensure the highest possible number of decision variants.

The study focused solely on electric vehicles, which must be charged. This creates an additional demand for electricity. Hence, we added the final electricity consumption in the road transport sector (criterion C4). We also expect that the more popular electromobility is in a country, the more electricity comes from renewable sources. This is due, among other things, to the regulations introduced within the EU. This is why we introduced criterion C2, i.e., the share of renewable electricity in total energy consumption in the transport sector. Finally, the demand for electricity generated by the transport sector influences a country's energy security. Criterion C1, i.e., the share of electricity import, aims to introduce the security aspect into the study. Incidentally, it is the only destimulant among all criteria.

**Table 5.**

*Weights determined for criteria, divided into passenger and commercial vehicles*

Criteria	2014	2015	2016	2017	2018	2019	2020	2021
	<b>Passenger cars</b>							
K1	0.3276	0.1146	0.3084	0.3227	0.3382	0.3242	0.293	0.2967
K2	0.309	0.4312	0.3268	0.3201	0.3358	0.3271	0.3596	0.3567
K3a	0.118	0.1653	0.1513	0.1653	0.152	0.1608	0.1474	0.1404
K4	0.2454	0.2889	0.2134	0.1919	0.174	0.188	0.2	0.2063
<b>Heavy-Duty Trucks</b>								
K1				0.3724	0.3683	0.34	0.2853	0.2834
K2				0.3777	0.3706	0.3475	0.3712	0.3576
K3b				0.0598	0.1001	0.1288	0.1534	0.1794
K4				0.1901	0.1611	0.1837	0.1901	0.1795

Source: own calculations.

Table 5 shows the weights determined by the Shannon's entropy method. We determined a separate set of weights for each year and the two study options. For criteria C3a and C3b, weights took the lowest values, while the highest occurred for criteria C1 and C2.

Table 6 shows the first part of results from the TOPSIS method. These rankings indicate the performance of each country based on the criteria adopted, with 1 being the best performing option. The dark grey colour cells indicate the top five countries in each year. Bold numerical values highlight the three worst countries in each ranking. We chose to highlight the top five positions in the rankings, as the first two places belong, throughout the entire study period, to Norway and Sweden. Their dominance is particularly evident towards the end of the sample. On the other hand, greater variability is observed in positions 3 to 5, where countries such as Germany and the Netherlands appear and have been trying hard to develop electromobility in recent years.

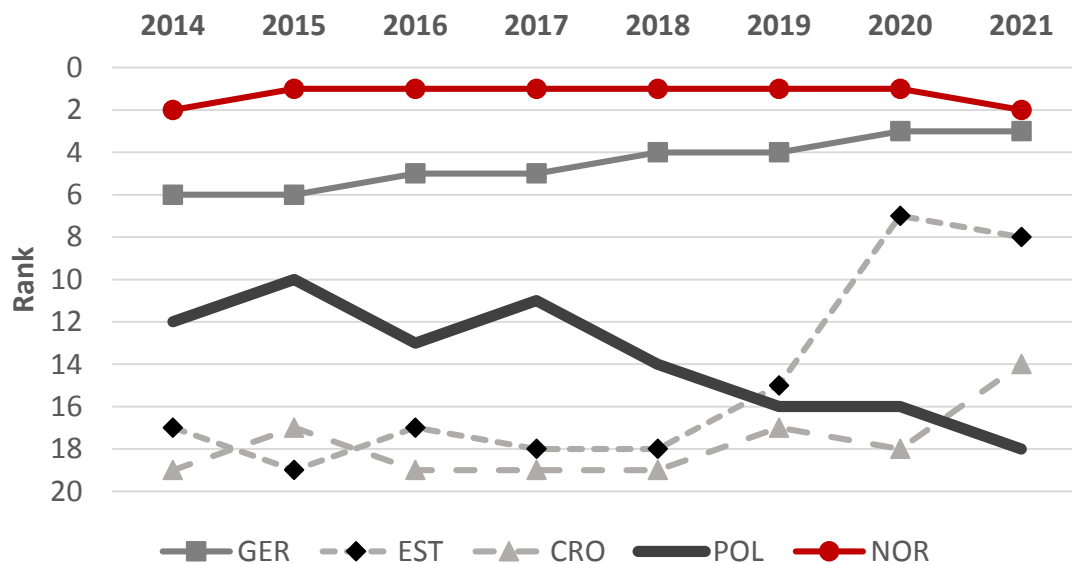


**Table 6.**  
*TOPSIS rankings for passenger cars*

Country	2014	2015	2016	2017	2018	2019	2020	2021
AUT	7	7	6	7	7	7	12	12
BEL	14	15	11	12	10	10	8	9
CRO	19	17	19	19	19	17	18	14
DEN	13	11	9	13	11	14	13	7
EST	17	19	17	18	18	15	7	8
FIN	1	2	7	4	6	6	6	4
FRA	3	4	3	3	5	5	5	6
GER	6	6	5	5	4	4	3	3
HUN	11	8	8	8	9	11	9	17
IRE	15	12	14	10	12	9	14	19
LAT	8	14	16	16	16	18	17	15
LIT	10	13	15	15	17	19	19	16
NET	5	5	4	6	3	3	4	5
NOR	2	1	1	1	1	1	1	2
POL	12	10	13	11	14	16	16	18
ROM	9	9	10	14	13	12	15	13
SLO	18	18	18	17	15	13	11	11
SPA	16	16	12	9	8	8	10	10
SWE	4	3	2	2	2	2	2	1

Source: own calculations.

The bottom positions in the rankings, i.e., the weakest results based on the adopted criteria, are occupied by smaller countries with less developed economies such as Croatia or the Baltic countries (Lithuania, Latvia, and Estonia).



**Figure 2.** Changes in rankings over time for passenger cars.

Source: own calculations.

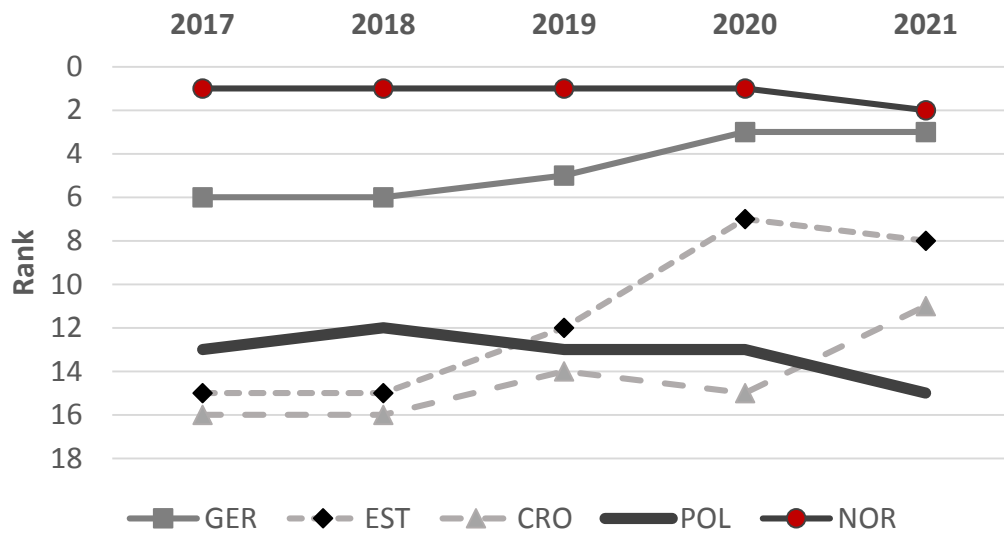
**Table 7.**  
*TOPSIS rankings for heavy-duty trucks*

Country	2017	2018	2019	2020	2021
AUT	7	7	7	10	9
CRO	<b>16</b>	<b>16</b>	<b>14</b>	<b>15</b>	11
EST	<b>15</b>	<b>15</b>	12	7	8
FIN	3	4	6	6	4
FRA	4	3	4	4	5
GER	6	6	5	3	3
HUN	9	10	11	9	<b>14</b>
IRE	10	11	10	11	<b>16</b>
LAT	<b>14</b>	13	<b>15</b>	<b>14</b>	12
LIT	12	<b>14</b>	<b>16</b>	<b>16</b>	13
NET	5	5	3	5	6
NOR	1	1	1	1	2
POL	13	12	13	13	<b>15</b>
POR	8	8	9	12	10
SPA	11	9	8	8	7
SWE	2	2	2	2	1

Source: own calculations.

Figure 2 illustrates the changes in rankings over time for a few selected countries. Over an eight-year period, Norway has typically ranked first, outclassing the other countries. This is due to both its energy policy (Norway exports large amounts of electricity) and its measures to promote electromobility. However, noteworthy are Germany's methodical ascent in the rankings and Estonia's substantial improvement since 2019. Estonia is the only one of the Baltic states to have seen such a big improvement. The bold line without markers corresponds to Poland. Since 2015, it has gradually declined in the rankings. 2015 saw the seizure of power by the Law and Justice party, which maintained its rule until the end of the surveyed sample. The party advocates for a strong reliance on coal in the energy sector for several more decades. Additionally, Polish government efforts to increase the share of RES in the energy mix and promote electromobility proved to be largely ineffective. Consequently, the large gap between Poland and leaders like Norway or Germany has grown over time.

Table 7 presents another summary of TOPSIS rankings, this time for heavy-duty trucks. Like in the previous table, dark grey shading indicates the five highest ranks, while bold formatting highlights the three lowest values. Once again, the results in Table 7 are dominated by Norway and Sweden. France, which has a large transport sector, also performed well. The bottom positions in the rankings still belonged to Croatia and the Baltic countries.



**Figure 3.** Changes in rankings over time for heavy-duty trucks.

Source: own calculations.

In Figure 3, we present a graph of the change in rankings over time for the same countries as before. This figure concerns electric trucks. Germany again showed an improvement in rankings. Estonia, as was the case for passenger vehicles, has started to climb very strongly in 2019. Poland's situation is only slightly better when it comes to heavy-duty trucks. The declining trend has clearly weakened, yet the distance from the ranking leaders remains substantial.

## 6. Discussion

The electricity economy and electromobility are closely intertwined. A well-functioning power grid fosters innovation and increased interest in electric vehicles. In countries facing an energy crisis, consumer and business interest in electrically powered equipment and machinery declines. Moreover, European countries are witnessing a rising share of RES in the energy mix resulting from the EU's climate and emissions reduction policies. These factors are influencing the development of electromobility on the continent. Part two of the article showed how much the development of road transport is affected by the regulations introduced by the EU and the parliaments of the Member States. EC directives and Polish laws regularly emphasise the importance of developing infrastructure for the operation and charging of electric vehicles. After all, the lack of infrastructure is seen as the biggest obstacle to the development of electromobility.

Electricity production is one component of the European energy economy. The other is its export and import. An extensive energy network connecting individual countries minimises network overloads and transfers energy between states according to demand. This not only stabilises the network but also minimises energy losses. In addition, energy storage facilities are being developed to store surplus production, but this is not an ideal solution. Governments, energy distributors, and leading energy storage component companies recognise the following problem: modern energy storage methods are neither efficient enough nor cost-effective.

The balance between electricity exports and imports is important for the country's energy security. Based on the results in subsection 5.1 (see Table 1), we find that only a few countries have a surplus of energy that they can export. Poland is not in this group.

As our first objective, we aimed to evaluate the extent to which electromobility solutions have been implemented in road transport. The data utilised in this study allows for the following conclusions to be drawn:

1. There are very large differences in the popularity of electromobility among European countries. Only in a few countries has this process yielded significant results. In most of them, the transportation sector is just beginning the electric transformation, with public bus transport performing best in this regard.
2. All countries experience a year-on-year increase in the number of electric vehicles compared to their combustion counterparts. The aforementioned transformation is therefore taking place across Europe even if the pace varies from country to country.

In subsection 5.2 we opted for the number of newly registered vehicles instead of the total number. The greater diversity in the former better reflects changes in transitioning to electromobility over time and differences between countries. Additionally, interest in purchasing EVs is strongly linked to technical solutions used. The gradual development of batteries increases a vehicle's range, which is important for potential buyers who may still choose a combustion engine vehicle. The study therefore needed a variable to somehow represent the technical progress being made with electric cars, and in our opinion, it is the number of newly registered vehicles that describes this process well.

The criteria used in TOPSIS take into account the popularity of electromobility, energy security and the relationship between road transport and RES. Both parts of the analysis (cars and trucks) in subsection 5.3 were dominated by Norway and Sweden. These countries had a surplus of electricity exports over imports. However, this is not the only reason for their dominance as other countries with a surplus perform much less well, e.g. Slovenia. It is the size of the export surplus and the related strength of the economy that is decisive. We have pointed this out when describing the rankings in Tables 6 and 7.

## 7. Conclusions

We have met both goals stated in the introduction. The implementation of electromobility solutions in road transport across Europe is limited to only a handful of countries, namely Norway, Sweden, the Netherlands, and Germany. However, this implementation aligns with the European Commission's plans outlined in a series of documents. Public bus transportation performs particularly well in this regard. Most countries do not have sufficiently developed grid infrastructure and charging stations. On the other hand, we have observed a clear upward trend in the number of electric vehicles compared to their combustion counterparts. This trend applies to the entire EU, although there are differences among member states.

Poland compares very poorly with the leaders in road transport transformation and occupies roughly the same distant position in the rankings. In the case of passenger cars, it has been steadily declining since 2015. Government actions have not yielded sufficient results, and Poland can compare itself with other Central and Eastern European countries rather than with Western Europe.

We have demonstrated that the use of RES and electromobility in transportation is undergoing dynamic changes. EU authorities are aware of the reasons that hindered their ambitious plans. They will certainly take remedial actions. It is therefore worth monitoring these processes and continuing research in the future.

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## THE WAY FORWARD. THINKING ABOUT RESILIENCE: HOW DO FARMERS ADAPT TO CHALLENGES AND ENSURE A BETTER FUTURE?

Agnieszka KURDYŚ-KUJAWSKA<sup>1</sup>, Michał SOLIWODA<sup>2</sup>, Marcin OLKIEWICZ<sup>3\*</sup>,  
Virginia NAMIOTKO<sup>4</sup>

<sup>1</sup> Department of Finance, Faculty of Economic Sciences, Koszalin University of Technology;  
agnieszka.kurdys-kujawska@tu.koszalin.pl, ORCID: 0000-0002-6024-2947

<sup>2</sup> Department Corporate Finance, Institute of Finance, University of Lodz; michal.soliwoda@eksoc.uni.lodz.pl,  
ORCID: 0000-0003-4207-4641

<sup>3</sup> Department of Management and Marketing, Faculty of Economic Sciences, Koszalin University of  
Technology; marcin.olkiewicz@tu.koszalin.pl, ORCID: 0000-0001-6181-6829

<sup>4</sup> Department of Sustainable Food Systems, Institute of Economics and Rural Development of Lithuanian Centre  
for Social Sciences; virginia.namiotko@ekvi.lt, ORCID: 0000-0002-9210-8347

Department Corporate Finance, Institute of Finance, University of Lodz (IDUB Junior Researcher);  
virgiana.namiotko@eksoc.uni.lodz.pl

\* Correspondence author

**Purpose:** The purpose of the article is to identify the resilience capabilities of farmers from the Western Pomerania region in response to emerging economic, social and environmental challenges.

**Design/methodology/approach:** The research used literature studies and quantitative surveys. This study used a set of primary data obtained by direct survey using a structured survey questionnaire. The survey was conducted in 2022. This study focuses on the concept of thinking about resilience.

**Findings:** The subjective assessment of resilience (past, current and future) as well as its components showed that farm managers are aware of the formation of this economic and organizational category. Resilience was most frequently associated by respondents with adaptive capacity and least frequently indicated a link with transformation. It should be considered as worrying that the same percentage of farmers stated that the farm is and will be resilient to external factors. This indicates that farmers do not treat the category of resilience as a process that changes over time. Methods/techniques for strengthening resilience as one of the three dimensions mainly include those relating to the payment of current liabilities (equating current financial resilience with liquidity), long-term financial resilience, provisioning and the use of insurance (mainly crop insurance).

**Research limitations/implications:** The research adopted a purposive sampling method, which has its limitations.

**Originality/value:** The research contributes to the long-standing discussion on identifying pathways to improve the ability of agricultural actors to survive and recover from shocks in the light of the growing challenges of today's world, and to develop strategies and policies for the resilience of agriculture and related systems in the context of economic, social, and environmental challenges.

**Keywords:** resilience thinking, robustness, adaptation, transformation, farm.

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

## 1. Introduction

Agriculture is part of a complex global food production system, driven by economic, social, and environmental forces beyond farmers' control. These forces are responsible for most of the events that have raised concerns about food security and the sustainability of current agricultural production systems (Gardner, Ramsden, 2019). The global pandemic, climate change, social and political conflicts and unrest, increased inflation, rising input costs and shortages of production means have recently increased uncertainty as to the profitability and future direction of agricultural production not only in Poland but also in the world. The lack of actions to mitigate the adverse effects of events in the short term, combined with the lack of actions to improve the resilience of the agricultural sector, will deepen the problems in agriculture. This will make it significantly more difficult for agriculture to provide desired public and private goods, to the detriment of society and the economy. Farms play a key role in maintaining social cohesion, producing food, providing renewable energy, providing recreational and health care services, and maintaining the cultural landscape. In the longer term, accumulating economic, social, and environmental challenges are expected to significantly disrupt agricultural activities, resulting in reduced investment, erosion of human capital through job loss, farm abandonment, lack of successors, poverty, fragmentation of global trade and links with deliveries (Soliwoda, Kurdyś-Kujawka, 2022). This situation is a major challenge that requires institutional support and action at the farm level to reduce vulnerability and build a shock-resistant agricultural sector in both the short and long term.

Agriculture needs the capacity to withstand and adapt to various shocks and disruptions. This capacity is called agricultural resilience and is defined by USAID as the ability of people, households, communities, countries and systems to mitigate, adapt to, and recover from shocks and stresses in ways that reduce chronic vulnerabilities and facilitate integration growth (USAID, 2012). Building the resilience of the agricultural sector means strengthening the ability of its components to anticipate, absorb, adapt, or recover from the effects of a hazardous event in a timely and effective manner, including by ensuring the preservation, restoration or improvement of its basic structures and functions (IPCC, 2012).

Various solutions are available to build farm resilience. Farmers can protect themselves against future threats through insurance and can obtain loans or credits to adapt to change, e.g., by purchasing appropriate production inputs for climate-smart agriculture. They could also pool resources by working more closely with other farmers. Such pooling could help access financial services, reduce costs, negotiate interest rates, aggregate product sales, etc. (Bolt, 2019).

The need to adapt agriculture to unpredictable challenges is well established in world literature, in Poland there is relatively little research that shows how challenges related to agricultural activity affect farms and how farmers adapt their farms to survive shocks and stand become resistant. This study fills this gap by presenting conclusions from research on the analysis of disruptions in agricultural activities, as well as farmers' attitudes and reactions to emerging challenges. In our study, we focus on the concept of thinking about resilience. Resilience thinking offers a comprehensive approach that can be used to interpret past and present conditions and identify possible futures for agricultural systems (Sinclair et al., 2017). Resilience thinking shapes contemporary EU policy and its implementation to increase the ability to respond to crises and future challenges in all areas of human life and activity. We use resilience thinking to identify how farmers adapt to challenges and ensure a better future. The aim of our study is to identify the resilience capabilities of farmers from the Western Pomerania region in response to emerging economic, social and environmental challenges. The research questions we address in this article are:

- 1) What events have occurred that challenge agricultural activities and how have these challenges generated threats to the farm?
- 2) How did farmers perceive overall farm resilience?
- 3) What resilience actions were implemented by farmers in the face of the challenges?

Our research contributes to the long-standing discussion on identifying pathways to improve the ability of agricultural actors to survive and recover from shocks in the light of the growing challenges of today's world, and to develop strategies and policies for the resilience of agriculture and related systems in the context of economic, social, and environmental challenges.

## **2. Conceptualization of resilience**

Changes, although some are intended, can also be triggered by sudden and unexpected events. The impact of such events on agricultural systems is unpredictable and may be far-reaching (Darnhofer, 2021). There can be many sources of unpredictability. Sadowski (2023) indicates, among others, sources of unpredictability of a natural nature (e.g. droughts, floods, pandemics), political (new political solutions, sanctions, wars), technological (new production methods, new energy sources), social (new market preferences, changes in behavior) or economic (changes in prices), emphasizing that this is not a closed list of possible sources of unpredictability in business activities, including agricultural ones. Agricultural systems face increasing challenges from economic, environmental, social, and institutional changes (Meuwissen et al., 2020; Olkiewicz, Wolniak, 2018). This means that the current approach to conducting agricultural activities will no longer be sufficient (Sinclair et al., 2014).

Farm managers will need to implement adaptive or transformational change if they want to secure their future (Viljoen et al., 2008; Wyszomirski, Olkiewicz, 2020; Olkiewicz, Wolniak, 2020).

The increasingly changeable conditions of running a business and functioning of societies are an important reason to explore the category of resilience (Grzelczak et al., 2023). Darnhofer (2021) states that much research on change in agricultural systems has focused on slow, predictable, controlled, planned, and managed changes, with much less attention to their ability to cope with the unexpected, cope with surprises and benefit from unpredictable events. Resilience thinking provides an alternative narrative to the conventional concept of resilience, based on the dynamics of equilibrium and the predictability of change, with the implicit understanding that change must be resisted to maintain stability (Folke, 2016). According to Linkov and Trump (2019), thinking about resilience requires considering potential future threats and developing countermeasures or safeguards to prevent long-term losses, not just immediate losses resulting from historical threats. Resilience thinking is not about mitigating and managing threats based on a snapshot in time, but about seeking flexibility in the support system, ultimately ensuring a "soft landing" and a quick return to pre-event status.

In the context of agriculture, resilience should be understood as the ability to prepare and plan for, absorb, recover from, and more successfully adapt and transform in response to adverse events (NAS, 2012). This is consistent with the definition of resilience developed by The National Academy of Sciences (NAS) and includes all relevant possible adverse events, highlights the multidimensional capabilities needed to achieve resilience, and recognizes that in the long term the system must be able to change in order to survive (OECD, 2020). Folke et al. (2021) agricultural resilience refers to coping with complexity, uncertainty and change and to continuous development in the context of constantly changing environments. Meuwissen et al. (2019) understands resilience as the ability to perform the functions of a farm (i.e., provide public and private goods) in the face of economic, social, environmental, and institutional shocks and stresses by using immune capabilities such as robustness, adaptability, and transformability. These three capabilities are essential for farm resilience (Kuntke et al., 2022)

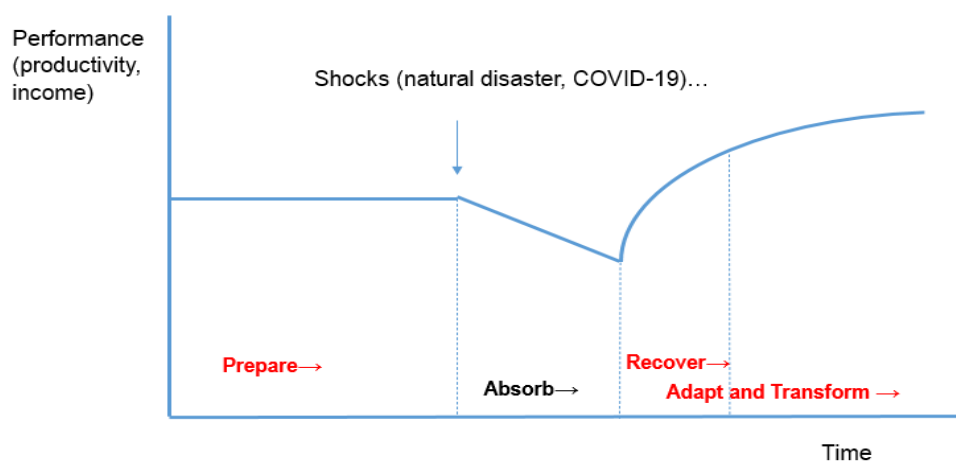
Robustness is related to traditional risk management strategies, including preventive strategies to reduce exposure to an adverse event, mitigation strategies to reduce the potential impact of an adverse event, and coping strategies to reduce the impact of an adverse event on indirect losses following the occurrence of a risky event (OECD, 2011).

Adaptive ability allows you to adapt to undesirable situations by undergoing certain changes, but without changing internal structures (Meuwissen et al., 2019). It refers to solving current, specific problems, not on integrated solutions (Swart et al., 2023). At the farm level, adaptation involves autonomous "learning by doing" (Vermeulen et al., 2018). Adaptation measures often take the form of adjustments to the organization of production, such as shifting planting dates, adjusting crop composition, adjusting the source of labor, or reducing labor

needs through mechanization or investing in more efficient water use technologies or better seed quality (Ignaciuk, 2015).

Transformability, in turn, means the ability to significantly change internal structures in order to return to normal or improved operation (Meuwissen et al., 2019). Implementing a transformation requires effort to initiate it and then sustain that effort, often over extended periods of time (Kates et al., 2012). Transformation means moving to a new system in which a separate set of factors become important in the design and implementation of shock response activities. This is a change in which the farm adopts new basic operational assumptions, new "rules of the game", i.e., a different logic organizing resource flows and linking activities on the farm and beyond (Folke et al., 2002). In agriculture, transformational change may include large-scale adoption of technologies, business changes to exploit demand for niche or high-value-added products, reorganization of the value chain to better exploit current or future market opportunities, or even exit from agriculture (Kates et al., 2012).

The capacity for resilience will vary depending on farms, their prior preparation before the occurrence of a possible event/shock, through the use of different ex ante strategies that could strengthen some ex-post capacities. Not all farms have the same level of absorption, i.e., the ability to cope with the direct consequences of an unfavorable event, which contributes to their stability. After the shock, farms must rebuild, which in turn requires readiness and flexibility in adaptation and transformation to achieve at least the level of efficiency (productivity, income) before the shock or to achieve higher income or productivity compared to the period before the shock but overall (Sauer, Antón, 2023). This, in turn, may be determined by farmers' attitude towards changes or having sufficient resources (land, labor, capital) to introduce these changes. A graphical presentation of the resilience capacity is shown in Figure 1.



**Figure 1.** Resilience capacities according to impact of shock on reference performance variable.

Source: Sauer, Antón, 2023.

In its most basic form, building resilience in agriculture is about maintaining agricultural productivity despite the inevitable uncertainties that exist. Agricultural resilience ensures that management actions do not push the surrounding landscape beyond its boundaries; future opportunities to produce goods or income will not be lost; and new opportunities are being created that enable manufacturers to go to market, learn, innovate, and adapt when shocks occur (CRAWL, 2023).

Resilience should be treated as a crucial factor for the success of every organization in unstable and uncertain times, allowing it to cope with various types of disruptions, from unfavorable events to major crises (McCann, Selsky, 2012).

### **3. Methodology**

#### **3.1. Data collection and analysis**

This study used a set of primary data obtained by direct survey using a structured survey questionnaire. The survey questionnaire was built based on the literature review, including identified research gaps. 380 users of individual farms from the Western Pomerania region took part in the survey. The sample size was determined based on the assumed values: confidence level: 95.00%; maximum estimation error: 5.00%; size of general population: 25,401; fraction size: 0.5. The research was conducted in December 2022. The Western Pomerania region was selected for research deliberately due to the typically agricultural nature of the region. Agriculture in the Western Pomerania region is characterized by dominance of farms focused on market production, large farm area, the lowest percentage of people working in agriculture in the country, a high degree of mechanization and the best conditions for highly commercial production. Constant changes in the structure of farms mean that their average size exceeds 32 ha and is three times higher than the corresponding value for the entire country, even higher than the EU average. This creates the possibility of specialization, concentration of production, as well as the use of the scale effect and the generation of high incomes, as well as the dissemination of the best patterns for large-scale farms (Strategia WZP do 2030, 2019).

#### **3.2. Characteristics of farms**

In the analyzed group, the average age of users of individual farms was 49 years. The average age of farmers participating in the study was similar to the average age of a farm user in Poland (50 years), but it was much lower than the average age of an EU farmer (57 years). In terms of age, the analyzed group of farmers did not differ significantly (coefficient of variation: 17.72%). The youngest user of an individual farm was 28 years old, and the oldest was 71 years old. More than half of the farmers managed their farms on their own for 25 years



or more. It can therefore be assumed that the surveyed farmers had quite extensive experience in farm management. The average age at which they took over the farm was twenty-four. Among the users of individual farms, the majority were people with secondary/post-secondary education (45.00%) and vocational education (31.58%). Every fifth farmer surveyed had higher education. A small group were farmers with primary/lower secondary education (2.11%). Over 70% of farmers declared agricultural education. In this group, the highest percentage were farmers with secondary and vocational agricultural education.

Taking into account the agricultural space management system in the field of plant and livestock production, traditional entities based on family labor resources dominated the analyzed farms. A feature of these farms is family solidarity and simultaneous flexibility in the face of periodic crises - the family can respond to them by reducing their needs in the event of lower income (NIKiDW, 2023). 27.89% of farmers followed an agricultural model focused on intensive production using all available means to obtain the highest possible efficiency and profit maximization. 11.05% of users of individual farms used industrial means of production in a moderate way to combine high efficiency with ecology. Such a management system is referred to as integrated plant production, which is a modern food quality system that uses technical and biological progress in a sustainable manner in cultivation, plant protection and fertilization, and pays special attention to environmental protection and human health (MRiRW, 2023). Precision farming based on the use of digital techniques to monitor and optimize agricultural production processes was characteristic of 8.95% of users of individual farms. Pro-environmental farming methods and agrotechnical treatments aimed at protecting the natural environment were used by a small percentage of farmers (3.68%).

The average area of agricultural land in the analyzed farms was 59.11 ha. Most farm users operated on an area exceeding 50 ha (median). In terms of the area of agricultural land, the analyzed group was quite diversified (change rate: 69.47%). The minimum plot on which agricultural activity was conducted is 2.00 ha, and the largest is 300 ha. Farms defined as very small (1-5 ha) constituted a small group of the analyzed farms. The analyzed group was dominated by very large farms (> 50 ha) and medium-sized farms (20-50 ha). In the group of very large farms, the user of an individual farm declared an agricultural area of more than 100 ha (average 139 ha). The basic form of land ownership was private ownership. The share of leased land in the total area of agricultural land on the farm was 22.70%. The average area of leased land was 13.68 ha. In terms of the area of leased land, the analyzed group was very diverse (coefficient of variation: 148.79%).

More than 40% of farmers declared that in 2021 they achieved gross revenues from sales of agricultural products and services above PLN 100,000. 12.89% of farmers declared income below PLN 50,000, and every third farmer achieved income between PLN 50,000 up to PLN 100,000. Income from agricultural activities was the main source of income for 89.47% of users of individual farms. In 41.05% of the analyzed farms, its user or a family member conducted non-agricultural activities or worked outside agriculture (Table 1).

**Table 1.**  
*Characteristics of farm resources*

Specification	Category	%
Farming system	Traditional	48.42
	Conventional	27.89
	Integrated	11.05
	Precision	8.95
	Organic	3.68
Area of agricultural land (ha)	1-5	1.32
	5-15	3.95
	15-20	5.00
	20-50	42.11
	> 50	47.63
Revenues from sales of agricultural products and services in 2021 (PLN)	< 50,000	12.89
	50,000-100,000	28.68
	> 100,000	58.42
Main source of income: income from agricultural activities	Yes	89.47
	No	10.53
Non-agricultural sources of income	Yes	41.05
	No	58.95

Source: own study.

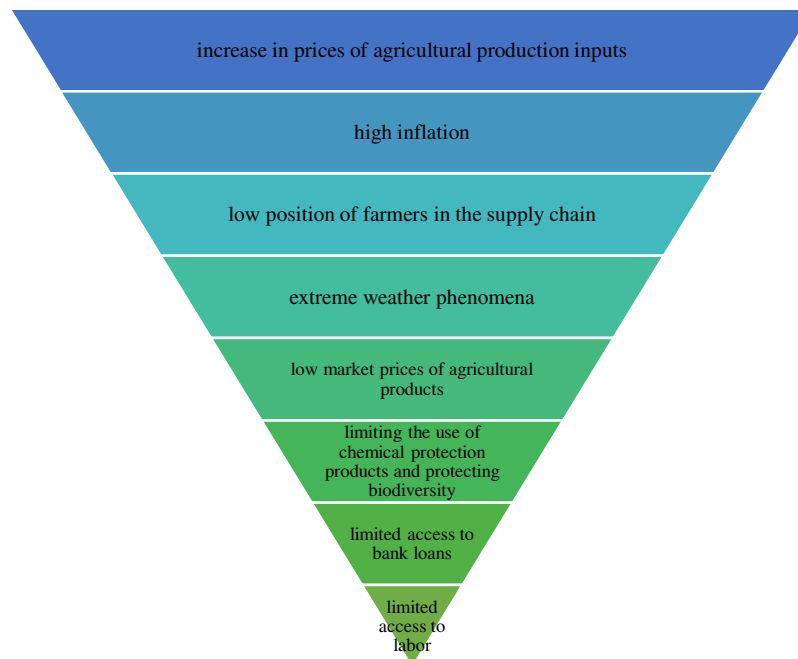
## 4. Results and discussion

### 4.1. Challenges of farms

Agricultural systems face a variety of potential short-term shocks and long-term stresses that may undermine their resilience, pose certain risks, and threaten the provision of system functions. These challenges can be differentiated according to their economic, environmental, social, or institutional dimensions (Popp, Nowacka, 2020). The surveyed users of individual farms could assess the current challenges that agricultural activities are exposed to. For this assessment, a 5-point Likert scale was used, where 1 - slight/small challenge, 5 - very serious/very big challenge. As shown in Figure 2, the greatest challenges for users of individual farms in the Western Pomerania region were primarily economic challenges, including the increase in prices of agricultural production inputs (fuels, energy, fertilizers) (average score 4.87) and high inflation (average score 4.80). The Russian invasion of Ukraine in February 2022 significantly disrupted global agricultural markets, leading to a sharp increase in prices of key agricultural products and agricultural inputs. In the first quarter of 2022, the average price of goods and services used in agriculture (excluding investment outlays) increased by 9.5% compared to the fourth quarter of 2021. The prices of artificial fertilizers and other materials used to improve soil quality increased significantly (by 21.1%), the prices of energy carriers and lubricants (by 17.4%) and the prices of animal feed (by 9.2%) (Bank.pl, 2023). This resulted in a significant increase in food prices. According to data from the Central Statistical Office, the prices of consumer goods and services in December 2022 compared to the previous year

increased by 16.6% (GUS, 2022). The increase in prices of production inputs is one of the most important challenges reported by farmers, because it has a direct impact on the costs of agricultural production and ultimately determines its profitability.

Increased prices of agricultural production inputs, high inflation, poor position of farmers in the supply chain, extreme weather phenomena, low market prices of agricultural products, limited use of chemical protection products and biodiversity protection, limited access to bank loans, limited access to labor.



**Figure 2.** Challenges of farms.

Source: own study.

The low position of farmers in the supply chain was another very serious challenge for the surveyed farmers (average score 4.39), as were extreme weather phenomena (average score 4.27) and low market prices of agricultural products (average score 4.16). According to farmers, a serious challenge was the implementation of regulations under the European Green Deal limiting the use of chemical crop protection products and increasing the protection of biodiversity (average score 3.79). According to farmers, this order will contribute to a decline in yields and a lack of effective protection of production. Limited access to bank loans (lack of creditworthiness) was not considered by farmers to be a serious challenge to running agricultural activities (average score 2.86). This was mainly due to the low interest rates in that period, but also the launch of the Agricultural Guarantee Fund. The social challenge related to limited access to labor force, in the opinion of farmers, was not significant for their agricultural activities (average score 2.84). This resulted from the fact that almost half of the surveyed users of individual farms conducted traditional agriculture based on family labor resources.

## 4.2. Resilience of farms

Table 2 presents the characteristics of farms in terms of their current resilience, adaptive capacity, transformability, and past and future overall resilience. We based this part of the research on the concept of "subjective" resilience to allow farmers to determine the resilience of their farm based on their own experiences and perspectives. This concept has been used before in research on (Quandt, 2023; Quandt, Paderes, 2022) resistance. 95.00% of users of individual farms indicated that in the last 5 years their farm had experienced difficulties resulting from various external shocks. Despite the existing challenges, mainly of an economic and environmental (climatic) nature, over half of farmers (64.47%) believed that their farms are currently generally resilient, i.e., they have the ability to absorb all disruptions that affect the farm. This state of affairs was influenced by actions taken at the farm level in the past and actions aimed at adapting to the prevailing conditions in response to emerging challenges. As Käyhkö (2019) stated, farm-scale adaptation is often a process that emerges in response to existing challenges, rather than an intentional process. As Rammel and van den Bergh (2003) notes, the ability to cope with changing conditions and the ability to initiate new development trajectories is an indicator of adaptive capacity. Thus, in response to the emerging challenges, 82.11% of farmers took adaptive actions - they changed agricultural practices to better adapt to emerging challenges (mainly falling prices of agricultural products and the occurrence of climate threats). It can be assumed that the challenges occurring in recent years have created space for reorganization, renewal, and innovation, providing an opportunity for new ways of organizing farms, thus increasing the resilience of most of them (Milestad et al., 2012). This is confirmed by the results of our research. In the group of farmers who had made changes to their farming practices, more than half believed that the farm was now generally resistant to shocks. 8.68% of farmers introduced significant changes to their farms in response to challenges occurring over the last 5 years. In this case, the majority were also farmers from farms assessed as generally resistant to shocks. This suggests that farmers on farms that did not have general resilience to shocks were not looking for opportunities to change. Rather, they felt comfortable managing what they already knew. If farmers introduced changes, the vast majority of them were changes enabling them to adapt rather than permanent changes (transformation). This is because transformational changes are associated with larger, more radical and at the same time costly changes in the area of agricultural activity (Soliwoda, Kurdyś-Kujawska, 2022). Moreover, as shown by Wheeler and Lableya (2021) in relation to long-term business planning and farmers' approach to introducing specific significant changes, farmers are reluctant to introduce them because they are not sure that they will meet market requirements and do not know what their real economic benefits will be. Making significant changes is therefore particularly difficult and potentially very risky at the moment. Darnhofer (2014) points out that adaptive changes mean adapting to the changing context, using new technologies, access to new markets, implementing new crops, acquiring new knowledge and

skills, etc. Transformation is triggered by crises and takes place when farmers perceive their farms as dysfunctional units that are unable to ensure the desired production. This may mean that the challenges that farms have been exposed to over the last 5 years have not significantly affected their ability to continue agricultural activities.

**Table 2.**

*Current, past, and future resilience of farms*

Resistance category	Specification	Yes	No
Robustness (Current resilience)	Despite many challenges, my farm is characterized by overall resilience.	64.47%	35.53%
Adaptability	Changes have been made to agricultural practices to better adapt to uncertain conditions.	82.11%	17.89%
Transformability	Significant changes (e.g., exclusion of part of the land for non-agricultural purposes, afforestation, changes in the agricultural system) were introduced on the farm in response to various challenges.	8.68%	91.32%
Past resilience	Over the last 5 years, my farm has often experienced negative consequences of agricultural challenges.	95.00%	5.00%
Future resilience	I think that the farm will be resistant to external challenges in the next 5 years.	64.47%	35.53%

Source: own study.

Most farmers were optimistic about the future resilience of their farms. 64.47% of respondents believed that their farm would be resistant to external challenges in the next 5 years. A significant part of the group were farmers who believed that their farms were now also resilient. It can therefore be assumed that the surveyed farmers believe that over time, the conditions in which they conduct agricultural activities will not change significantly and the risk of their activities will not increase. Almost every third farmer surveyed (35.53%) showed a more pessimistic attitude towards the future resilience of the farm. The vast majority in this group (23.68%) were farmers who believed that their farms were currently not stable and resilient. Additionally, it is noted that in the group of farmers who declared the implementation of changes aimed at increasing adaptation to the changing conditions of agricultural activity, the vast majority of them believed that their farm would not be resistant to external shocks in the next 5 years. In turn, in farms where farmers introduced significant transformational changes, the vast majority believed that in the next 5 years the farm would be resistant to economic, social, and environmental challenges.

#### 4.3. Resilience measures

Farms need a range of different measures to ensure their resilience. The possibility of mobilizing these funds will not be the same on all farms. Due to the available financial, technological, human, and physical capital, not all activities can be implemented on the same scale. Farmers from the Western Pomerania region took various actions to face the identified economic, social, and environmental challenges. Table 3 categorizes the resilience measures we identified from our interviews according to their ability to improve overall resilience, adaptability, and transformability.

**Table 3.**  
*Farm resilience measures*

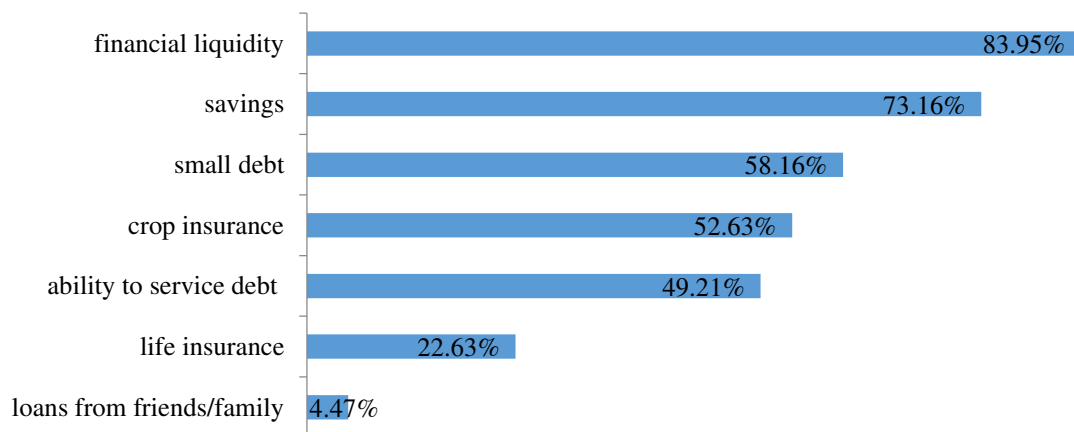
<b>Robustness Measures</b>	<b>Adaptation Measures</b>	<b>Transformation Measures</b>
<ul style="list-style-type: none"> <li>- savings,</li> <li>- small debt,</li> <li>- financial liquidity,</li> <li>- ability to service debt,</li> <li>- life insurance,</li> <li>- crop insurance,</li> <li>- loans from friends/family</li> </ul>	<ul style="list-style-type: none"> <li>- new crop varieties,</li> <li>- crop diversification,</li> <li>- cost optimization,</li> <li>- cooperation with other farmers</li> </ul>	<ul style="list-style-type: none"> <li>- off-farm work,</li> <li>- allocating part of the land for commercial purposes,</li> <li>- non-agricultural or agricultural-related activities,</li> <li>- sale/lease of fixed assets</li> </ul>

Source: own study.

The measure of the overall strength (resilience) of farms seems to be the way in which farms gain access to financial assets, create and protect them, limit their financial liabilities, and use risk transfer tools. This is tantamount to financial resilience of farms. As pointed out by Birhanu et al. (2017), financial resilience is an important dimension of overall farm resilience because access to credit, the ability to generate savings and other income-generating services are essential to mitigate the costs arising from shocks. In addition to savings, Popp and Nowacka (2020) also point to insurance. In their view, both savings and insurance seem to be the most important measures when it comes to protection against extreme weather, animal disease, liability risks, payment defaults, health problems or other unforeseen shocks. According to Jacobsen (2009), financial resilience allows you to maintain good financial condition, restore your livelihood and prevent financial shocks and failures resulting from various threats. Therefore, financial inclusion, including access to external sources of finance, taking actions to increase financial security at farm level and the use of insurance should be considered as a means to achieve overall farm resilience.

In the analyzed farms, financial liquidity, i.e., the ability to settle current liabilities, was most often indicated by farmers as a measure of the overall resilience of the farm (Figure 3). It should be noted that financial liquidity is a particularly key factor shaping the economic situation of an entity, because it is one of the basic determinants of its economic efficiency (Wędzki, 1995). In the short term, financial liquidity determines the survival of a farm. Loss of liquidity, and not the losses incurred by the entity, are the main cause of their bankruptcy (Ryś-Jurek, 2013). The ability of farms to settle current liabilities is also one of the symptoms of its financial balance. Another important measure to ensure overall farm resilience was the ability to generate savings. As proven by Wieliczko et. al. (2020), savings affect the possibility of using external sources of financing, they are an essential element of maintaining financial liquidity, but they are also considered one of the methods of protection against the risk of unfavorable events (self-insurance method). They also allow farmers to develop and make changes to their business activities. A low level of financial liabilities, and in particular not increasing existing liabilities, according to 58.16% of farmers, increases the chances of surviving shocks and is an important aspect of building resilience. A low level of financial liabilities, especially long-term ones, helps maintain financial security and reduces financial risk. Wasilewski and Mądra (2008) rightly note that the use of bank loans, especially long-term

ones, through investment processes contributes to increasing the production potential, improving labor efficiency, as well as increasing the productivity and profitability of farms. However, stronger, and better organized farms show less interest in bank loans, especially in the conditions of relatively high availability of non-repayable external funds (subsidies, subsidies) that support operational activities as well as modernization and development processes of farms (Kata, 2020). An equally high percentage of farmers indicated increasing overall resilience through crop insurance and debt servicing capacity. The ability to service debt is possible thanks to farmers generating sufficiently high gross profits from agricultural activities. Insurance, in turn, is a means of compensating for losses in agricultural activities, ensuring farmers can continue to operate. A small percentage of farmers believed that loans from friends/family were a means of strengthening their resilience. Farmers are rather focused on strengthening the resilience of their farms mainly based on generated savings and crop insurance.

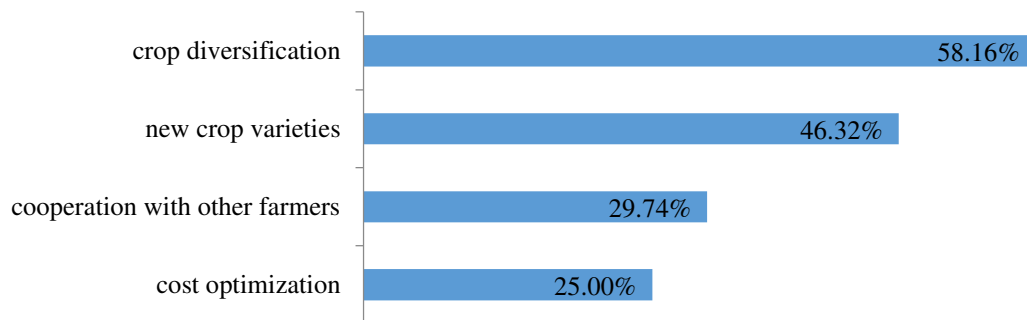


**Figure 3.** Robustness measures used on farms.

Source: own study.

Measures supporting adaptation include introducing changes to crops that are more profitable and/or more drought-resistant, crop diversification, cost optimization (e.g., leasing instead of purchasing, employment contracts for fixed-term workers) and cooperation with other farmers (e.g., joining to a producer group or cooperative). These are measures to build resilience through adaptation and refer to simple changes in the organization of farms. They do not require high implementation costs, only appropriate knowledge to introduce these changes. They are also not exceptionally durable (they cannot be quickly changed). However, as Leśny (2009) emphasizes, adaptation activities must be implemented in a comprehensive manner to be effective. For example, the introduction of new varieties of crops that are more tolerant to drought should coincide with the simultaneous development of irrigation systems. At the same time, detailed monitoring of the appearance of pests cannot be neglected, introducing more effective and at the same time less harmful methods of plant protection. The most frequently used adaptation measure by the surveyed farmers was crop diversification

(58.16%). This is because increased exposure to adverse risk can be mitigated by aggregating a portfolio of activities that reduces expected losses (Pironon et al., 2019). Moreover, crop diversification enables farmers to manage soil fertility, pests, and diseases, as well as the excessive costs of production inputs (Lovo, Veronesi, 2019). A high percentage of farmers have adapted to changing conditions by introducing new crop varieties that are more profitable and/or more resistant to environmental conditions. Every third farmer surveyed saw increased resilience in cooperation with other farmers (joining a producer group or cooperative), and every fourth farmer took measures to optimize costs related to agricultural activities (Figure 4).

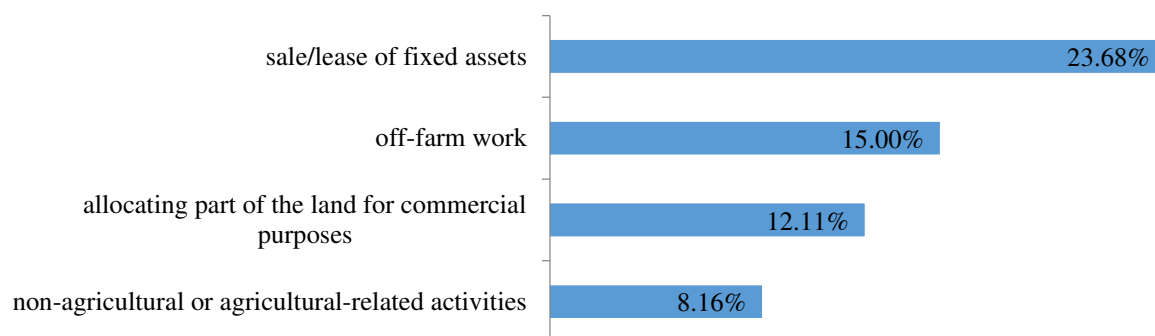


**Figure 4.** Adaptation measures used on farms.

Source: own study.

Transformation measures, unlike adaptation measures, are related to changes in the farm organization system, e.g., by allocating part of the land for commercial purposes (e.g., for photovoltaic panels, construction plots) or employment outside agriculture. The actions taken are mainly aimed at reducing farmers' vulnerability to threats and switching to a mode of collecting income from sources more stable than agricultural activity. In the long term, these activities may result in a reduction in the share of income from agricultural activities in the income of the farmer's family farm or a complete departure from agriculture. In the analyzed group of farmers, a small percentage of them introduced significant changes to their farm. Mainly farmers sold or leased all or part of fixed assets. 15.00% of farmers found work outside the farm, a slightly smaller percentage were farmers who took up non-agricultural activities and activities related to agriculture (processing of agricultural products, agritourism services, crafts). 12.11% of farmers allocated part of their land for commercial purposes, in particular in the form of long-term lease for photovoltaic farms (Figure 5).





**Figure 5.** Transformation measures used on farms.

Source: own study.

## 5. Conclusion

Agriculture is an important economic sector for ensuring food security for the country's citizens. Variable macroeconomic and even geopolitical conditions indicate that agricultural production takes place under conditions of uncertainty and risk. Agriculture, like any other economic sector, needs the capacity to withstand and adapt to various shocks and disruptions, which is referred to as resilience. This is reflected in the definitions of international organisations, including the OECD, FAO or the US Agency for International Development. Farm resilience is directly referred to in one of the strategic objectives of the Common Agricultural Policy, CAP 2023-2027.

There is an acute research gap regarding empirical studies on the perception of resilience, as well as the identification of determinants of resilience and management methods/techniques that build resilience. This is particularly true for Polish agriculture.

The empirical analyses conducted empower the authors to formulate the following conclusions and recommendations:

- The subjective assessment of resilience (past, current and future) as well as its components showed that farm managers are aware of the formation of this economic and organisational category. Resilience was most frequently associated by respondents with adaptive capacity and least frequently indicated a link with transformation. This indicates the need for farmers to deepen their knowledge, e.g. through training offered by agricultural advisory centres, commercial courses or popular science articles, or postgraduate studies for those without an agricultural background.
- It should be considered as worrying that the same percentage of farmers stated that the farm is and will be resilient to external factors. This indicates that farmers do not treat the category of resilience as a process that changes over time. This may be a rationale for deepening even informal education of farmers, particularly in the area of risk management.

- Methods/techniques for strengthening resilience as one of the three dimensions include those relating to the payment of current liabilities (equating current financial resilience with liquidity), long-term financial resilience, provisioning and the use of insurance (mainly crop insurance). It is not surprising that farm financing instruments should be considered in conjunction with production insurance. It would be worthwhile to consider initiatives leading to a deeper knowledge of farmers in the financial-insurance field.
- Less than 60% of the farmers surveyed mainly used crop diversification as their dominant adaptation technique. New crop techniques were used less frequently. The use of cooperative techniques with other farmers by only 30% should be considered a worrying situation. This points to the need to improve the quality of human capital, including in terms of so-called group activities, even informal ones.
- The dissemination of the concept of short supply chains (SSCs) in agriculture can foster the deepening of various forms of cooperation. Cost optimisation skills can be improved, e.g. through various forms of informal education.
- Transformation as a component of resilience can be served by ownership transformation, including the sale/lease of fixed assets. However, it should be noted that the trade in agricultural land is not quite liquid, which is due, among other things, to the inability to treat agricultural land as collateral for bank claims. Ergo: this has contributed to the reduction of farmers' long-term credit debt (Prawo.pl, 2023; KOWR, 2023).

A limitation of the research is the selection of research sample, namely the purposive sampling of the research sample from Western Pomerania. Further research may include the use of a panel approach, which allows the exploration of resilience in a dynamic perspective, which is recommended, inter alia, in reports published by the OECD (Sauer, Antón, 2023).

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## AI AND ROBOTIC PROCESS AUTOMATION IN FINTECH: ANALYZING THE SHIFT TOWARDS DIGITIZED CUSTOMER SERVICES AND OPERATIONAL EFFICIENCY

Pascal Muam MAH<sup>1</sup>, John MUZAM<sup>2\*</sup>, Tomasz PEŁECH-PILICHOWSKI<sup>3</sup>,  
Daniel Tambi MBUH<sup>4</sup>, Eyong AKO<sup>5</sup>

<sup>1</sup> AGH University of Science and Technology, Poland; mah@agh.edu.pl,  
ORCID: 0000-0001-6851-1518

<sup>2</sup> Silesian University of Technology, Poland; john.muzam@polsl.pl,  
ORCID: 0000-0002-5163-7576

<sup>3</sup> AGH University of Science and Technology, Poland; tomek@agh.edu.pl,  
ORCID: 0000-0003-2212-7806

<sup>4</sup> University of Bamenda, Bambili, Cameroon; tambi2015@yahoo.co.uk,  
ORCID: 0000-0001-6937-8392

<sup>5</sup> University of Bamenda, Bambili, Cameroon; akorolly87@yahoo.com,  
ORCID: 0009-0005-8689-6788

\* Correspondence author

**Introduction:** The need to replace human interaction in financial sectors with robotic process automation (RPA) has led to advanced services that have boosted productivity in financial sectors. RPA has systematically improved the output quality of financial services with high efficiency, service effectiveness, human resource engagements, advanced personnel management supports, employee loyalty, and customer satisfaction.

**Objectives:** The study aims to lay out systematic measures for potential customers to self-evaluate financial sectors before engaging in their services. Also, aims to understand how Fintech uses AI and RPA to advance the amalgamation of traditional financing into a digitized system with modern services.

**Problem:** Fintech with the help of RPA has led to social interactions through advanced transformative financial services that have pushed potential customers into limbo.

**Method and Material:** The study developed three pre-train deep learning techniques of digital evaluators called robotic process automation indicators. Bank satisfactory score survey was sample to validate and determine the study statistical data. Bank satisfactory score (BSAT) and bank effort score (BES) were used to examine banking services. Each robotic process automation indicator (RPAI) helps to evaluate five (5) financial service transformations identified by the study.

**Results:** Based on the Bank satisfactory score survey validation statistics, the bank satisfaction score (BSAT) and bank effort score (BES) a score of 2.2 and 2.2 respectively was recorded which indicates that the said bank is very affordable for customers.

**Conclusion:** The study concluded that Fintech is the best part of cognitive robotic process automation of intelligent systems empowered by cognitive computing technology that assists financial sectors and customers using best practice services.

**Keywords:** Fintech, robotic process automation, artificial intelligence, financial service transformation, deep learning.

## 1. Introduction

Lately, the banking sector has been able to achieve a lot in its entirety (Arasli et al., 2005). The banking sector has been able to focus on services in the last ten years, which has greatly engaged the financial sectors with a wide variety of users and clients through social and communicative interactions with RPA. Banking services are the best options for servings and have tremendously impacted banking activities. Information technology and other digital support technologies like artificial intelligence, big data, cloud computing, the internet of things, deep learning, and natural language processing, banks have broken their boundaries (Zhao, Zhang, 2021). Recently, customer satisfaction has improved tremendously with the help of modern machine learning algorithms (Pouyanfar et al., 2018). Deep learning algorithms have helped improve learning and customer satisfaction improved as well. Since the unprecedented changes in the traditional banking systems to a digitalized format, banking engineers have been working hard to train advanced robotic process automated systems to detect loopholes and manage customers' demands. Robotic process automation has been able to detect money laundering with the help of modern machine learning algorithms which has helped to prevent financial monitoring (Villar, Khan, 2021; Madakam et al., 2019). There is a need for separate transactions such as money laundering from legitimate transactions and machine learning is needed for it to reach its full capacity in tracing out unwanted transactions (Gotthardt et al., 2020).

In today's world, digital transformation is creating value for financial sectors with the help of robotic processes (Mavlutova, Volkova, 2019; Ulas, 2019). Robotic process automation is used as specialized computer programs known as software robots to fulfilled financial transactions. The modern banking system has realized that one of the best options is advancing sales, optimizing services to achieve customer satisfaction, and upholding safety management (Bose, 2009; Poirier, 1999). Analyses have weak big gains with the use of direct, optimize, and discovering of it is a much bigger leap to take the output. Digital financial services and loan-issuing applications use machine learning algorithms with the help of alternative devices such as smartphones, and related devices to help in evaluating loan eligibility. Artificial Intelligence is one of the Fintech services that help in optimizing sales and prices as well as prevent fraudulent transactions of digitized content. Artificial intelligence has homeowners build wealth by optimizing debt (Riikkinen et al., 2018). Robotic process automation has tremendously



changed financial sectors in many ways that have advanced savings and improved business processes. With the help of robotic process automation banks have relatively achieved customer satisfaction. Artificial intelligence, biometrics, and cloud services, big reduce the costs of payment transactions by optimizing the cost of accounting services with the use of robots (Melnychenko et al., 2020). Robotics process automation with the help of artificial Intelligence is a live serving system in the banking sector that has tremendously boosted customer satisfaction. Machine learning algorithms are nowadays used to achieve high-level network security for financial sectors. Robotic process automation built on a well-developed machine learning-enabled algorithm provides financial sectors with a technology that gives advanced market insights and allows managers to identify specific market changes.

Robotic process automation built on a well-developed machine learning technology can access customer information, interpret strange behaviors and compare with previous activities (Kumar et al., 2019). The ability to track and identify unnecessary activities and follow up using recognized patterns algorithms has helped maintain security with most financial services and automated processes. Recognizing pattern algorithms can be used to achieve customized support systems that work similarly to a real human but solve threats, queries, and concerns tailored to customer's needs.

## **2. Literature Review**

Robotic Process Automation (RPA). This is a kind of software that is consistent and error-free in operations performed by the robot (Met et al., 2020). Financial technology enhances innovative services that financial sectors use to execute financial transactions and manages fraudulent transactions (Zheng et al., 2022; Bouzidi et al., 2022). Tremendous growth has been seen in the financial sector and digital service industry recently (Zhou et al., 2015). Financial services are probably the most digitized industrial sector (Rasheed et al., 2019). Bank financing has been found as the main source of funds for small and medium enterprises with its significant growth which can be seen in their e-commerce activities.

### **2.1. Focus areas of robotic process automation in Fintech**

This section explains the most advanced areas where robotic process automation and artificial intelligence are applicable in the financial sector. RPA of software robots to automate processes are easy to configure (Gotthardt et al., 2020). Robotic process automation are providing intelligent service recognition that makes it possible to automate a variety of financial processes that transform used traditional methods into executed digital services. Artificial intelligence is enabled system software that helps to verify the information and generates digital banking transactions, records, and documents (Engin, Treleaven, 2019; Mosteanu, Faccia, 2020).

### **2.1.1. Robotic process automation and artificial intelligence for credit decisions**

Artificial Intelligence provides faster robotic process automation that securely processes financial transactions more accurately. RPA firms, focus on artificial intelligence-based issues and not directly on audit automation (Moffitt et al., 2018). Modern robotic process automation help in the assessment of potential borrowers at less cost, and securely accounts for a wider variety of factors than humans (Beerbaum et al., 2022). The coming of modern machine learning algorithms has led to better-informed data-oriented services and data-backed decision automatons (Kunwar, 2019; Sculley, 2014). Fintech has introduced credit scoring with artificial intelligence-based methods using more complex and sophisticated rules compared to those used in traditional credit scoring systems. This system has led to more secure meaningful credit monitoring and evaluation and has reduced credit default.

### **2.1.2. Robotic process automation and artificial intelligence for investment Trading**

Since the development of robotic process automation, financial services like investment, have had a tremendous change (Fernandez, Aman, 2018). Information on investments has increased steadily over the past decades (Michaely et al., 2008). Machine learning algorithms have trained advanced quantitative high-frequency trading systems that automatically recognize the best trading opportunities (Ashta, Herrmann, 2021). Findings have shown that automated trading is more accurate in predicting than humans. Investment in automated trading has expanded rapidly across the globe.

### **2.1.3. Robotic process automation and artificial intelligence for risk management**

Thanks to robotic process automation systems have led to advanced risk mitigation. Robotic process automation in financial sectors has come with automated services that remind systems of the initial time and alert them on closing time. Robotic process automation allows vast amounts of data to be handled on short notice with the help of cognitive computing. Robotic process automated algorithms analyze past risk cases and compare them with newly identified early cases of potential future issues (Beerbaum, 2022). Machine learning algorithms deliver comparable accuracy in risk management to other software systems and applications (Leo et al., 2019). To identify current and future research issues, automated data quality monitoring algorithms need (Thoben et al., 2017).

### **2.1.4. Robotic process automation and artificial intelligence for Fraudulent Prevention**

In the past two decades, artificial intelligence has been very successful in fraud prevention. Auditors will require a good understanding of analytics and artificial intelligence in areas of information protection (Griffiths, Pretorius, 2021). The future of financial technology with advanced robotic process automation is making financial services look very bright (Fernandez, Aman, 2018). Fraud detection systems built on well-developed Robotic process automation help analyze clients' behavior, location, and buyers' habits with aim of triggering a security mechanism.

### **2.1.5. Robotic process automation and artificial intelligence for Personalized Banking services**

Robotic process automation benefits both employees and customers within the financial sector (Met et al., 2020). Since banking services move digital, a lot of comforts have been enhanced at the individual user's level. Artificial Intelligence has empowered digital systems with smart chatbots that provide customers with comprehensive self-help solutions. The banking sector now has years of data related to customers and employees thanks to RPA (Kumar, Balaramachandran, 2018). With a prime objective to reduce call centers' workload, robotic process automation has been able to enact a smooth transformation from traditional banking services into digitalized services.

## **2.2. Analysis of the three (3) robotic process automation indicators of social implications in the Fintech model**

The following are financial implications identified by the study to help customers make better choices.

### **2.2.1. Financial processes operations**

Financial processes operations can be called financial primary processes. Financial operations must be monitored carefully to prevent any breaches of being applied (Tsai et al., 2016, March). Financial processes operations in the banking sector deal with the core business value chain. Also, they deliver value to the customer and stand a chance to boost the production of products and services. Financial process operations represent essential business activities that accomplish business goals, vision, objectives, and mission. The integration of operations and finances must take into account that budgeting models applied for financial control emerged earlier than operational scheduling models (Guillén et al., 2006). Some of the core financial process operations are:

- Customer financial orders.
- Financial processing of products operations.
- Financial accounting management operations.

### **2.2.2. Financial process support**

Financial process support is also known as financial secondary processes of banking. Supporting processes, and finally, its effects mainly at the firm level open the black box of financial innovation (Mention, Torkkeli, 2012). These are financial processes that involve back-office support services in a bank. Financial process support functions in a way that keeps the banking sector running. One key difference between financial process operations and financial process support is that financial process support does not directly provide value services to customers but financial process operations do. The environment which supports financial services sales dialogs (Felfernig et al., 2007). Some of the core services of financial process support are:

- Financial automated management suport.
- Virtual HR management suport.
- Digital security services and safety management suport.

### **2.2.3. Financial process management**

These are the digital process services of determining, measuring, monitoring, evaluating, and controlling the activities that directly relate to financial procedures and network systems. Financial management is essential for increasing wealth and equity (Chandra, 2013). One of the key differences between financial process support and financial process management is that financial process management provides value services directly to the customers while financial process support does not. Process management impacts organizational performance (Hernaus et al., 2012).

Some of the financial process management are:

- Financial services of internal communications management.
- Financial services of governance.
- Financial process strategic planning management.
- Financial services of budgeting management.
- Financial services of infrastructure management.
- Financial services of capacity management.

## **2.3. Fintech social implications of RPA for Financial service transformation**

The following paragraphs provide detailed elements that potential customers sourcing for the best financial sectors can use to find out the best alternative. In this section, two approaches are applied: robotic process automation indicators and financial service transformations.

### **2.3.1. Three (3) robotic process automation indicators of social implications in the Fintech model**

These are self-developed three pre-train deep learning techniques of systematic digital evaluators that the study uses to measure and compare different financial sectors. The system works in an inverse relationship. The higher the value the lesser should be the choice of selection. The lower the value the more attractive the selection choice. A higher value indicates a higher cost and a lower value indicates a lower cost of financial service transformations. The following are three robotic process automation indicators:

- Financial process operations.
- Financial process supports.
- Financial process management.

The table below represents elements of financial sectors that the study uses to match with some elements of financial transformation evaluators. The two systems can help customers predetermine the best financial sector that they can use to select the most appropriate institution.

**Table 1.***Robotic process automation and financial service transformations evaluators*

<b>Robotic process automations indicators</b>	<b>financial service transformations evaluators</b>
Financial process operation	Cost of personnel re-skilling
	Cost of financial operations
	Cost of financial services
	Feeling of richness in consumers
	Error cost
Financial process supports	Cost of personnel re-skilling
	Cost of financial operations
	Cost of financial services
	Feeling of richness in consumers
	Error cost
Financial process management	Cost of personnel re-skilling
	Cost of financial operations
	Cost of financial services
	Feeling of richness in consumers
	Error cost

Source: Author's Own copy.

Table 1 above-mentioned factors are closely linked with financial digital services. The study uses them to indicate their direct relationship with most financial services in the Fintech model.

### **2.3.2. Five (5) financial service transformations evaluators of digital services**

These are elements of financial services that the study uses to help potential customers understand if a financial sector is providing services at an affordable cost or not. The robotic process automation indicators are examined along with financial service transformations across three sectors of the finance sector using scoring criteria. Once a higher value is indicated, the financial service transformation records a high value for all its services. This is because the factors that determine financial service transformation are a chain that interrelates and flow throughout digital services. The following are financial service transformation.

**Table 2.***Five (5) plus and minus financial service transformations evaluators of digital*

<b>Five (5) financial service transformations evaluators of digital services</b>	<b>Five (5) favorable financial service transformations evaluators of digital services</b>	<b>Five (5) unfavorable financial service transformations evaluators of digital service</b>
Cost of personnel re-skilling	Available personnel Re-skilling	Unavailable personnel Re-skilling
Cost of financial operations	Low costs of financial operations	High costs of financial operations
Cost of financial services	Low cost of financial services	High cost of financial services
Feeling of richness in consumers	Advance a feeling of richness in consumers	Low feeling of richness in consumers
Error cost	Low error cost	High error cost

Source: Author's Own copy.

Table 2 above elements are in general conation. They neither represent nor indicate a positive value or a negative value. A positive value represents flexible and easy-to-get financial sectors accessible to customers.

### **2.3.3. Five (5) favorable financial service transformations evaluators of digital services**

The following elements represent the aspects of financial service transformation that represent a bet option for potential customers.

- Available personnel Re-skilling.
- Low costs of financial operations.
- Low cost of financial services.
- Advance a feeling of richness in consumers.
- Low error cost.

The following points above represent aspects of financial technology that provide very cheap service. The higher the value of financial service transformation n evaluators of digital service shows the level of financial sectors.

### **2.3.4. Five (5) unfavorable financial service transformations evaluators of digital services**

The following elements below indicate the financial services transformation evaluators that modern sectors use. The study uses these elements to present higher cost and expensive services, and providers.

- Unavailable personnel Re-skilling
- High costs of financial operations
- High cost of financial services,
- Low feeling of richness in consumers
- High error cost

Unfavorable financial transformations evaluators of digital technology are the aspects of FinTechs that enable very expensive services. The products are very expensive and a common man can't afford them. The study presents these elements not to lower bank stands but to help customers to evaluate their stand and determine their capacity in times of choice.

## **3. Results**

This section provides details on how the results of the study were developed. The study uses a Bank satisfactory score survey to developed the statistics for this study The survey received responses which help the study to determine and validate the results of the study presented in table 3 link to responses (Reference, 43). The study developed a method on how to evaluate different banking systems. The evaluation can be evaluated based on the observation of any user or customer in comparison with other banking sectors. The following paragraphs provide a step-by-step evaluation method.

### 3.1. Bank Satisfaction (BSAT) Score

A BSAT Score is a value or service of a bank that reflects how a customer feels about a specific contact/product/service. The name is derived from the term bank satisfaction (BSAT) Score.

The study makes use of multiple scores for different rates for customers and accumulated them into an average BSAT Score, which tells how happy customers able to make a decision. This score can be used to benefit many other customers in terms of deciding their best-performing banks, retaining customers, and much more (Ying et al., 2016).

### 3.2. How to Calculate a BSAT Score

On a scale of 1–5, how satisfied a customer is with the bank service?

Different methods to ask find out: “On a scale of 1-5, how satisfied are the bank service” This is commonly referred to as the “BSAT Question”. With your BSAT Question, you can then use the BSAT formula below to calculate the mean average of all the scores.

$$\text{BSAT Score} = \frac{\text{Sum of all scores}}{\text{Sum of the Maximum Possible scores}} \times \text{Maximum Score}$$

For example, let’s say that we collected question from a single customers and it gave us the following responses.

**Table 3.**

*Robotic process automation and financial service transformations evaluators*

Robotic process automations indicators	Financial service transformations evaluators	Measurement range					BSAT Question	BSAT Score	Max. score
		1	2	3	4	5			
Financial process operations	Cost of personnel re-skilling	1	2	3	4	5	Cost of personnel re-skilling is?	1	5
	Cost of financial operations	1	2	3	4	5	Cost of financial operations is?	2	5
	Cost of financial services	1	2	3	4	5	Cost of financial services is?	4	5
	Feeling of richness in consumers	1	2	3	4	5	Feeling of richness in consumers is?	2	5
	Error cost	1	2	3	4	5	Error cost is?	1	5
Financial process supports	Cost of personnel re-skilling	1	2	3	4	5	Cost of personnel re-skilling is?	2	5
	Cost of financial operations	1	2	3	4	5	Cost of financial operations is?	4	5
	Cost of financial services	1	2	3	4	5	Cost of financial services is?	1	5
	Feeling of richness in consumers	1	2	3	4	5	Feeling of richness in consumers is?	3	5
	Error cost	1	2	3	4	5	Error cost is?	2	5
Financial process management	Cost of personnel re-skilling	1	2	3	4	5	Cost of personnel re-skilling is?	2	5
	Cost of financial operations	1	2	3	4	5	Cost of financial operations is?	5	5
	Cost of financial services	1	2	3	4	5	Cost of financial services is?	1	5
	Feeling of richness in consumers	1	2	3	4	5	Feeling of richness in consumers is?	2	5
	Error cost	1	2	3	4	5	Error cost is?	1	5

Source: Author’s Own copy.

Table 3 represents elements of Robotic process automation indicators, financial service transformation evaluators, BSAT Questions, BSAT Score, and Maximum score. These elements help the study demonstrate how potential customers can evaluate a bank. The higher the amount the cost of services in the bank and the lower the amount the lower the cost of services in the bank.

**Table 4.**

*Bank satisfaction range*

BSAT range score	1	2	3	4	5
Grade	Low cost	Fairly cost	Moderate cost	Costly	Very costly

Source: Author's Own copy.

Table 4 provide possible items and grading system to measure the level of expensiveness or affordability.

**Table 5.**

*Bank satisfactory score and Maximum score rates*

Bank satisfaction (BSAT) Question	BSAT Score	Maximum score
Cost of personnel re-skilling is?	1	5
Cost of financial operations is?	2	5
Cost of financial services is?	4	5
Feeling of richness in consumers is?	2	5
Error cost is?	1	5
Cost of personnel re-skilling is?	2	5
Cost of financial operations is?	4	5
Cost of financial services is?	1	5
Feeling of richness in consumers is?	3	5
Error cost is?	2	5
Cost of personnel re-skilling is?	2	5
Cost of financial operations is?	5	5
Cost of financial services is?	1	5
Feeling of richness in consumers is?	2	5
Error cost is?	1	5
Total	33	75

Source: Author's Own copy.

In table 5, we would simply divide our total BSAT score of 29 by our total of maximum score of 75 and multiply that by maximum score of 5.

### **Solution**

BSAT score = 1+2+4+2+1+2+4+1+3+2+2+5+1+2+1

Total of maximum score = 5+5+5+5+5+5+5+5+5+5+5+5+5+5+5

Maximum score = 5

$$\text{BSAT Score} = \frac{\text{Sum of all scores}}{\text{Sum of the Maximum Possible scores}} \times \text{Maximum Score}$$

$$\text{BSAT Score} = \frac{33}{75} \times 5 = 2.2$$



### 3.3. Bank Effort Score (BES)

Bank Effort Score (BES) is a bank service metric that measures the levels of effort of its services and employers put into a certain interaction with customers to achieve customer's satisfaction.

#### 3.3.1. How to Calculate a Bank Effort Score

Bank Effort Score = Sum of all bank satisfaction Scores ÷ Total sum of all bank satisfaction score respondent.

Bank Effort Score = BES

Sum of all bank satisfaction Score = SBSS

Total sum of all bank satisfaction score respondent=TSBSSR

$$\text{Bank effort Score} = \frac{\text{Sum of all bank satisfaction score}}{\text{Total sum of all bank satisfaction scores respondent}}$$

#### Solution

SBSS ::) 1+2+4+2+1+2+4+1+3+2+2+5+1+2+1 = 33

SBSSR :::) (1+2+4+2+1+2+4+1+3+2+2+5+1+2+1) = 15

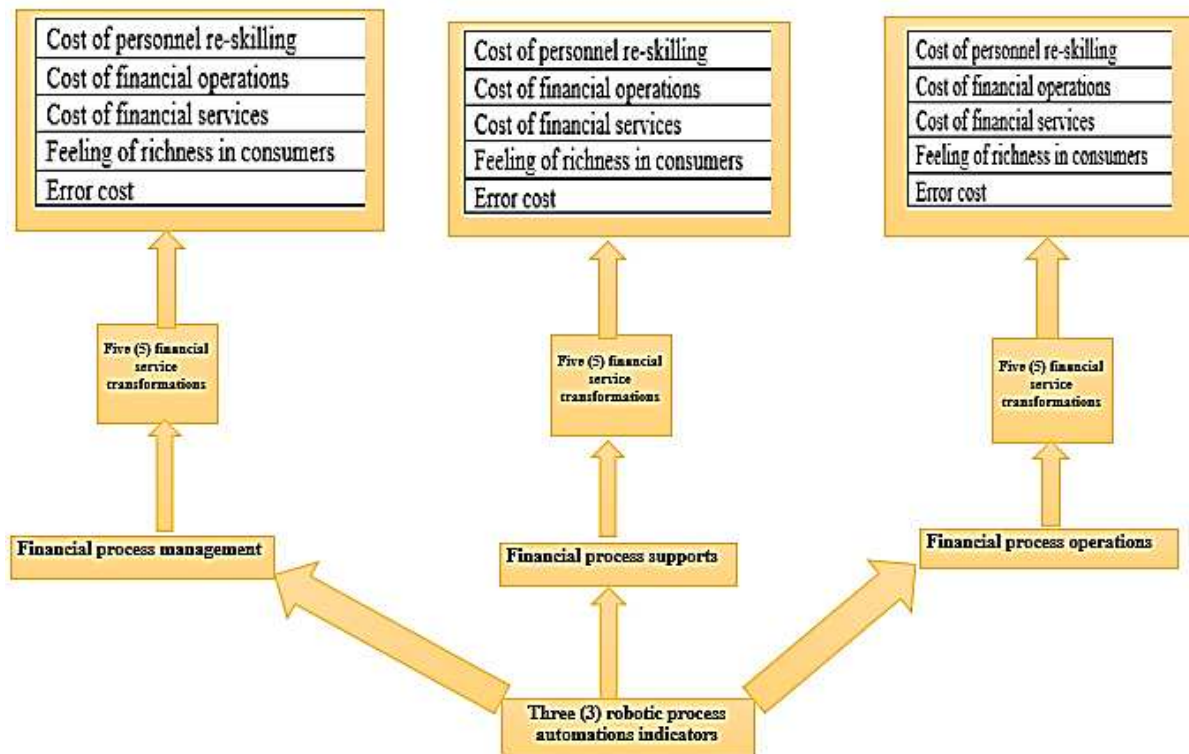
$$\text{Bank effort Score} = \frac{33}{15} = 2.2$$

## 4. Method

In this section the study presented the stages used in the development of the study. First step was to identify the core basic elements that interconnected all aspects of the study. The first step was to identify the three robotic process automations indicators. Secondly, the study selected some financial service transformations evaluators. The financial service transformations evaluators are made up of financial service transformations evaluators, favorable financial service transformations evaluators, unfavorable financial service transformations evaluators, and bank satisfactions range and grade. Thirdly, bank satisfaction score and grades. Lastly, the decision tree.

### 4.1. Three (3) robotic process automations indicators

This section contains financial process management, financial process supports and financial process operations.



**Figure 1.** Robotic process automation indicators.

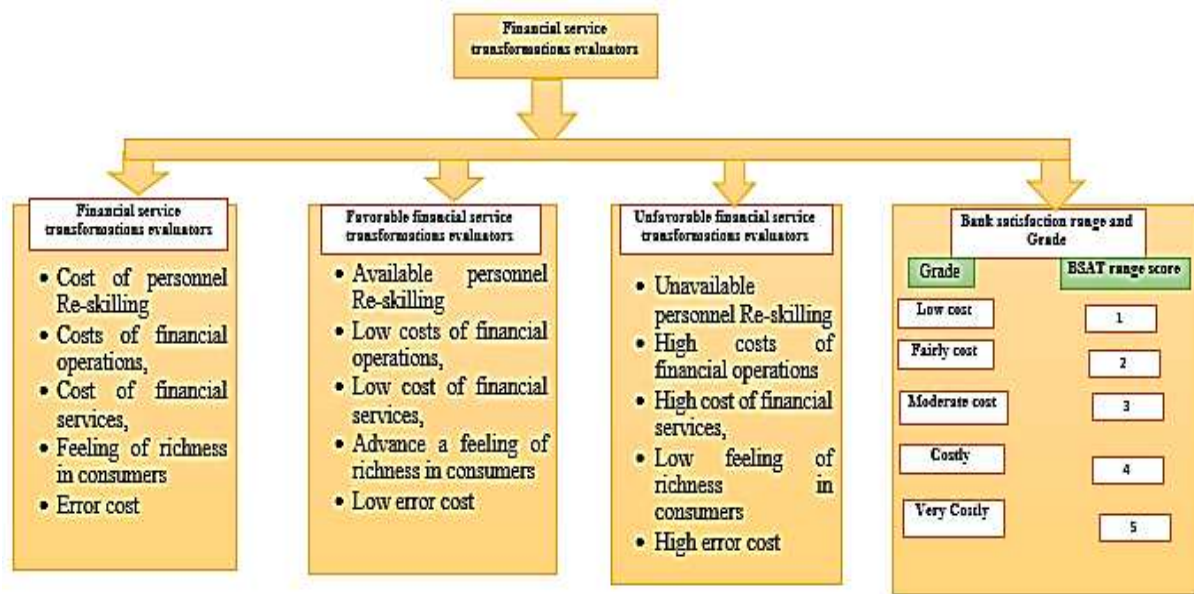
Source: Author’s Own copy.

Figure 1 above uses the three robotic process automation of financial process management, the financial process supports, and financial process operations to ensure each element of financial service transformations satisfied the five indicators of bank services for potential customers.

The section uses financial process management to evaluate bank services using the cost of personnel Re-skilling, cost of financial operations, cost of financial services, feeling of richness in customers, and error cost. Also, uses financial process supports to evaluate bank services using the cost of personnel Re-skilling, cost of financial operations, cost of financial services, feeling of richness in customers, and error cost. Lastly, uses financial process operations to evaluate bank services using the cost of personnel Re-skilling, cost of financial operations, cost of financial services, feeling of richness in customers, and error cost.

**4.2. Financial service transformations evaluators**

This section consists of financial transactions evaluators, favorable financial transactions evaluators, unfavorable financial service transformations evaluators, and bank satisfactions range and grades



**Figure 2.** financial service transformations evaluators.

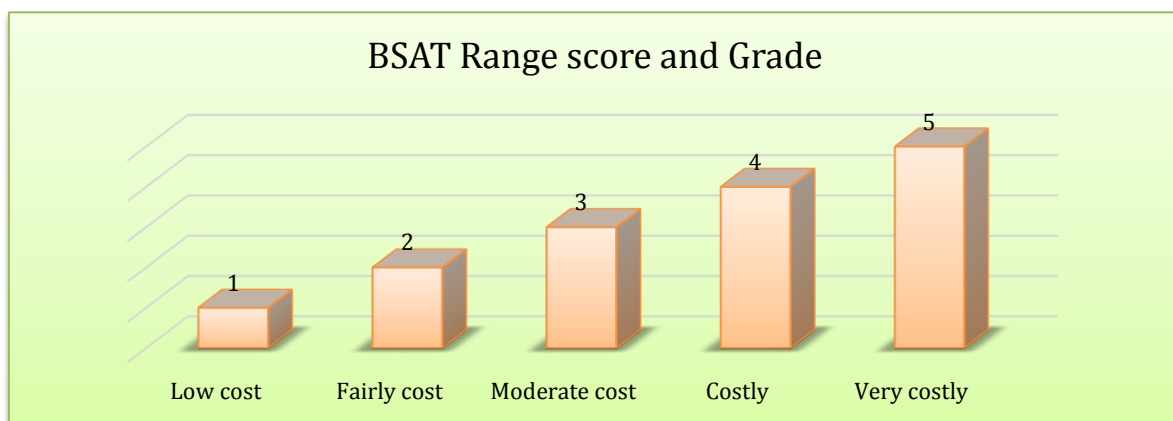
Source: Author’s Own copy.

Figure 2 above uses the cost of personnel Re-skilling, cost of financial operations, cost of financial services, feeling of richness in customers, and error cost to evaluate bank services with regards to the three robotic process automation indicators.

Also, to effectively engage the three robotic process automation indicators and the five financial transactions evaluators. Bank satisfactions range and grades are used. The lower the cost of services the better the bank and the higher the services the more expensive is the bank.

**4.3. Bank satisfactions range score and grades**

The bank satisfaction range score is abbreviated as BSAT. The bank satisfaction range helps banks and customers target the best possible choice and services



**Figure 3.** Bank satisfaction range.

Source: Author’s Own copy.

Figure 3 above provides grades of lower cost, fairly cost, moderate cost, costly, and very costly.

The range grows with fewer engagements. The higher the range score the less necessary the bank services.

#### 4.4. Decision three

Decision three used in the study helped in the implementation of statistical analysis and understanding of the concept developed using deep learning techniques.

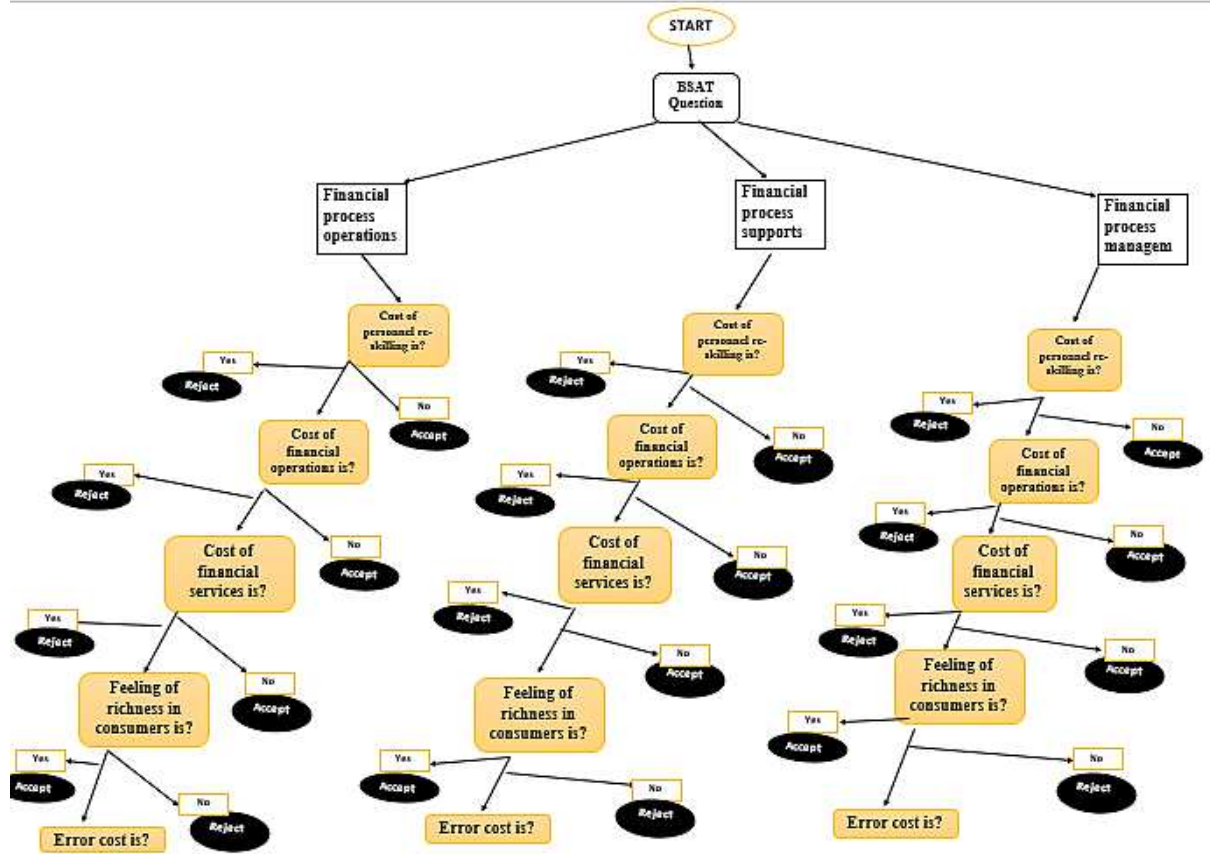


Figure 4. Decision tree.

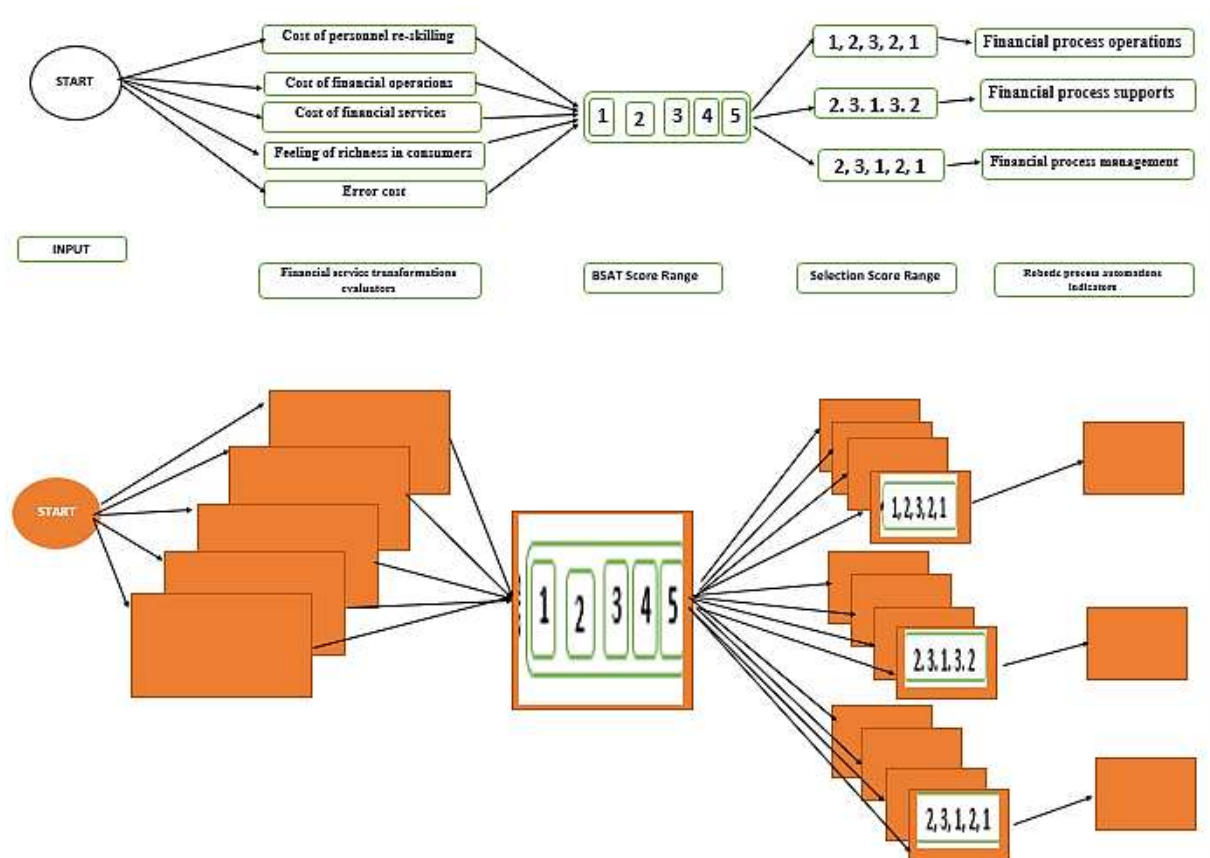
Source: Author's Own copy.

Figure 4 above is a decision tree that breaks down five elements of financial process operations, the financial process supports, and financial process management. The maximum range score is used here with values between 1 to 5. The values of 1 and 2 are affordable while 3, 4, and 5 grades are unaffordable grade. All five 5 elements reflect cost except one which determines the richness of the customer. The statement "NO" reflects the least cost for some of the 4 grades or elements of the decision tree while the element determines the richness of customers. Also, in the decision tree, "YES" indicates high cost for some 4 elements of the decision tree except one of the elements that determine the richness of customers.

The decision tree uses bank satisfaction questions to determine if the bank services are at an affordable cost or not. All three robotic process automation indicators of financial process operations, the financial process supports, and financial process management uses the same questions that reflect the five financial service transformations.

#### 4.5. Deep learning Architect summarization of BSAT Model

The figure below presents the pre-train steps require to compute the result presented in the study. Unlike other figure represented in the study, this part of the study allow an in-depth understanding of various steps needed to construct a computational system that will help in evaluating various financial systems.



**Figure 5.** Architect summarization of BSAT.

Source: Author's Own copy.

Figure 5 represents five stages of evaluating financial sectors to determine whether winch provides the best and cheapest financial services. The first step is the input data followed by financial service transformation evaluators, followed by BSAT service range, selection score range, and robotic process automation. The output of proposed architect achieves the desired output when it reaches an appropriate selection score range with an in-depth evaluation of the cost of the services of robotic process automation.

## 5. Conclusion

We examine Fintech for social and communications of robotic process automation and how intelligent automation empowered by cognitive computing improves financial services. We examine robotic process automation indicators and financial service transformations evaluators that, can be adequately implemented to assist customers with digital services and can also assist banks in updating technical controls, Based on bank satisfaction score (BSAT) and bank effort score (BES) a score of 2.2 and 2.2 respectively and was recorded which indicates that the said bank is very affordable for customers. The study concluded that Fintech is the best part of cognitive robotic process automation of intelligent systems empowered by cognitive computing technology that assist financial sectors and customers using best practice services.

## 6. Licence Open Access

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## IS IT WORTHWHILE TO BE RESPONSIBLE? THE IMPACT OF COMPANY'S INTERNAL CSR ON EMPLOYEES' SATISFACTION

Agnieszka MAREK<sup>1\*</sup>, Kalina GRZESIUK<sup>2</sup>, Szilárd BERKE<sup>3</sup>

<sup>1</sup> The John Paul II Catholic University of Lublin, Poland; agnieszka.marek@kul.pl,  
ORCID: 0000-0003-2803-1194

<sup>2</sup> Maria Curie-Skłodowska University, Poland; kalina.grzesiuk@mail.umcs.pl, ORCID: 0000-0003-1513-1081

<sup>3</sup> Óbuda University, Hungary; berke.szilard@uni-obuda.hu, ORCID: 0000-0002-4915-4516

\* Correspondence author

**Purpose:** The purpose was to identify the relationships between employee satisfaction and companies' internal Corporate Social Responsibility (CSR) activities in five dimensions: justice and fairness, health and safety, availability of training, work-life balance and empowerment.

**Design/methodology/approach:** Based on an analysis of the literature and current trends in the workplace, the authors proposed a new classification of internal CSR dimensions. On its basis, an empirical study of 283 employees of Polish companies implementing CSR was carried out, which allowed verification of the relationships between internal CSR and its dimensions and employees' job satisfaction.

**Findings:** The study confirmed the validity of the proposed classification of the internal CSR dimensions. The results show a statistically significant positive relationship between internal CSR and its individual dimensions and job satisfaction perceived by employees.

**Research limitations/implications:** The main limitation is that the research was only conducted in one country.

**Practical implications:** Employee evaluations can provide managers with an indication of which areas of internal CSR activities are most valuable to employees and to what extent they translate into their Job satisfaction.

**Originality/value:** The paper contributes to internal CSR theory by introducing a new classification framework of dimensions. It also contributes to empirical research by presenting the results of an empirical study to confirm the relationship between intrinsic CSR and employee job satisfaction.

**Keywords:** Corporate social responsibility, internal CSR, job satisfaction.

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

## 1. Introduction

Building a competitive advantage in today's market is a challenging task like never before. The VUCA business environment means that organisations must cope with increasingly dynamic change, a diverse workforce and hard-to-predict consumer expectations. Such business context determines companies' search for new sources of a sustainable competitive advantage (Hamadamin, Atan, 2019). One of the strategic ways to create such an advantage is to properly shape the Human Resource Management (HRM) system so that the organisation can have highly engaged and high-quality employees (Hamid, 2019). Internal Corporate Social Responsibility (CSR) is often regarded as a good foundation for building relationships within the organisation and, as such, is seen as a successful strategy to achieve this goal.

However, research regarding CSR practices tends to concentrate on the perception of external stakeholders and their behavioural outcomes rather than the internal aspects of CSR and its impact on employees (Hansen et al., 2011). Even the studies that measure employees' perception of CSR focus on its external level, considering mainly activities aimed at the external social or ecological environment and based on the external perceptions to explain their impact on employees (Kim, Lee, 2022). However, it seems that an extremely important, although understudied, area is the impact of internal CSR activities on shaping the performance and attitudes of employees. Though some academics have conducted research on internal CSR in this regard (Jamali et al., 2019; Marek, Kozak, 2021; Mory et al., 2016; Papasolomou, 2017; Rank, Palframan, 2021), the area still seems to require a more in-depth analysis. Moreover, the approach to CSR is often very narrow as it focuses on its instrumental dimension, studying the impact of specific tools on stakeholders' reactions.

Internal CSR actions might increase the employer's credibility and integrity in employees' eyes because employees might treat this way of showing responsibility as a sign of recognition and respect (Hameed et al., 2016; Mory et al., 2016). Neglecting internal CSR practices and, at the same time, pursuing external CSR goals that can bring material benefits may easily result in an employer's actions being perceived as merely superficial and hypocritical and hindering the realisation of external CSR goals due to employees' resistance (Haski-Leventhal, 2018; Hawn and Ioannou, 2016). In line with the theory of cognitive dissonance (Festinger, 1957), when there is disconfirmation of CSR initiatives and employees' expectations regarding them, adverse outcomes may emerge, such as intention to quit, reduced job satisfaction, reduced organisational trust, and decreased job performance (Carlini et al., 2019).

As with internal and external CSR, research on CSR and job satisfaction relationships also concentrates more on CSR in general than internal activities. Raihan and Al Karim (2017) revealed that philanthropic and ethical CSR activities have the highest influence on employees' job satisfaction, while legal and economic dimensions of CSR have less impact on that issue.

In research conducted by Trivellas et al. (2021), the results show that only ethical aspects of CSR reflecting internal orientation positively influence job satisfaction, while an organisation's environmental and philanthropic engagement has a strong negative impact on job satisfaction. Murshed et al. (2021) examined social and environmental CSR activities, concluding that CSR activities are significant for employees and job satisfaction depends heavily on procedural justice, which means that employees are satisfied with their jobs when CSR practices are based on transparent and fair procedures.

These and several other studies of the relationship between external and internal areas of a company's CSR commitment and the level of employee job satisfaction inspired us to undertake a research literature analysis regarding the significance of the impact of internal and external dimensions on job satisfaction. We studied the existing literature to answer this question, which led to developing a framework introducing a synthetic classification of internal CSR dimensions. It also has become the basis for an empirical study investigating their relationship with employee job satisfaction.

## **2. Internal CSR and its dimensions**

As stated earlier, the dominant approach in CSR research uses the instrumental perspective, where CSR is treated more like a tool to attract and retain the most talented and appropriate candidates who meet the needs of a company (Zainee, Puteh, 2020). We want to contribute to a different approach according to which CSR is a vital part of organisational culture and strategy that implements management based on authentic responsibility towards various groups of stakeholders, including employees, and might substantially influence employee well-being (Carlini et al., 2019; Haski-Leventhal et al., 2020).

Researchers emphasise that there is no consensus on a single definition of CSR, and this "phenomenon is highly dynamic and will continue to evolve as the demands on organisations change" (Homer, Gill, 2022, p. 18), which makes it difficult to measure and develop theoretically (Mory et al., 2017). Nevertheless, various academics distinguish different dimensions of internal CSR. According to Mory et al. (2016), internal CSR consists of employment stability, skill development, workforce diversity, work–life balance, tangible employee involvement, and empowerment, while Lee (2021) takes the first four from this set and adds the working environment, which is more general and may contain many different factors. A relatively broad set of dimensions was introduced by Antonio Vives (2006), who mentions the health and well-being of workers, training and participation in the business, equality of opportunities, the work–family relationship, and also some corporate governance practices like independent audits, CSR towards suppliers, and internal control of corruption practices. Pappasolomou (2017), on the other hand, enumerates health and safety in the

workplace, organisational justice and fairness, employee training and development, and work–life balance. Given the scope of the considerations addressed in this paper and the results of the literature analysis, we decided to propose our classification of dimensions, hoping to achieve the best coverage of features and contemporary changes within workplaces. Therefore, we analysed the following internal CSR dimensions: organisational justice and fairness, health and safety, work–life balance, employee training and development, and empowerment.

### **2.1. Organisational justice and fairness**

Organisational justice can be seen in different managerial practices. In general, it refers to employees' perception of the fairness of their treatment by the organisation and decisions taken by their supervisors (Colquitt et al., 2005). Organisational justice consists of three dimensions: distributive, procedural, and interactional (Colquitt, 2012; Yean, Yusof, 2016). Distributive justice is manifested in fairness in reward and resource distribution. Fairness in the process of making decisions and reaching outcomes is procedural justice (Farid et al., 2019). Interactional justice is crucial to perceive individual compensation and rewards as fair or unfair and refers to decent and respectful interpersonal behaviour. In further research, interactional justice is developed into interpersonal justice and informational justice. The first one demands that the employer shows concern about an employee while redistributing the outcome and the latter refers to "providing knowledge about procedures that demonstrate regard for people's concerns" (Greenberg, 1993, p. 84).

Nowadays, one may see the realisation of organisational justice and fairness not only in respecting fundamental work rights but also in practices promoting diversity and preventing discrimination and mobbing in the workplace. Mobbing means long-term (at least six months) aggression towards an employee at the level of communication and relationships, often aimed at humiliating the person. It might be committed by colleagues or a manager and lead to weakening the person's position within the organisation, resignation from the post, or even resignation from the field of activity (Mihăilescu, Tomescu, 2017).

Successfully leading a company to common goals requires diversity management, which means "understanding that there are differences among employees and that these differences, if properly managed, are an asset to doing work more efficiently and effectively" (Furunes, Mykletun, 2007, p. 975). The main issue in diversity management is to increase diversity within an organisation and create as inclusive a workplace as possible (Köllen, 2021) to make employees feel accepted and involved in organisational actions. To gain a sustainable competitive advantage based on diversity, managers should base all decisions in recruitment and development processes on employees' competencies and potential fairly and inclusively (Emmott and Worman, 2008).

Introducing all the aspects of organisational justice and fairness in corporate practices results in higher loyalty of employees because in a just and fair organisation, their rights are respected, and they can better predict what benefits they will receive for their efforts. Moreover, in just and fair organisations, there is no tolerance for any discrimination or favouritism of a person or a group of employees (Yean, Yusof, 2016). Organisational justice also helps build trust between supervisors and employees and increases job satisfaction (Kals, Jiranek, 2011).

## **2.2. Health and Safety**

Health and safety in the workplace are constantly changing in response to new scientific discoveries and legal regulations. These factors became unprecedentedly important during the COVID-19 pandemic, and employers had to take many actions to adjust to governmental rules. Perceived risk of infection with COVID-19, according to the research results, led to employees experiencing emotional exhaustion and a sense of violation of their well-being and safety at work, as well as their self-efficacy and mental health (Falco et al., 2021). Health and safety indicators might include respecting legal standards in this area, providing a comfortable workplace and appropriate health insurance, or requiring a suitable number of working hours (Papasolomou, 2017).

Organisations can improve safety by introducing workplace safety management programmes, including health and safety training, wellness programmes, stress management, or health and safety auditing (Aldana, 2001; Mearns et al., 2003). Introducing such programmes creates a safety climate by increasing consciousness and engaging employees in pro-healthy behaviours (Vu et al., 2022). Through such programmes, a management board can prevent negative work behaviours such as workplace violence comprising behaviours aimed at "using one's body or tools to threaten working staff or a group in the workplace which results in psychological harm, physical injury, deformity or even death"(Zhao et al., 2018, p. 2621).

## **2.3. Employee training and development**

The job market is dynamic in a changing economy and society and constantly requires new competencies. A stable career is a rarity in those conditions, and lifelong learning seems inevitable. Employees can satisfy these expectations by choosing a protean career where they take control of their career development and initiative to find the best career options and choose an organisation where the work will be meaningful and congruent with their values (Direnzo et al., 2015). People are aware that taking responsibility for their career requires lifelong learning because gaining new skills and adjusting them to the demands of the job market will increase their value on the job market and open new possibilities for promotion and higher income in the present company or, in the case of the employees motivated mainly by their interests, may result in finding work in a competing organisation where they can find "better" opportunities for themselves (Nerstad et al., 2018). On the other hand, leaders want to participate in shaping their followers' careers to adjust them to the organisational goals and

invest in career development programmes. Employees can perceive such programmes as a form of taking care of their long-term growth, which might increase job satisfaction and result in a willingness to stay in the company (Lee, Bruvold, 2003).

#### **2.4. Work-life balance**

One of the narrowest definitions of work–life balance is the one coined by Hill et al. (2001, p. 49), who defines it as "the degree to which an individual is able to simultaneously balance the temporal, emotional and behavioural demands of both paid work and family responsibilities". On the other side of the scale is the definition authored by Kirchmeyer (2000, p. 81), for whom it means "achieving satisfying experiences in all life domains. To do so requires personal resources such as energy, time and commitment to be well-distributed across domains". The latter definition introduces a broader context than only the equilibrium between job and family roles. It allows also to include passions, voluntary activities, and so on. Given that the models of social life are constantly changing, managers have to be aware that many employees perceive their professional and private life as a whole, so they want to work flexible hours to have time for their passions as well as to develop in a wide variety of fields and achieve success in a short time (Bieleń, Kubiczek, 2020). That leads to an increased importance of achieving a match between organisation and employee (Jehanzeb, 2020) and to the necessity of looking at work–life balance more broadly, going towards a work–nonwork balance (Casper et al., 2017; Kelliher et al., 2019).

#### **2.5. Empowerment**

In general, we can understand empowerment in two ways. On the one hand, it is the leaders' behaviour that empowers their followers; on the other hand, it is the psychological state of the employees caused by their leaders' empowerment methods (Stavrinoudis, Psimoulis, 2021).

Delving deeper into its meaning, empowerment consists of two interrelated dimensions: psychological and structural. Leaders enable followers to take extended responsibility for their tasks and at the same time strengthen their self-efficacy and the belief that they can influence the organisation's performance through their individual work. That is why those behaviours are a part of psychological empowerment, which is often perceived as a motivational tool (Yu et al., 2018). Structural empowerment, though, is strictly related to organisational structures and requires delegation of tasks and responsibility to the lower levels of the organisational hierarchy. Thanks to those practices, employees are given decision-making authority and are able to execute their work tasks with greater autonomy (Leach et al., 2003, p. 28). If empowerment is one of the key values within the organisation, it may manifest itself in empowering leadership, which "refers to a set of behaviours of the leader who shares power or allocates more responsibilities and autonomy to his or her followers through enhancing the meaningfulness of work, expressing confidence in high performance, promoting participation



in decision making, and providing autonomy from bureaucratic constraints” (Cheong et al., 2016, p. 603).

When discussing internal CSR, researchers distinguish CSR-fostered empowerment as a "motivating tool in the organisation's internal CSR implementation through which employees receive the opportunity to proactively influence their working processes and contexts" (Mory et al., 2017, p. 176). Corporate ethical empowerment encourages employees to actively participate in CSR activities instead of just implementing a stated strategy. In that way, employees are co-creators of the company's philosophy and may propose and conduct initiatives congruent with shared values and the company's mission statement (Carlini et al., 2019).

### **3. CSR and job satisfaction**

The image of a socially involved company causes its employees to have a sense of pride and raises their self-esteem and morale (Maon et al., 2009; Schaefer et al., 2020). They feel that by belonging to a particular organisation, they are "changing the world for the better", and their work gains additional meaningfulness. This sense of pride also translates into their communication with external stakeholders, and through positive word-of-mouth, the positive perception of the company by job seekers, customers, or communities is also strengthened (Carlini, Grace, 2021; Gully et al., 2013; Okolocha, Decker, 2020; Schaefer et al., 2020). However, to achieve these positive effects, the company must meet two conditions (Lee et al., 2012): firstly, compatibility of CSR initiatives with the company's culture and practices, and secondly, compatibility with the employees' values. These two factors determine the credibility of an organisation's involvement in prosocial activities (Benitez et al., 2020; Schaefer et al., 2020).

Locke (1976, p. 1304) defined job satisfaction as " ... a pleasurable or positive emotional state resulting from the appraisal of one's job or job experiences", and that is the most popular definition among scholars. According to newer literature sources, job satisfaction is connected to happiness and passion with the work that helps achieve fulfilment through accomplishing different goals, recognition and promotion, resulting in financial gain (Kaliski, 2007). We can also understand it as people's attitudes toward their jobs, internal feelings about it and emotional states associated with the job (Chen, 2023).

Many factors influence job satisfaction; according to the research, one of the most important ones is the nature of the job, understood as its intrinsic characteristics. It considers employees' autonomy, flexibility, job challenge, scope and variety (Bellamy et al., 2003; Saari, Judge, 2004). Those factors are present in the dimensions of internal CSR we proposed above, especially in the last three – employee development and training, work-life balance and

empowerment. That allows us to assume that internal CSR activities that reveal the employer's care of employees increase job satisfaction. On the other hand, internal CSR practices perceived as a just and beneficial treatment, based on the norm of reciprocity, may trigger a better perception of organisation and a sense of obligation to concrete positive behaviour (Murshed et al., 2021). In that manner, Velnampy (Velnampy, 2008) states that job satisfaction increases employees' commitment to the organisation and, at the same time, has a positive influence on their job performance.

## 4. Materials and methods

### 4.1. Objective, Hypotheses and Research Methods

The main objective of the study was the identification of the relationship between the level of employee satisfaction (SAT) and the extent of the employer's socially responsible activities towards them in the identified five dimensions: justice and fairness (JUST), health and safety (H&S), availability of training (TRAIN), work-life-balance (WLB) and empowerment (EMP).

This objective, together with the analysis of the literature on the relationship between CSR activities and employee satisfaction, has led us to the following research hypotheses:

H1: Positive evaluations of the employer's internal social responsibility (CSR) activities increase employees' satisfaction (SAT).

H2: Positive evaluations of the employer's activities related to justice and fairness (JUST) from internal social responsibility increase employees' satisfaction (SAT).

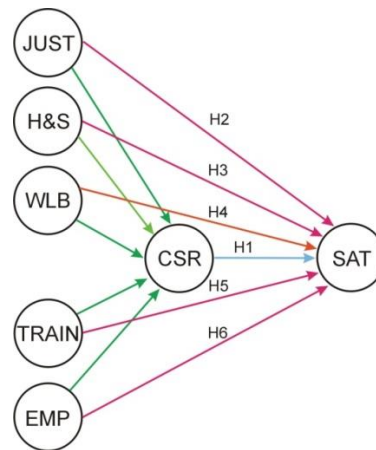
H3: Positive evaluations of the employer's health and safety (H&S) related activities from internal social responsibility increase employees' satisfaction (SAT).

H4: Positive evaluations of the employer's work-life balance (WLB) related activities from internal social responsibility increase employees' satisfaction (SAT).

H5: Positive evaluations of the employer's training-related activities (TRAIN) from internal social responsibility increase employees' satisfaction (SAT).

H6: Positive evaluations of the employer's activities related to empowerment (EMP) from internal social responsibility increase employees' satisfaction (SAT).

Figure 1 presents a graphic presentation of the research model hypotheses.



**Figure 1.** A graphical presentation of the research model hypotheses.

Source: Authors' elaboration.

We used the diagnostics survey (CAWI - Computer-Assisted Web Interview) method and statistical analysis tools to achieve the research objective. We adopted a non-random purposive and convenience sampling, which included Polish employees of organisations undertaking CSR activities that agreed to fill the questionnaire. We conducted the research in August 2023. The areas and dimensions indicated in the purpose of the study were described using multivariate characteristics, and the source here was research available in the literature, which became the basis for creating a research tool in the form of a questionnaire containing 15 items in the CSR area and 6 in the satisfaction area. The CSR area was divided, according to the study's premise, into five dimensions, which were described by a corresponding number of items: JUST (4 items), H&S (2 items), WLB (3 items), TRAIN (3 items) and EMP (3 items). All items were adopted from the available literature of empirical studies to ensure the reliability and reproducibility of the results. The statements that the respondents evaluated were translated into Polish, and we consulted their translation with an expert in English philology to ensure the exactness of their meaning. A full description of the research tool structure with the identification of statements, sources and relevant dimensions and areas is presented in Appendix 1 (Table 7). All the questionnaire questions used the R. Likert scale, based on ranking variables often used in social research (Croasmun, Ostrom, 2011). The following response scale was adopted: 1 - agree entirely; 2 - rather agree; 3 - neither agree nor disagree; 4 - rather do not agree; 5 - entirely do not agree.

The reliability of all multivariate characteristics was confirmed by scale reliability analysis. The determined values of Cronbach's alpha coefficient for the aggregated variables CSR (0.908), JUST (0.751), H&S (0.853), WLB (0.733), TRAIN (0.869), EMP (0.808) and SAT (0.922) allowed the set of all areas and dimensions studied to be considered consistent, which in turn provided a basis for using all the assumed aggregated variables in the analysis.

We verified the research hypotheses using mixed analytical methods, which in social sciences is considered the most effective solution (Johnson, Onwuegbuzie, 2004). The methods included a qualitative analysis using measures of central tendency. Then, we conducted a correlation analysis using Pearson's chi-square independence test. We used Symmetric Measures: Cramer's V and Contingency Coefficient to determine the strength of the relationship between the variables. The normalisation of the data, giving them a quantitative character, conditioned the possibility of examining the correlation using Pearson's test and the directionality of the analysed relationships based on simple and multiple linear regression results. The statistical analysis was performed using the IBM® SPSS® Statistics Ver. 29.

#### 4.2. Demographic Profile of the Respondents

We tested the designed questionnaire in a pilot study. All identified problems have been eliminated, and the revised survey tool has been sent to respondents of the main study, which included 283 respondents representing various business organisations. A detailed description of the research sample is provided in Table 1.

**Table 1.**  
*Sample demographic profile*

Group	Number of Respondents	Percentage
<b>Total</b>		
-	283	100.0
<b>Gender</b>		
Women	148	52,30%
Men	134	47,30%
I identify myself differently	1	0,40%
<b>Age</b>		
18-24 years	18	6,40%
25-34 years	85	30,00%
35-44 years	102	36,00%
45-54 years	45	15,90%
55-64 years	29	10,20%
<b>Education</b>		
primary	1	0,40%
vocational	10	3,50%
secondary	82	29,00%
higher (bachelor's degree)	52	18,40%
higher (master's degree)	137	48,40%
other (engineer)	1	0,40%
<b>Size of the organisation</b>		
6-10 people	21	7,40%
11-49 people	67	23,70%
50-249 people	91	32,20%
250 people and more	104	36,70%

Cont. table 1.

<b>Industry type</b>		
Public administration	23	8%
Construction	25	9%
E-commerce	2	1%
Education, science	24	8%
Pharmacy and healthcare	3	1%
Finances and insurance	38	13%
Wholesale and retail trade	21	7%
Hotels, restaurants, gastronomy	5	2%
IT and new technologies	28	10%
Logistics	8	3%
Media/Commercials/PR/Editors	4	1%
Healthcare and social aid	8	3%
NGOs	2	1%
Production and industrial processing	50	18%
Agriculture, forestry, hunting and fishing	4	1%
Transport, warehouse management, communication	15	5%
Services	23	8%
<b>Job position</b>		
Manager	101	35,70%
Specialist	112	39,60%
Executive employee (not managing a team or a department)	70	24,70%
<b>Employment status</b>		
employment contract of indefinite duration	218	77,00%
fixed-term employment contract	49	17,30%
contract of mandate	7	2,50%
contract	7	2,50%
Other (own business)	2	0,70%
<b>Employment time</b>		
below 1 year	20	7,10%
1-2 years	32	11,30%
2-5 years	84	29,70%
5-10 years	88	31,10%
over 10 years	59	20,80%
<b>Employment experience</b>		
This is my first job	38	13,40%
I have worked for 2-5 employers	215	76,00%
I have changed employers more than 5 times	30	10,60%

Source: Authors' elaboration.

### 4.3. Research results

The descriptive statistics presented in Table 2 indicate that employees rate the area of internal CSR activities highly (mean 3.91), but the ratings of the individual dimensions vary. Above average for the area as a whole, respondents rated health and safety (4.25) and justice and fairness (4.13). Slightly below average were the dimensions of accessibility to training (3.88) and empowerment (3.84). Respondents awarded the lowest rating to the work-life balance dimension (3.52). It is worth noting here, however, that employees' evaluations in this area were quite diverse, as can be seen from the highest standard deviation of all dimensions (1.03). The level of satisfaction was also rated by employees at a fairly high level, obtaining

a mean of 3.87. It is, therefore, only slightly lower than the assessment of the CSR area, and the high median and dominant indicate that a large group of respondents rate their satisfaction very highly.

**Table 2.**  
*Measures of central tendency of the studied variables*

Variable	Mean	Standard deviation	Median	Dominant
CSR	3,91	0,69	3,93	3,67
JUST	4,13	0,73	4,25	5,00
H&S	4,25	0,80	4,50	5,00
WLB	3,52	1,03	3,67	4,00
TRAIN	3,88	0,93	4,00	5,00
EMP	3,84	0,83	4,00	4,00
SAT	3,87	0,90	4,00	5,00

Source: Authors' elaboration.

The analysis of the results indicates that at the level of all variables, there is an influence of both the aggregate variable describing CSR and its dimensions (Table 3). The Chi-square independence test returns values indicating the existence of statistically significant relationships between all pairs of characteristics (Table 2). We should also note that all relationships are strong. The strongest is found for the CSRxSAT pair (0.930) and the relatively weakest for the WLBxSAT pair (0.772).

**Table 3.**  
*CSR and Dimensions of CSR vs. Satisfaction –Chi-Square Tests Results*

Variable	Chi-Square Tests			Symmetric Measures	
	Value	df	p*	Cramer's V	Contingency Coefficient
CSR x SAT	1808,467	946	0,000	0,539	0,930
JUST x SAT	617,697	286	0,000	0,410	0,828
H&S x SAT	453,740	154	0,000	0,479	0,785
WLB x SAT	416,498	264	0,000	0,350	0,772
TRAIN x SAT	624,054	264	0,000	0,429	0,829
EMP x SAT	714,795	264	0,000	0,459	0,846

\* Asymptotic Significance (2-sided). Significant for  $p < 0.05$ .

Source: own elaboration.

These relationships are also confirmed by the Pearson correlation coefficient analysis (Table 4). All the correlations are statistically significant, and since all of them are in the range of 0.4-0.7, all indicate a moderate strength of the relationship between the characteristics.

**Table 4.**  
*CSR and its Dimensions vs Satisfaction –Pearson Correlation Results*

Variable Coefficient (p)	SAT
CSR	.683** (.000)
JUST	.560** (.000)
H&S	.533** (.000)
WLB	.466** (.000)
TRAIN	.578** (.000)
EMP	.602** (.000)

\*\* . Correlation is significant at the 0.01 level (2-tailed).

Source: own elaboration.

The next step of the analysis was to test the statistical significance of the relationships and their direction and strength using the linear regression method. All relationships tested are statistically significant ( $p < .001$ ), indicating a good fit of the model to the data. The results indicate that all the assumed variables for CSR in the aggregate and its dimensions significantly impact employee satisfaction. The strongest impact appears for CSR as an area (0.319) and the weakest for the aggregate impact of individual dimensions on SAT (0.145). It is worth noting that a relatively strong impact appeared for the justice dimension (JUST = 0.297). For the other dimensions, the strength was 0.198 (TRAIN), 0.171 (H&S), 0.156 (EMP) and 0.155 (WLB), respectively. The adjusted determination coefficient ( $R^2$ ) indicates that almost half (46,6%) of the employees' satisfaction depends on the aggregate CSR variable. For individual CSR dimensions, the results are relatively lower, with above 30% effects on satisfaction in the case of empowerment (36.3%), access to training (33.4%) and justice and fairness (31.4%). The remaining two dimensions have index levels above 20%: health and safety 28.4% and work-life balance 21.7%.

**Table 5.**  
*CSR and its dimensions vs Satisfaction –Linear Regression Results*

Variable	R Square	Durbin-Watson	ANOVA		Test t		Unstandardised Coefficients
			F	F	T	p*	
CSR→SAT	0,466	2,001	62.766	62.766	7.922	<.001	.319
JUST→ SAT	0,314	2,126	40.479	40.479	6.362	<.001	.297
H&S→ SAT	0,284	1,871	39.256	39.256	6.265	<.001	.171
WLB→ SAT	0,217	1,855	24.110	24.110	4.910	<.001	.155
TRAIN→ SAT	0,334	2,076	46.611	46.611	6.827	<.001	.198
EMP→ SAT	0,363	1,949	21.223	21.223	4.607	<.001	.156

\*. Acceptable level:  $p < 0.05$ .

Source: Authors' elaboration.

The obtained results of the analyses allow us to conclude that, although the strength of the relationships varies, there are statistically significant relations between the examined variables concerning both the CSR area and its dimensions and the level of job satisfaction perceived by employees. It allows us to confirm all the assumed research hypotheses (Table 6).

**Table 6.**  
*Hypotheses results*

Hypotheses		Decision on hypotheses
H1	Positive evaluations of the employer's internal social responsibility (CSR) activities increase employees' satisfaction (SAT).	Confirmed
H2	Positive evaluations of the employer's activities related to justice and fairness (JUST) from internal social responsibility increase employees' satisfaction (SAT).	Confirmed
H3	Positive evaluations of the employer's health and safety (H&S) related activities from internal social responsibility increase employees' satisfaction (SAT).	Confirmed
H4	Positive evaluations of the employer's work-life balance (WLB) related activities from internal social responsibility increase employees' satisfaction (SAT).	Confirmed
H5	Positive evaluations of the employer's training-related activities (TRAIN) from internal social responsibility increase employees' satisfaction (SAT).	Confirmed
H6	Positive evaluations of the employer's activities related to empowerment (EMP) from internal social responsibility increase employees' satisfaction (SAT).	Confirmed

Source: Authors' elaboration.

## 5. Discussion

The results allow us to confirm the validity of the dimensions chosen to describe internal CSR. All the areas selected for classification are characterised by statistical reliability and describe the studied area well. It is also worth noting that the different dimensions were rated by respondents at different levels, with significantly higher ratings for areas related to the ethical dimension of CSR, such as justice and fairness, and the legal dimension concerning health and safety. Employees rated significantly lower in the areas related to their development and involvement in the company, such as availability of training and empowerment. On the other hand, the lowest rating was given to work-life balance, which seems to be particularly influenced by the survey's limited to one country range (Ollier-Malaterre et al., 2013).

In this study, all dimensions of internal CSR had a statistically significant impact on employee job satisfaction. Such a result is atypical in relation to the previous studies of this relationship. In most cases, the study's results only confirmed a statistically significant impact of some of the dimensions adopted. For example, Tran et al. confirmed the significant impact of work-life balance and health and safety dimensions. In contrast, they failed to identify a statistically significant relationship between job satisfaction and dimensions such as human rights, training and education and work diversity (Tran et al., 2021). Hossen et al., on the other hand, only confirmed the relationship job satisfaction had with empowerment and employment stability of all the dimensions studied. However, they did not find evidence of an impact on job satisfaction for dimensions such as training education and working environment (Hossen et al.,



2020). Similarly, Obeidat et al. found only selected dimensions such as working conditions, work-life balance, and empowerment statistically related to job satisfaction (Obeidat et al., 2018). However, they could not confirm the impact of employment stability and skills development.

Relating the results obtained to studies available in the literature creates a need to explain why we obtained such a positive result in relation to other researchers. This question requires a deeper analysis of both the internal CSR model adopted, with particular reference to the classification of its dimensions. It would also be helpful to analyse how the company's involvement in each of them was measured and, therefore, the question of item selection. It is also worth highlighting the potentially strong cultural and economic influence of the country where the survey was conducted and, therefore, the specificity of employer responsibility perceptions among Polish employees.

## **6. Conclusion**

### **6.1. Theoretical contribution and managerial implications**

Based on the content presented in the previous sections of the paper, we can conclude that a new, broader approach to CSR activities is needed in the research concerning this concept. On the one hand, it seems that it would be worthwhile to attach more importance to its internal dimension, as employees are a crucial success factor for organisations. Caring for them and treating them with genuine care makes it possible to achieve many benefits for an organisation. Secondly, it seems very limiting to treat CSR activities instrumentally, solely as one of the tools aimed at receiving a bunch of assumed results. Meanwhile, in our opinion, it is too narrow. It does not capture the full range of possibilities offered by assuming that CSR is not what an organisation uses but wants to be, especially for its employees.

It is also worth pointing to the findings of the comprehensive review of the literature, which indicate that the issues identified as dimensions of internal CSR are subject to change and evolution. Although some general dimensions remain the same, their understanding seems to expand to include new issues. An example of this is the area of justice and fairness, which initially focused on fundamental human rights but now also includes topics such as diversity and inclusion, anti-discrimination, and anti-bullying.

The paper offers an important contribution to the development of theory on internal CSR by proposing a new classification framework that considers the specificities of operating in contemporary organisational settings. It is particularly relevant given the dynamic and challenging environment in which companies must operate.

However, the paper can also provide implications for managers. Firstly, the new classification framework can indicate where a company can behave responsibly towards its employees. Secondly, the research results indicate areas for developing currently taken activities, especially training, empowerment and work-life balance. It is worth emphasising that, as research on the characteristics of Generation Z representatives indicates, these factors are the key criteria young people consider in the labour market (Kirchmayer, Fratričová, 2020). Thus, it is these activities that are the premise of their assessment of the attractiveness of a potential employer. Therefore, to attract the most talented candidates of the younger generation to the company, managers should pay attention to the responsible actions taken by organizations towards their employees precisely in this regard. Especially since, as mentioned earlier, having high-quality and engaged employees is now becoming the most critical source of sustainable competitive advantage.

## **6.2. Limitations**

The study has several limitations, which may limit the possibility of concluding the entire population based on the results obtained. The first addresses a problem faced by all research of a social nature. Response bias, such as positive skew or social desirability, related to the social sciences method based on self-reporting may influence the objectivity of respondents' answers. It might be relevant for our research because some questions require respondents to know about the organisation's activities, and some of the concern issues researched are subjective. The survey was conducted on respondents in only one country. The results may, therefore, be influenced by the economic and cultural specificities of Poland, so to be able to generalise the results to the entire population of employees, the research should be replicated in other countries to exclude the impact of local factors.

## **6.3. Further research**

In this paper, we analysed the relationship between the dimensions of internal CSR and employees' job satisfaction. Meanwhile, several studies indicate that other attitudes and behaviours of employees are also beneficial to the organisation due to their positive assessment of the extent of the employer's responsible actions towards them. Among these, organisational commitment, identification with the organisation, extra-role behaviours, internal employer brand or employee retention are worth mentioning. Therefore, it might be worthwhile to expand the range of effects to include other benefits as well.

Effects at the level of employee attitudes and behaviours are social factors and, as such, are mainly measured at the declarative level. An interesting area for further research would be to include hard metrics that allow specific, measurable, objective facts, such as effects on employee performance, to be included in analyses. It also seems interesting to continue research into the effects of internal CSR on organisation-wide or market-level results. Such effects could consist of economic efficiency or the company's market situation. It would then be possible to

demonstrate a link between a company's engagement in internal CSR and the achievement of sustainable competitive advantage.

It might also be worthwhile to carry out a study in other countries to exclude the effect of factors with a local character resulting from the functioning of the organisation and the conditions of human resources management in a given country.

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## Appendix 1

**Table 7.**

*Items, indicators of items and variables used in the research*

General item symbol/CSR deimension symbol	Item name	Answers/variables	Source
<b>CSR</b>	<b>Corporate Social Responsibility</b>		
<b><i>JUST</i></b>	<b><i>Organisational justice and fairness</i></b>		
	My last performance rating was free from bias		(Baird et al., 2020)
	My organisation creates an equitable work environment		(Carlini, Grace, 2021)
	My organisation does not discriminate when hiring employees		
	In this organizations, employee get adequate financial incentives		(Rahi, 2022)
<b><i>H&amp;S</i></b>	<b><i>Health and safety</i></b>		
	My organization's policies always provide a safe and healthy working environment for the employees.		(Lee, 2021)
	My company always analyses and monitors the health and safety risks that are associated with its activities, to create an excellent working.		
<b><i>WLB</i></b>	<b><i>Work-life balance</i></b>		
	I can choose part-time work at my organization.		(Smith, Gardner, 2007; Thang, Fassin, 2017)
	To ensure a good balance between work and private life, my company offers its employees flexible working time options		(Lee, 2021)
	I have enough time after work to carry out personal matters.		(Thang, Fassin, 2017; Wong, Ko, 2009)
<b><i>TRAIN</i></b>	<b><i>Employee training and development</i></b>		
	My organization is fully supportive of a career-management program for the employees.		(Lee, Bruvold, 2003; Thang, Fassin, 2017)
	My organization provides a systematic program that regularly assesses employees' skills and interests.		
	My company supports and promotes lifelong learning and further development of the employees intensely		(Lee, 2021)
<b><i>EMP</i></b>	<b><i>Empowerment</i></b>		
	In my organisation, I have the opportunity to actively participate in the development of new CSR practices		(Carlini, Grace, 2021)
	In this organization employees have the liberty to take a new initiative		(Rahi, 2022)
	Employees have complete authority to perform organizational tasks		
<b>SAT</b>	<b>Employee satisfaction</b>		
	Overall, I am quite satisfied with my job		(Homburg, Stock, 2005)
	I do not intend to work for a different company		
	I like my job		
	There are no fundamental things I dislike about my job.		
	I like my job more than many employees of other companies		
	I consider this employer as first choice		

Source: own elaboration.

## THE ENERGY CONCEPT OF MONEY

Oleksandr MELNYCHENKO

Department of Finance, Gdansk University of Technology; oleksandr.melnychenko@pg.edu.pl,

ORCID: 0000-0002-7707-7888

The London Academy of Science and Business, UK

**Purpose:** This paper aims to provide the literature review seeking an answer whether energy can be used as a universal equivalent instead of money.

**Methodology:** The author conducted a review of available literature and data sources related to the money theory and energy concept of money.

**Findings:** It was found that the definition of energy as a general equivalent has a contextual and dynamic nature, and this field's consolidation and logical expansion require a conceptual review. In this study, we talk about the basic principles of the energy concept of money: origin, recognition, and circulation. Throughout this paper, we explore key aspects of this new agenda, demonstrating that energy is at the heart of money circulation.

**Research limitations:** It is suggested three areas for future research: quantifying the stability of energy price in the context of fiat money in dynamics, technological implementation of transactions, and the development of accounting technologies.

**Practical implications:** Consolidating the available literature and providing suggestions on how money theory can be developed in light of the current energy challenges. The author's approach the energy concept of money from an interdisciplinary perspective, including knowledge of economics, business, accounting, payment systems, law, and philosophy, to reflect on their own experiences. The energy concept of money in this study refers to the use of energy in a broad sense as a universal equivalent, the role of which is played today by money.

**Originality:** In this paper, the author seek to contribute to a deeper understanding of the energy basis of money by exploring the conceptual and empirical relationship between money, trust, and energy.

**Keywords:** money; energy; trust; universal equivalent.

**Category of the paper:** Conceptual paper.

## 1. Introduction

Modern money circulation is based mainly on trust (Brandl, 2020, p. 545; Ingham, 1996a, p. 18; Ingham, 1996b, p. 507; Ingham, 1998, p. 4). People trust the government by exchanging their time, which will never return, skills and knowledge for money issued by government institutions and guaranteed by them as a means of payment. A state is also responsible for preserving the value of money and its purchasing power (Friedman, 2001; Giannini, 1995, p. 219). People also trust banks and other money circulation participants, which guarantee the preservation of financial resources, their transfer in the appropriate direction. They trust other people, transferring money to them in anticipation of receiving a service or product. From ancient times, the usefulness of money and financial transactions is based on the community of trust, which is social and moral, confirmed by historical facts and archaeological excavations (Baron, Millhauser, 2021). Of course, in the modern world, such confidence is supported by various legal norms, rules, legal consequences for the parties to fulfill their obligations and responsibilities (Burlaka et al., 2019; Kwilinski, Volynets, Berdnik, Holovko, Berzin, 2019; Kharazishvili, Kwilinski, Grishnova, Dzwigol, 2020). However, how many times have people experienced situations where commitments have not been met? From the mundane sale of goods lacking the quality to international financial crises, which led to significant losses for those who, indeed, trusted the other side (Dalevska, Khobta, Kwilinski, Kravchenko, 2019, p. 1842). The Great Depression, the global crisis of 2008, and many local upheavals in different countries led to a decrease in the purchasing power of money and significant economic and social problems for citizens. Moreover, since money is created out of nothing, it can be transformed back to nothing by the institutions that have created it (Galvin, 2020). Awareness of this may cause some people to fear working in exchange for the national currency, especially in regions where governments do not enjoy the popularity and trust of the population.

By paying with a card in the supermarket for purchases, customers believe that the funds placed on their bank account and earned will be debited from this account and transferred to the seller. They are confident that they will be able to take things from the cart home and use them at will. They believe it because none of the financial transaction processes depends on them: customers cannot influence it, standing at the checkout in the supermarket. By touching the card to the payment terminal and waiting for the transaction to be complete, we believe it will succeed. Some people know how a payment transaction works and trust in the successful completion of each stage. In contrast, others have no idea what happens after the payment card touches the terminal and simply believe that the payment will go through. At the same time, the card payment itself is essentially a series of significant and technically complex transactions. The number of factors that may affect its successful completion approaches infinity.

In the case of bilateral relations between, for example, sellers and buyers in legal countries with developed economies, the former are more often fully liable for improper performance of their financial obligations in the form of full compensation for customer losses or otherwise under the law. When it comes to monetary losses of the population at the national or international level due to inflation, no one is actually responsible to those affected by it. Of course, there are tools for indexing earnings and market mechanisms for income growth. Still, these are the existing ways of dealing with the consequences of money value decrease, not a measure of personal responsibility to prevent losses.

On the other hand, money creates a sense of trust in society, which is one of its most important social functions. Let us say that money does not exist and economic relations are built on trust. People would receive goods and services without payment, having only a sense of responsibility to society as a whole and specific people, in particular, to give their knowledge, skills, and time in full also without monetary payment and additional guarantees that their work or goods would be valued in financial terms. However, the level of responsibility as a human personality trait is different for all people. We can hardly imagine today a society in which everyone would have the required responsibility level to support such a system. Therefore, the level of trust between people is different because everyone understands that the responsibility of the other is not ideal. This is also confirmed by various studies (Thielmann, Hilbig, 2015, p. 249), in particular, that the level of trust can change significantly under certain circumstances, so it is not stable (Rahman, Lee, Shabnam, Jayasinghe, 2020, p. 460). “Most people care about collective interests, but they are reluctant to contribute because they fear that other people free ride and their contributions would be exploited and wasted” (Tam, Chan, 2018, p. 183). In such circumstances, we need guarantees, a universal tool, and an equivalent that would guarantee the fulfillment of obligations and equalize the level of trust. Such a tool today is money.

Trust is an integral concept of social cohesion. It is one of the pillars of society. This idea is supported in a number of scientific publications (Bejarano, Gillet, Rodriguez-Lara, 2021; Grossmann et al., 2021; Van Den Akker, van Assen, Van Vugt, Wicherts, 2020), which emphasize that it can be a resource for individual or social development, while its lack can hinder cooperation and contribute to conflict. But can the money be a guarantee of obligation fulfillment and equalize a level of trust? Although we do not seek to answer this question directly, we publish this study in a series of key discussions in the field of money theory and social science research and the growing use of energy-oriented approaches to addressing financial problems.

In its modern sense, money has existed for hundreds and even thousands of years (Davies, 2016); only its forms, recording methods, and types of media change. The essence of cash is realized in its physical form as a means of legal payment in a certain area, and the non-cash form is realized as an accounting system, which registers the records of who owes whom and how much. The so-called fiat money has no value based on the materials from which it is made (such as precious metals or other valuable components), and its use is based solely on trust. It has a number of different disadvantages (Melnychenko, 2021b), which have a significant impact on society, economic relations, the functioning of businesses and households, and states and international associations. Therefore, it is advisable to find a perfect, universal tool that would perform the functions inherent in money yet be devoid of its shortcomings. A possible scenario for improving this social phenomenon is the use of energy as a universal substitute and equivalent in modern economic relations. This hypothesis is not new and is reflected in modern scientific publications. However, it has not been studied conceptually but only indirectly in the form of individual assumptions (Haug, 2020), when assessing energy poverty (Grossmann et al., 2021; Halkos, Gkampoura, 2021; Churchill, Smyth, 2020), the energy of finance (Korol, 2021; Melnychenko, 2021b; Melnychenko, Kwiliński, 2017), energy justice, poverty, and security (Jenkins et al., 2016; Kharazishvili et al., 2021; Pająk, Kvilinskyi, Fasiiecka, Miskiewicz, 2017). Samid (2015) also asks the question, “Is money energy?” However, it is not a key question in his study, and therefore the answer to it is not provided directly. According to Douthwaite (Douthwaite, 2012), the decisions on money distribution concerning who, for what, and how much can borrow will be made by those who supply energy to society and not banks. “Money once bought energy. Now energy, or at least an entitlement to it, will actually be money, and energy firms may become the new banks” (Douthwaite, 2012, p. 190).

Therefore, a conceptual overview is now needed to consolidate and expand this research area. The biggest problem of modern money is the decline in its confidence due to a number of inherent flaws. Therefore, it is advisable to continue the search for more perfect universal equivalent to uphold the socio-economic relations given the low level of public confidence in institutions, other people, and financial instruments. Given the current energy fever in which energy needs constantly grow (IEA. Data statistics, 2020), and the struggle for energy sometimes develops into a fight for life (San-Akca, Sever, Yilmaz, 2020; Johnstone, McLeish, 2022; Johnstone, McLeish, 2020), we could seek to answer the question of whether energy, in addition to its inherent and known functions, can also play the role of the general equivalent that money plays today. In this paper, the author seek to contribute to a deeper understanding of the energy basis of money by exploring the conceptual and empirical relationship between money, trust, and energy.

In view of this, this paper has two purposes: first, section 3 provides an overview of modern literature and give examples of the shortcomings of contemporary money from the standpoint of trust, and secondly, section 4 proposes new uses of energy as general equivalent replacing modern money. Thus, a conceptual overview and research agenda are proposed while consolidating the available literature and providing suggestions on how money theory can be developed in light of the current energy challenges. The author's approach the energy concept of money from an interdisciplinary perspective, including knowledge of economics, business, accounting, payment systems, law, and philosophy, to reflect on their own experiences. The energy concept of money in this study refers to the use of energy in a broad sense as a universal equivalent, the role of which is played today by money.

This study is intended to provide an overview of some major economic aspects of the functioning of energy as a general equivalent. The task we set ourselves is challenging due to the novelty and interdisciplinary of the topic and the large number and variety of literature covering it. Accordingly, some issues are only partially addressed and require further discussion, elaboration, and in-depth research. The author made a snowballing review of predominantly English-language literature on this topic by an extensive direct and reverse search. It was found more than 100 relevant links and peer-reviewed publications from the SCOPUS, Web of Science, and ScienceDirect scientific research databases were included that we used to support our idea. The author has used such keywords as trust, energy, money, money theory, energy theory of value, functions of money, payment, energy poverty, etc. The literature review focused primarily on the 1974 and 2022 literature to capture the latest trends and advances in specified areas for these keywords.

## **2. Research method of the systematic literature review**

The methodology adopted in this section involves a literature review underpinning the dimensions of the problem investigated and the elements that need to be tested via primary data analysis.

We use the three-step procedure conforming to the methodological approach of systematic literature review, which is “a powerful technique in social science research, which is about systematically locating, evaluating and synthesising all available information to an effect or a topic area” (Tsigdinos, Tzouras, Bakogiannis, Kepaptsoglou, Nikitas, 2022; Davis, Mengersen, Bennett et al., 2014). This approach showed its efficiency in many scientific papers such as (Tsigdinos, Tzouras, Bakogiannis, Kepaptsoglou, Nikitas, 2022; Bask, Rajahonka, 2017, p. 565; Wray, 2004; Oliveira, Bandeira, Vasconcelos, Schmitz, D'Agosto, 2017) and consists of the following steps: (1) planning, which identifies the need for the systematic review, defines the sources and procedures for literature searching, and contains a review protocol;

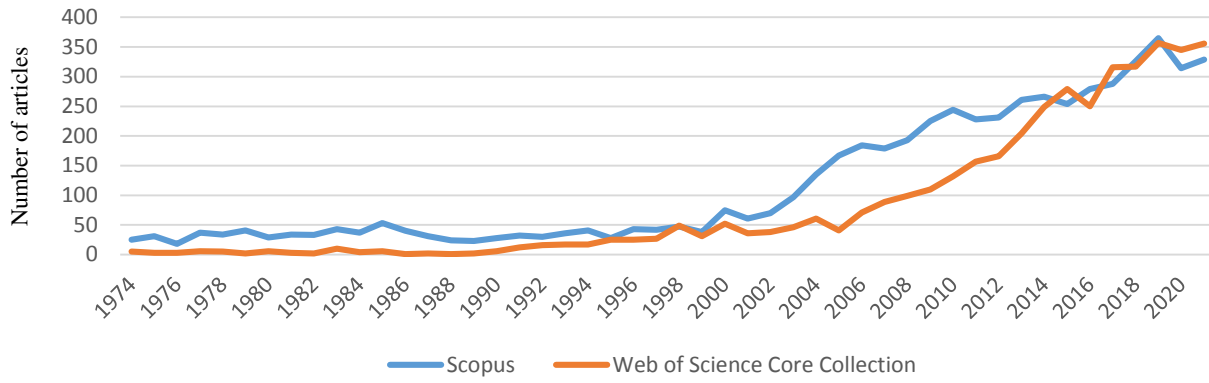
(2) the review process realization implementing the defined criteria, identification, selection, inclusion, and evaluation of the selected papers. At the end of this step is data extraction and its synthesis; (3) presentation and dissemination stage, which includes preparing the reports and presenting the results.

Hence, we made the research plan, which included aim and questions, keywords, and a set of inclusion and exclusion criteria. The literature review's purpose was to identify the perspectives in the scientific papers related to the energy concept of money and investigate research to answer the question of whether can energy be used as a universal equivalent instead of money. We assembled keywords, namely, "energy" "money", "energy money", "money theory", "energy money theory", "energy theory of value" and limit their to subject area related to economics, business, management, finance and accounting, because the most energy studies related expectable to other scientific areas like engineering, environmental science, etc. The following databases were used for the development of the protocol of the review: SCOPUS, Web of Science (WoS), and ScienceDirect according to the recommendation of Nord and Nord (Nord, Nord, 1995, p. 35), who suggest using more than two databases to ensure the identification of a better diversity of papers.

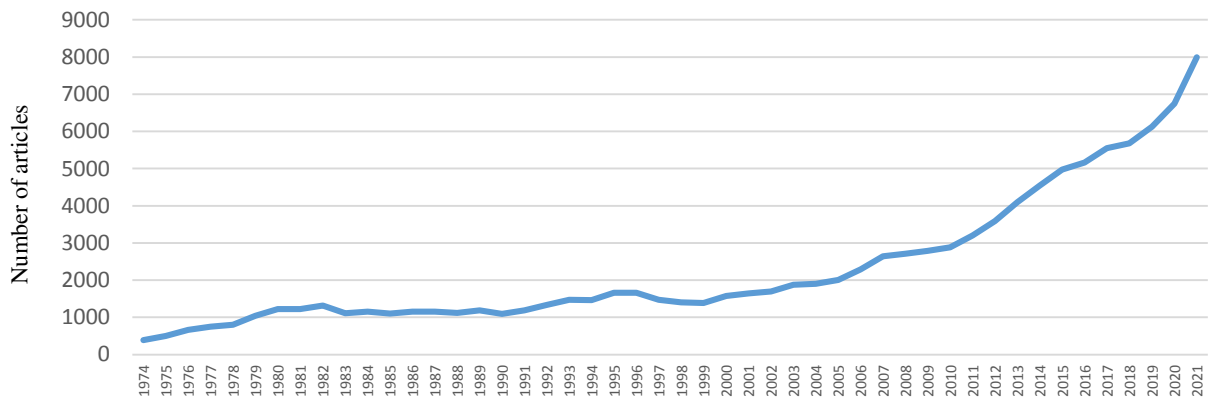
The inclusion criteria were defined as academic peer-reviewed journal papers written in English that are in line to the research objectives. Furthermore, the papers examined were published after 1974, when the issue of energy and money was started complex, dynamically, and rapidly investigate. The results of a bibliometric analysis of the changes dynamics in the number of publications on energy and money in the Scopus and WoS databases show its gradual growth. In 2003, the number of publications on energy and money indexed by the SCOPUS database increased significantly to 97 from 70 in 2002. A similar situation is observed in 2006 with publications on the problem of energy and money in the WoS database. These trends are related to the historical milestones and energy crisis: 1973 oil crisis (Alpanda, Peralta-Alva, 2010, p. 830), 2003-2008 oil price boom (Casertano, 2013, p. 213). In general, energy consumption from 1995 to 2015 grew exponentially, and in 2021-2022, energy has become a weapon, especially in relations with Russia (Stegen, 2011, p. 6508). That is why, to ensure the timeliness of the selected texts and based on the mentioned search assumptions the period from 2004 to 2022 was set.

In step 2, the search was performed for article titles, abstracts, and keywords. The search was performed in June 2022. No time restrictions were applied to the search in the first stage. Initially, the search returned a total of 133 699 articles including journal articles and conference proceedings found in Scopus, Web of Science, and ScienceDirect databases by keywords "energy" AND "money" (Figure 1).





a)



b)

**Figure 1.** Number of articles in the a) Scopus, WoS and b) ScienceDirect databases on energy and money, 1974-2021.

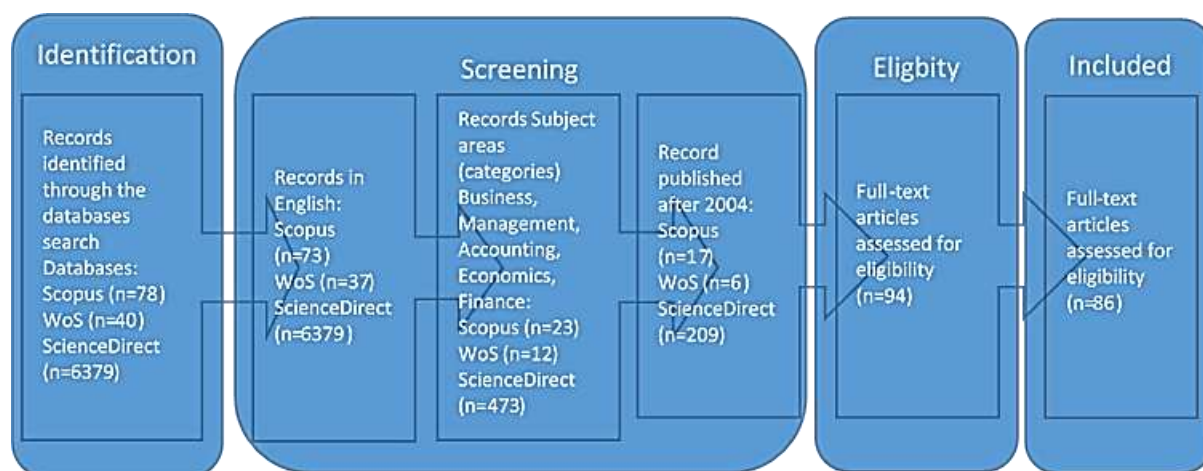
Source: Compiled by the author on the basis of the Scopus, Web of Science, and ScienceDirect databases.

The bibliometric analyses results conducted by VOSviewer tools show the relationship of the energy and money with a number of economic categories (Fig. 2), in particular, such as price, business, cost, good, and demand, which are closely related.



To help ensure the quality of the pool of identified papers “Grey literature” and conference proceedings, books, technical reports and webpages were excluded from the set. The search was conducted using Scopus, Web of Science, and ScienceDirect presents the number of papers found for each combination of keywords. It was also made a filter that limits articles language to English because the phrases of the energy concept of money has different translations in various languages that do not fully reflect its proper understanding.

The search for journal papers written between 2004 and 2022 limited to English; Subject areas (categories) Business, Management, Accounting, Economics, Finance; Article document type, Final publication stage, Journal source type by keywords "energy money", "money theory", and "theory of value", returned 1546 papers. Then the search was performed by keywords "energy money theory", “energy theory of value”, “energy” AND "money theory", and “energy” AND “theory of value” and limited to English; Subject areas (categories) Business, Management, Accounting, Economics, Finance; Article document type, Final publication stage, Journal source type. It returned 232 papers. These passed a title and abstract screening and were ‘eye-balled’ for consistency and precision of the keyword search purposes, also duplicates were removed. The final set of relevant papers included only 94. The full text of these initially screened articles was then compared to the study’s research focus. This led to a review pool consisting of 86 articles, which were re-read, reviewed, categorised, and analysed. This literature selection procedure is illustrated via a PRISMA diagram (see Fig. 3) that ensures transparent and complete reporting of the Systematic Literature Review process. Therefore this systematic literature review develops strong foundations for future research in the chosen area.



**Figure 3.** PRISMA workflow and number of collected papers in each step.

Source: <http://prisma-statement.org/PRISMAStatement/Checklist>

In stage 3 (presentation and dissemination), the work focused on presenting findings related to identifying the concepts underpinning the energy concept of money. Particularly, a synthesis process was undertaken, highlighting and combining different elements to formulate the concept in question. At this stage, other publications on the topic were also integrated as additional supporting literature evidence to better comprehend the issue and elaborate better

results. The total number of reviewed publications was 166. Based on the bibliometric analysis and literature research we are presenting the knowledge review in the next paragraphs.

### 3. The Problem of Trust

Galvin (Galvin, 2020), answering the question of what money is and analyzing different approaches to its interpretation, explains the artificial nature of the origin of money. It is, in essence, “a relationship of obligation and entitlement between a debtor and creditor. It is thereby a basic social phenomenon grounded in power relationships that are backed up by the state with its rules, institutions, and coercive apparatus. Most money today is created out of nothing by the commercial banking system as loans to customers”. “Banks do not transfer real resources, but rather create money and purchasing power” (Li, Wang, 2020; Werner, 2014, p. 5; Werner, 2016, p. 363; Eeghen, 2021; Azarenkova, Samorodov, Melnychenko, 2014, p. 360). Indeed, money does not exist in nature, and its appearance is the result of human activity. Its recognition as a general equivalent is based on the rules and coercion set by the state. This thesis also underlies the statement of the European Central Bank (ECB), which is developing the digital euro project, stating that “just like cash, a digital euro would be a direct claim on the central bank and would therefore have no risk – no liquidity risk, no credit risk, no market risk” (Preparing for the euro’s digital future...; Kwilinski, Vyshnevskyi, Dzwigol, 2020). The ECB will be the debtor, the owner, to whom each person can claim for the single European currency. However, what can such requirements look like in practice? If, under the gold standard, a banknote holder could apply to a bank to exchange paper money for gold, to which asset can the creditor exchange the central bank’s liabilities? To the same money with the same obligations and real assets such a person will not receive due to the credit nature of money.

Therefore, the level of trust in money directly depends on trust in the government and other institutions involved in their creation. “But as the 2008 crash demonstrated, the institutions in which we place our faith are liable to let us down” (Haug, 2020). Moreover, in Europe, trust in existing elected democratic institutions is fading (Grossmann et al., 2021; Valdez, Kluge, Ziefle, 2018, p. 133), but it is a vital component of reforms (Caferra, Colasante, Morone, 2021). As Greenberg notes, “the major reason why trust is an issue for society is that public concerns about risk appear to have intensified” (Greenberg, 2014, p. 152). Distrust in money also grows in an environment where society repeatedly faces the problem of preserving the value of the local currency contrary to the assurances and obligations of relevant authorities. Thus, in the countries of Eastern Europe in recent decades, there have been several economic crises, leading to significant losses of savings and current solvency problems (Hofmarcher, 2021; Rodriguez-Alvarez, Llorca, Jamasb, 2021; Halkos, Gkampoura, 2021; Karpinska,

Śmiech, 2020; Kostyrko, Kosova, Kostyrko, Zaitseva, Melnychenko, 2021; Vatamanyuk-Zelinska, Melnychenko, 2020, p. 11). On the other hand, confidence in the euro, particularly cash, remains high in the European Union, which is not surprising given the low inflation rate in the eurozone of 0.7% in 2020 (HICP - inflation rate). This is evidenced by the fact that about three of the four banknotes stored in Germany are under the so-called mattress or in a safe (Beermann, 2020). Despite all the advantages of cash (The Eurosystem cash strategy and the role of cash), the share of payments made by non-cash methods is growing in the euro area for various reasons (Card payments in Europe...; Cabello, 2020, p. 25). However, there is no evidence that this increase is due to increased confidence in non-cash forms of payment and decreased trust in cash. On the contrary, distrust of cash transactions displaces and restricts their use (for example, to pay large sums of money) to increase control over those transactions where there may be doubts about their legitimacy and confidence in them and entities that carry out such operations. After all, if there were no doubts about the honesty and integrity of the participants in financial transactions, then there would be no need for measures to combat money laundering, terrorist financing, and so on.

In general, we can talk about trust based on its two pillars: 1) justice and 2) confidence, which are subjective and depend more on the experiences, feelings, and cognitive limitations of people who assess the level of trust (Melnychenko, 2020).

Let us take a closer look at each of these pillars in terms of trust in the modern monetary system in light of the possibility of using energy as a general equivalent.

- 1) The distribution of goods, not money, is the primary concern of any society that seeks to be fair. An example of this in retrospect is an influential study in the field of archeology (D'Altroy, Earle, 1985, p. 188), which shows that the leaders of ancient peoples strengthened power over other elites through control over the production and distribution of rare and valuable items, and through control over necessities for ordinary people to prove themselves as a source of legitimate power. Today, the distribution of money is more convenient (Buchanan, Roberts, 2021) because the problems with logistics in the distribution process are not as significant as with, for example, necessities; money does not require high costs to be delivered or stored; it can be distributed conveniently among recipients. However, according to Sovacool (Sovacool, 2014, p. 3), it is energy that must be distributed in the first place to achieve a sense of justice, which, in addition to being a commodity, is also a rare and precious resource.
- 2) Society's confidence in the future is based on the belief that the existing system and the very life of man will continue in a state not worse than today. And "money and the desire for physical well-being is one of the most fundamental human motivators" (Franzen, Mader, 2022). In this case, well-being directly depends on energy because energy is one of the key elements of a modern economy and the functioning of an entire civilization. Without energy, neither living organisms can function, particularly people, whose work is the basis of economic relations, nor machines, which perform most types

of work in modern conditions. Without energy, the movement of capital underlying the economy, the growth of which depends on energy prices, is also not possible (Ayres et al., 2013, p. 9). After all, money production itself requires a significant amount of energy to extract and process all components of cash (for example, to produce one US dollar banknote, 97 850 MWh is needed for printing, which is equal to 0,35 million GJ, and to manufacture pulp – 0,45 million GJ) (Ahlers et al., 2010), the operation of servers, and other payment infrastructure for non-cash money (Melnychenko, 2021a). In turn, energy security is the reliable supply of energy at reasonable prices to support the economy, industry (Dorian, Franssen, Simbeck, 2006, p. 1984; Vivoda, 2010, p. 5285), and social order. Accordingly, there is a possibility of being in energy danger, energy poor (Churchill, Smyth, 2020), or energy vulnerable (Middlemiss, Gillard, 2015, p. 146), which can lead to violation and destruction of the existing order and life in both biological and socio-economic sense. According to Middlemiss and Gillard (Middlemiss, Gillard, 2015, p. 147), this problem consists of six key issues: housing quality, energy costs and supplies, household income stability, rental housing, social relations inside and outside households, and the state of health. These problems are directly related to financial vulnerability, as each of them is directly related to lack of funds, financial security (Melnychenko, 2020; Tkachenko, Kwilinski, Korystin, Svyrydiuk, Tkachenko, 2019, p. 376), and financial pillars (Thacker, 2013, p. 205), on which such security depends. Therefore, we can say that energy and money are closely related and interdependent.

What motivates society to trust the modern form of money and money circulation?

Modern research has revealed two aspects of trust: 1) based on the competence of agents, i.e., trust in knowledge and experience; and 2) based on the decency of agents, i.e., belief in the honesty and transparency of agents (Gordon, Brunson, Shindler, 2014, p. 579; Liu, Bouman, Perlaviciute, Steg, 2020; Terwel, Harinck, Ellemers, Daamen, 2009, p. 1130; Mayer, Davis, Schoorman, 1995, p. 709; Siegrist, Earle, Gutscher, 2003, p. 705; Poortinga, Pidgeon, 2003, p. 961). In some cases, trust built on competence prevails over trust built on values (Greenberg, 2015, p. 152). Each aspect of trust is based on information flows, which can also distort reality and manipulate people's minds in addition to any positive impact. Thus, achievements in marketing (Arasu, Seelan, Thamaraiselvan, 2020; Jacobson, Gruzd, Hernández-García, 2020; Salo, 2017, p. 115), social engineering (Hatfield, 2018, p. 104; Li, Wang, Ni, 2020, p. 47; Mouton, Leenen, Venter, 2016, p. 186; Prentice, Paluck, 2020, p. 13), as well as consumer experience and the vital need to purchase necessities show that the solution and trust in anything are sometimes only an illusion because modern virtual communities can form and change human perceptions and actions (Lee, Lee, Oh, 2015, p. 110; Sedera, Lokuge, Atapattu, Gretzel, 2017, p. 831). The spread and participation of society in various virtual communities (as of 2021, Facebook has more than 1.8 billion active users daily, i.e., 39% of global Internet users) (10 Facebook statistics every marketer should know in 2021; Global digital population as of

January 2021) influence human behavior according to Kelman's theory (Kelman, 1958, p. 56), which is also easier than ever because the compliance, internalization, and identification that shape human conduct are much faster and involve a much larger audience. Fear of loss (Przybylski, Murayama, De Haan, Gladwell, 2013, p. 1841) and other cognitive biases (Thaler, 2015) affect the behavior of people who, by their own actions, see their own decisions, which are modified by such cognitive biases and external referents (Wang, Meister, Gray, 2013, p. 299), as well as under previous life experience (Stamos, Altsitsiadis, Dewitte, 2019, p. 20). An outreach increases trust and helps build working relationships in society (Greenberg, 2014, p. 152). Thus, in addition to the positive aspects, trust can promote exploitation and predation, allow unethical conduct and fraud (Yip, Schweitzer, 2016, p. 2016). Accordingly, trust in money is formed in society based on information available to end-users and socio-economic conditions rather than objective reality, the essence of which is the need to own energy, not capital, to prolong life and further functioning of the economy and social order in general. At the same time, "trust is inevitably accompanied by a certain degree of risk and vulnerability" (De Filippi, Mannan, 2020). In this case, since a person decides to trust or not to trust, then in case of failure, he (or she) assumes part of the blame and is unable to demand compensation from the other party for losses (De Filippi, Mannan, 2020). This is the basis of the monetary policy: the population trusts the government, and when money loses its value, the people have no right to demand more than the expectation of indexation; they also have no right to demand full compensation for financial losses. Therefore, the modern monetary system is not fair and requires changes to be better. Moreover, there is evidence that society will appreciate any means of exchange that can be used to enter into transactions and complete transactions if people need to participate in personal, unreliable exchanges (Borgonovo, Caselli, Cillo, Masciandaro, Rabitti, 2021). In other words, for society, the use of energy as a general equivalent, a universal commodity, will not be a problem and will not lead to any difficulties.

#### **4. Problems of Financial Services**

Another disadvantage of using money as a universal equivalent is the cost because 97% of social costs for servicing payments (Schmiedel, Kostova, Ruttenberg, 2012; Melnychenko, 2013) are borne by trade facilities and banks (Przenajkowska, Polasik, 2018, p. 283; How much...; 2012). One-third to two-fifths of the large US commercial banks' income comes from payment services (Radecki, 1999, p. 53). Some costs are associated with providing energy to the payment infrastructure and creating and maintaining the means of payment. Most emissions come from the supply chain of financial services and energy, which is used for the production, transportation, and utilisation of cash, equipment for servicing payments, mining of cryptocurrencies, and ensuring their circulation (Melnychenko, 2021a).

And the ECB's confidence that "the energy needed by the settlement infrastructure we used is negligible compared with the energy consumption and environmental footprint of crypto-assets such as bitcoin, which uses more electricity than Greece or Portugal alone" (Preparing for the euro's digital future...) does not appear convincing due to, for example, the significant energy costs of servicing the payments borne by retailers (Melnychenko, 2021a). Therefore, energy is primary also in money circulation; that is why Haug (2020) suggests that "in the future, we could, for example, imagine all money being linked to energy, where the money transferred into your bank account would actually be in the form of energy transferred into a battery bank". The author shows the cost of energy required to store the smallest currency electronically: "the absolute smallest money unit is directly linked to the Planck scale and the Planck constant" (Haug, 2020). Although the categorical apparatus of his article is not perfect because it does not distinguish between the concepts of electronic money and non-cash money (Samorodov, Melnychenko, Koshcheeva, 2014, p. 204), it is noteworthy that any currency has its energy value. This hypothesis is supported in the work of Sun et al. (Sun, Qiu, Zhang, Meng, Yin, Dong, 2020), who propose the concept of an energy bank system "using a sharing economy model". The author considers "money is electrical energy", and the object of storage in such a bank will be "energy currency" in kilowatt-hours. The author's simulation results show that such a bank provides higher economic benefits and social welfare. Money can also be considered a source of energy in a broad sense, as discussed in (Korol, 2021; Melnychenko, 2021b; Melnychenko, Kwiliński, 2017, p. 67; Zawadzka, Strzelecka, Szafraniec-Siluta, 2021), and the financial energy of the enterprise can be considered its general financial position. Thanks to the energy of finance, it is possible to increase the capabilities of organizations, their ability to perform their functions. The question raised in this paper is whether energy can be used as a general equivalent instead of money in its current sense and manifestation. For an unambiguous answer, we should first turn to the essence of money and model the possibility of using energy where money today performs its functions and ensures the functioning of society.

The most important problem addressed by the general equivalent in the form of money is the absence of a double coincidence of desires, due to which barter exchange is impossible, and debt obligations issued by households will not circulate in equilibrium (Williamson, 2003, p. 475). Under the double coincidence of desires in this study, we mean socio-economic relations in which one party owns a product that it can exchange with the other for items of the results of its professional activity or obtain in another way as a result of previous events (purchases, exchanges, etc.). The absence of a double coincidence of desires means that one of the parties to the exchange does not need what the other side has to offer it. From this point of view, energy (like modern money) can play the role of the general equivalent. On the one hand, each person must ensure their livelihood; on the other, it can be exchanged as a universal commodity. As noted above, energy is the basis of money, not vice versa.



Another problem associated with the use of cash or non-cash is access to financial services where the organization of their provision is related to difficulties in financing, access to the Internet, or other technical problems. Therefore, in some countries, where most of the population does not have access to financial services, various methods are used to implement economic activity and money circulation, for example, mobile money (Lashitew, van Tulder, Liasse, 2019, p. 1201; Munyegera, Matsumoto, 2016, p. 127; Koibichuk, Ostrovska, Kashiyeva, 2021, p. 253; Pająk, Kamińska, Kvilinskyi, 2016, p. 208). On the other hand, such a society has access to electricity, as mobile phones need to be charged for such money to function. For developing countries, energy, in general, is a major factor in the aggregate consumer price index (Figueroa, Molière, Pegels, Never, Kutzner, 2019, p. 228); it is a key factor of living standards (Karekezi, Majoro, 2002, p. 1022). Thus, and in this way of organizing money circulation, energy is the basis. Although it is not necessary to have access to electricity in the case of cash (Hendrickson, Luther, 2021), thermal, mechanical, and another energy is required for its production and distribution.

Like any idea, the ability to use energy as money is not without its drawbacks. And we realise that energy markets are complex, and physical energy delivery requires expensive infrastructure and complicated processes (Kuzior, Kwilinski, Hroznyi, 2021; Lyulyov et al., 2021a; Lyulyov et al., 2021b). In this case, as noted by Ante et al. (2021), “the increasing share of renewable energy and its volatile supply of power only serve to amplify this complexity”.

In any case, in order to conclude whether energy can be used as money or its substitute, it is necessary to turn first to the functions of money and explore the practical feasibility of financial transactions using energy.

## 5. Money Functions in Energy

Among economists, three main functions of money have been considered for some time: the standard of value and unit of account, the medium of exchange, the store of value. We will consider each of them below in the context of our study.

For a certain asset to be considered money, it must be accepted by participants on the market as a means of exchange, i.e., when such an asset is used in trade, but not for direct consumption or production but further exchange for other goods. However, in some cases, the money itself may lose this function as in the case of high stakes in games, when players show contempt for money as a means of exchange (Lears, 1995, p. 10). On the other hand, in the modern literature, there is evidence that in the electricity market, electricity is traded as a commodity (Lekshmi, et al., 2018, p. 689), i.e., energy can be used as a means of exchange, not for further use in production but a further exchange. Like finance, energy can be viewed in terms of effects:

efforts to acquire it and final products manufactured with its direct participation (Baron, Millhauser, 2021).

Levulytė and Šapkauskienė recall that “for a financial instrument to act as a measure of value, the buyer must be able to understand the value by seeing the specified price of the good and be able to assess whether it corresponds to the market price or not. Moreover, they can immediately compare the store price with the implied market price and assess whether the item is relatively cheap or expensive” (Levulytė, Šapkauskienė, 2021, p. 46). Exploring the basics and proposals for environmental macroeconomic policy, Svartzman et al. define money as one of the most fundamental institutions that shape social relations. According to the authors, it creates proportionality and comparability between different goods and services, creating and legitimizing value (Svartzman, Dron, Espagne, 2019, p. 111; Aglietta, Ponsot, Ould-Ammed, 2016). However, with the complication of societies, the authors continue, money has made us forget about the fundamental role of energy and material flows. According to these researchers, money is not the basis of everything – energy and materials are. And no matter how the world changes, there are and will be problems that cannot be solved with money but can be resolved with energy, effort, and better monetary order. Therefore, the search for ecological endogenous money is needed. Such a tool could be “green” energy in the context of our study and the development of research by Svartzman et al. (Svartzman, Dron, Espagne, 2019, p. 110).

“In order to be considered as money, an asset should be able to store value”, i.e., “to be successful, an asset preferably should provide its user with some level of security” (Levulytė, Šapkauskienė 2021, p. 46). Accordingly, the lower the level of security provided by money, the less it performs this function and the poorer its user or owner becomes. Thus, despite the amount, money may not perform its fundamental function under the influence of macroeconomic, political, financial, technological, or other factors that lead to the loss of money value and ability to provide financial security for the user (Lakhno et al., 2018, p. 1807). Instead, energy poverty is caused by “energy deprivation and restricted access to energy services – including transport and mobility, and the resulting restriction of opportunities to participate in society” (Ambrosio-Albala et al., 2020). The availability of energy and its sufficient amount can ensure the safe existence of society. At the same time, the value of energy and the level of energy poverty do not depend on the factors that create financial poverty. Thus, becoming poor with sufficient access to energy and energy services is virtually impossible in today’s world, unlike economic poverty. Therefore, energy as an asset can more reliably perform the function of saving value. Moreover, energy is not a credit in its essence; the return and acceptance of energy are “in fact”. Moreover, in addition to supply and demand, its value is its actual value, which is determined by the number of materials for its extraction. Its use is also associated with actual processes (Dementyev, 2020). Thus, energy as money or “post-money” would have, in addition to the value in terms of goods and services, also the intrinsic value that modern money has long lost, so we can only believe in its value, as discussed

above. Moreover, unlike money, energy does not lose its value: 1 KJ of energy will always have this value.

Deepening the idea of the possibility of using energy as money and exploring its practical use in this role, it is worth paying attention to a currency as a narrower concept that characterizes money circulation. It is “a medium of exchange with a unique denomination, that relates to a unique standard of value, but which might take several forms as a means of payment (notes, coins, etc.)” (Larue, 2020; Tobin, 2008). Like any system of value assets, the system of energy-money circulation could probably use the joule as a currency divided into smaller microjoules, millijoules, and others. Of course, you can use invented names, the use of which, however, would take time to be accepted in society. Although such an example is successfully implemented today, the smallest bitcoin unit is satoshi, which is 0,00000001 bitcoin (10<sup>-8</sup>), also known as 1 SB. It did not take centuries for this currency to be recognized, but it is used successfully in a significant digital asset market.

Each medium of exchange is also linked to a payment mechanism (Borgonovo, Caselli, Cillo, Masciandaro, Rabitti, 2021), so attention should be paid to this technical and practical aspect of using energy as a substitute for money or a general equivalent. Ante et al. conducted a substantial bibliometric analysis of the intersection of blockchain and energy (Ante, Steinmetz, Fiedler, 2021), showing that the widespread use of blockchain technology in today’s energy sector is impossible. Although the authors did not consider the use of energy as a general equivalent in their work and did not find research in this area in the modern scientific literature, they concluded that “blockchain technology provides an immutable ledger for secure value transactions in a network” (Ante, Steinmetz, Fiedler, 2021). Furthermore, and most importantly, this technology does not focus on the exchange of money in the modern sense but on the exchange of values, which is also energy, because it has all the characteristics inherent in the actual values, assets, or resources. Therefore, the mechanism that could ensure the accounting of energy turnover as a general equivalent can be implemented based on blockchain.

**Table 1.**

*Theories of the origin of money*

Source	The money theory	Contribution	The energy impact
Smith, 1902; Marx, 1911	Labor theory	The essence of which is that money arose in the process of exchange, which in turn arose as a result of the division of labor	The use of energy has increased significantly in the last century, and the added value that is created with the help of energy has also increased significantly. It substitutes and complements “the labor of humans and other animals to multiply overall throughput”, “energy is what saves labor” (Singh, 1999, p. 754)

Cont. Table 1.

Wray, 2004	Credit theory	Money does not come from the commodity exchange but from credit, and that the currency issued by the state is simply required for public debt	In modern energy markets, capacity credits are widely used to overcome peak energy consumption, which indicates the possibility of using energy as capital along with financial capital (Sovacool, 2014, p. 5; Stamos, Altsitsiadis, Dewitte, 2019, p. 21)
Weber, 1978	“Chartalist” theory	Considers money primarily as a product of the state and its origin – in institutional accounting and debt payment	State control in the field of energy significantly affects its development (Tam, Chan, 2018)
Friedman, 1956	Quantitative theory	The long-term inflation is directly proportional to the long-term growth of money supply	With very low variability in inflation, it is difficult to find any connection between inflation and money supply growth (Svartzman, Dron, Espagne, 2019, p. 111)
Keynes, 1930	The general theory	The level of prices in the economy is determined by supply and demand and prices for individual goods are individual	“Demand and supply are measured from the consumption and production of energies” (Rakpho, Yamaka, 2009, p. 1132)
Sasakura, 2021	Macroeconomic theory	Prices are determined by supply and demand in the short term	
Caldentey, 2015	Neoclassical theory	In the economy of private property, there is a vector of prices compatible with all existing resources	“Energy inflation is correlated with headline inflation not only at a short-term horizon but also at lower frequencies” (Giri, 2021)

Classical and modern scientific literature identifies several concepts of the origin of money and its theories (table 1) each of which, in our opinion, does not contradict the possibility of using energy as a general equivalent. In this context, the energy theory of money would also not be meaningless, the essence of which could be that money arises from the amount of energy spent on resource production, and its value is determined by the influence of supply and demand for energy in the relevant energy markets.

## 6. Direct Transfer of Assets

Modern money also performs a communicative function to transfer information about past exchanges of assets that people use to purchase goods and services, the buyer, seller, and subsequent transfer of information to other agents with whom the seller may interact in the future (Townsend, 1989, p. 1326; Lacker, Weinberg, 2003, p. 384). In this case, the circulation of energy as a universal equivalent may have one significant and fundamental difference to money circulation, namely, the transfer of assets could occur directly, i.e., payment and calculation could coincide in contrast to modern payment systems when the actual calculation is made much later – after payment organizations and banks carry out corresponding operations, so-called clearing (Güntzer, Jungnickel, Leclerc, 1998, p. 213). This principle of calculation is

given by supporters of cryptocurrencies or smart contracts based on blockchain technology (De Filippi, Mannan, 2020; Eenmaa-Dimitrieva, Schmidt-Kessen, 2019, p. 70; Melnychenko, Hartinger, 2017, p. 29; Bogachov, Kwilinski, Miethlich, Bartosova, Gurnak, 2020, p. 488; Kuzior, Kwilinski, Tkachenko, 2019, p. 1358) as an advantage of its use. Therefore, energy, performing the functions of money, in this sense, may have the best characteristics of modern digital assets; however, without inherent defects. Combining energy and blockchain to organize payment turnover can also be promising because the example of the operation of payment systems based on blockchain has proven its effectiveness on the model of cryptocurrencies. However, this payment method is not gaining popularity in those circles where there is not enough trust in such assets as a cryptocurrency due to misunderstanding of their nature, lack of guarantees and collateral, non-transparency of pricing, and lack of intrinsic value. For example, in retail, which is essential for society, this type of payment has not gained popularity for these reasons. And blockchain technology itself does not look like a “savior” of trust in society today, despite all the hopes placed on it. And although some authors conclude that the value of the cryptocurrency bitcoin is related to the value of energy (O’Dwyer, Malone, 2014, p. 281), there is no evidence that its value is in energy. Along with energy-based ones, there are also “stablecoins are digital currencies that peg to non-volatile values” (Ante, Fiedler, Strehle, 2021), which, however, cannot be considered cryptocurrency, but rather e-money, especially if they are provided with fiat money (Singh, 1999, p. 758).

## 7. Discussion

Modern research confirms that “money is a tangible or electronic item universally accepted as a medium of payment in immediate or deferred time for goods, assets, and services in a given economy or socio-cultural environment” (Cunha, Melo, Sebastião, 2021).

Demonstration of the primacy of energy in money circulation is consistent with research into energy poverty in the sense that energy is the basis of life in general and the socio-communicative needs of people. Thus, when measuring energy poverty, the authors (Nussbaumer, Bazilian, Modi, 2012, p. 233) include in the index of multidimensional energy poverty, in addition to thermal energy for space heating, cooking (which is also, incidentally, a source of energy for humans), and electricity for the operation of various devices and equipment. Property rights that arise in connection with the acquisition of equipment, products that use energy and/or are its source. The authors combine and equate the financial capabilities of households to the energy component.

In modern financial systems, a unique defining feature of banks is their issuance of obligations on payment instruments; banks have the property by which their obligations serve as a medium of exchange. The idea of issuing energy obligations in the energy concept of

money is consistent with the aforementioned study by Douthwaite (Douthwaite, 2012, p. 190) that energy can be money and energy companies can become new banks.

The “payment economy” (Kahn, Roberds, 2009, p. 4; Lacker, Weinberg, 2003, p. 383) is based on exchange systems financed by private and/or public liabilities and institutions that facilitate settlements and settlements under these instruments. “The payments system is the network of private and public intermediation arrangements through which transactions take place” (Williamson, 2003, p. 478). And these agreements can be implemented on the basis of energy turnover because, in the modern literature, there is a significant amount of evidence that energy is traded as a commodity (Lekshmi et al., 2018, p. 689).

Moreover, the energy concept of money and the real value of energy money will not contradict the concept of debt, credit, and endogenous money, which is confirmed by Lagoarde-Segot (Lagoarde-Segot, 2020).

Our study of the possibility of using energy as a general equivalent and money is consistent with Jevons (Jevons, 1875), who lists the characteristics that a resource has to have to be considered money. Usefulness and cost, portability, recognisability, divisibility, indestructibility, value stability, and homogeneity are among them. Each of these characteristics is significant and, to a greater or lesser extent, can be applied to energy; to a much greater extent, in our opinion, than to Mayan salt cakes, which were used as money, according to archeologists (McKillop, 2021).

## **8. Conclusions and Further Research**

We carried out a systematic review of the energy concept of money in the scientific literature in the peer-reviewed publications from the ScienceDirect, Scopus and Web of Science scientific research databases, seeking an answer whether energy can be used as a universal equivalent instead of money. Our review against the framework of trust, energy, and universal equivalent in economic relations in the condition of the absence of a double coincidence of desires has revealed several issues about each of them in isolation and their interaction that have been attended in the extant literature. Based on the synthesis of those findings, we found that there is a diversity in the extant literature on the examination and conceptualization of energy use as money. However, we further found this diversity in the extant literature is a desirable diversity. It is needed to own energy in a broad sense, not capital, to prolong a life and further functioning of the economy and social order in general.

As other scientific publications show, modern money arose as a result of the evolutionary development of society. Still, it is not perfect from different points of view, particularly from the standpoint of its value because it has no intrinsic value. The trust to it as a measure of value, a standard of payment, unit of account, and means of storage is conditional and proportional to

its issuers' confidence. This is due to the credit nature of money and the inability to obtain real values from the debtor in the person of the issuer, namely, the state or bank. The imperfection of modern money is also due to its technical shortcomings. The essence is that money circulation is based on technical and technological systems, trust in which can be not unreasonably different, given the experience of users, failures, fraud, and error.

Through this review, we attempted to attend to the four broader objectives. First, we tried to study a conceptual framework of trust in the context of the modern monetary system that allowed us to organize and synthesize the existing trust in the literature of the modern monetary system. Second, through this synthesis, we have attempted to elucidate how the extant literature has concentrated on the contextual peculiarities of energy use as a universal equivalent. Third, by elucidating them, we have also tried to bring findings from various studies together in order to produce a better understating of the money function and money theories for using energy as a universal equivalent. Finally, we have also attempted to explain why energy could be used as a universal equivalent in the condition of the absence of a double coincidence of desires. The explanation of this lies in that everyone needs energy, and trust in money should be absolute and independent of institutions, equipment, technology. That is why a more perfect general equivalent is needed, which would be based on absolute values and their unconditional value. Energy could be such a universal commodity, equivalent, and means. It could solve the problem of lack of double coincidence of desires as a common equivalent. We can give up certain resources or products that result from our activities today and exchange them for energy that we can use to purchase goods or services later. The value of energy will not be lost. A striking example of the devaluation of money and the energy basis compared to modern money is the situation in the early 1920s in the Weimar Republic during hyperinflation. At that time, the cost of burning money for heating was higher than the purchasing power it provided: in some places, firewood was more expensive than a block of cash.

This paper emphasizes the direct and indirect connection between money and energy. We accumulated information on the role of energy in money circulation and the energy basis of money, but, as highlighted above, significant issues need to be addressed regarding the public recognition of energy as money at this stage. And while trust in energy is absolute, it will be impossible to convince people and shift institutions to energy circulation as a general equivalent until the subject is evaluated and researched to a greater extent than has been the case so far.

Of course, value stability should be studied in dynamics and quantitatively. A separate study should be devoted to this issue to explore the possibility of using energy as a general equivalent in modern socio-economic relations. Further studies of volatility analysis are consistent with the study of new forms of money in the 4th Industrial Revolution (Avgouleas, Blair, 2020, p. 6), which casts doubt that assets with high volatility are unlikely to function as money. Therefore, unambiguous conclusions also require quantitative research on this issue. An important area of further research will be the practical and technological implementation of payments in terms of the energy concept of money and accounting for transactions.

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## Conflicts of Interest

The author declares no conflict of interest.

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## BETWEEN TECHNOPHILIA AND TECHNOPHOBIA – THE PROBLEM OF TECHNOLOGICAL FEAR

Joanna M. MOCZYDŁOWSKA

Faculty of Engineering Management, Białystok University of Technology; j.moczydłowska@pb.edu.pl,  
ORCID: 0000-0003-1123-2555

**Purpose:** The aim of the article is to systematize knowledge about technological anxiety and to get to know the opinion of the management staff on the manifestations and potential effects of this phenomenon.

**Design/methodology/approach:** A critical literature analysis and qualitative research (FGI) was used as the research method.

**Findings:** Technological anxiety is a real problem in companies implementing solutions typical for industry 4.0. It mainly affects employees in the 55+ age group. It generates negative attitudes towards changes, in particular towards acquiring new competences necessary to work in the conditions of the digital economy. Employees experiencing technological anxiety rationalize it by exaggerating the potential negative effects of technological changes. Technophobia has social and health consequences for the workers it affects. From the perspective of the company, it is a psycho-social barrier to the implementation of the concept of industry 4.0.

**Research limitations/implications:** Conceptualization of the problem of technological anxiety may contribute to the development of research methodology on this issue, and, as a result, to its in-depth empirical diagnosis in the form of quantitative research.

**Practical implications:** Understanding the problem of a technological drug can help improve the work comfort of employees who are affected by it.

**Originality/value:** The text contains original own research. It is an attempt to conceptualize the problem of technological anxiety. It can contribute to the development of methodology for in-depth research on this issue and recommendations for management practice.

**Keywords:** technological anxiety, technophobia, attitudes towards 4.0.

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

### 1. Introduction

The development of new technologies as a part of the industry 4.0 development is analyzed primarily in the context of potential benefits (Bader et al., 2018; Mayer-Schonberger et al., 2013). It is pointed out that technologies offer unprecedented possibilities for collecting,

processing, analyzing, storing and using data quickly and efficiently. The use of cloud services, the Internet of things and tools analytically based on artificial intelligence means building values and generating new solutions based on the integration of data obtained from IT and operational systems equipped with sensors (Bader, Rahimifard, 2018). Advanced data integration and analysis enable making decisions either in real time or autonomously. For manufacturing companies, this means ensuring greater data integration and faster flow between IT and organizational systems (Moczyłowska, 2023). It is thanks to these solutions that it is possible to implement cyber-physical systems, automation of processes based on artificial intelligence and production robots characterized by much greater mobility, flexibility and the ability to cooperate with humans than before. New opportunities arise in the development of services throughout the product life cycle, and the integration of data on its use favors its personalization. It is possible to achieve efficiency not only in mass production, but also in small series. Competitiveness based on low production costs is growing (Śledziwska, 2020). These phenomena cause growing technophilia, a special kind of uncritical enthusiasm accompanying the creation and implementation of new technologies. It is an attitude according to which they constitute an extension of biological and intellectual abilities of people (Osiceanu, 2015). The problem of potential threats related to the implementation of 4.0 concept, especially those of a psychological and axiological nature, is much less frequently discussed in the scientific literature (Achuonye et al., 2011; Jamka, 2020). Meanwhile, the resistance of employees to innovation, including technological innovation, is listed as one of the key barriers to the implementation of the industry 4.0 concept (Khasawneh, 2018; Młody, 2019). In some cases, this resistance is extreme because it results from technological anxiety. This type of fear is the opposite of technophilia. It is a state of extreme and irrational fears of technologies treated as a threat to the established set of norms and patterns of behavior (Di Giacomo et al., 2019).

The aim of the article is to systematize knowledge about technological anxiety and to get to know the opinions of the managerial staff of 4.0 enterprises on the symptoms and potential effects of this phenomenon. The goal was achieved using the methodology of critical literature analysis and qualitative research (FGI). Conceptualization of the problem of technological anxiety may contribute to the development of research methodology on this issue, and, as a result, to its in-depth empirical diagnosis in the form of quantitative research.

## **2. Technological anxiety – literature review**

Fear is one of the primary emotions that a person struggles with. From the beginning of time, people were afraid of something or someone. Initially, it was nature, animals or - generally speaking - the unknown or incomprehensible. Currently, it is technology that takes over the role of the "Other", while binding all gative projections to this notion (Szpunar, 2018). Anxiety is

usually defined as an unpleasant, intensely felt state of malaise, produced by a feeling of close and unspecified threat, in contact with which a person feels powerless. It is a relatively common phenomenon, as it is estimated that various anxiety disorders affect approximately 20% of the population (Paxling et al., 2013).

O.Y. Khasawneh (2018a, 2018c) defines technophobia as fear and/or anxiety resulting from a reaction to a new stimulus taking the form of a technology that modifies and/or changes an individual's normal or previous routine while performing certain tasks. Technophobia manifests itself primarily on the emotional level, but its consequences take the form of specific behaviors (Martínez-Córcoles et al., 2017). The symptoms of technological anxiety include experiencing irrational anxiety towards objects such as computers, drones or autonomous cars, but also towards phenomena related to work automation, information flow in cyberspace, data processing (including personal data) by technologically advanced solutions (Nimrod, 2018). A special type of technophobia is the fear of misunderstanding a device based on a given technology, the consequence of which is usually lack of attempt to learn how to use this device. The fear in question is more than a lack of trust in new technologies (Ejdys, 2018) or digital minimalism (Newport, 2020). This is an existential and axiological phenomenon (Xi et al., 2021; Tańczuk, 2018). It is related to cultural measures and images. New technologies confront people with questions about the nature of technological entities born in science laboratories, "living machines", the Internet of things, artificial intelligence and its limits (Di Giacomo et al., 2019; Khasawneh, 2018c). They inevitably change people as well, therefore technophobia must be analyzed in a much broader context: of the position of technology towards the human subject and nature. It can be treated as a specific side effect of existential questions about human nature, identity and boundaries, as well as the species future and the possibility of interaction, coexistence and creation of community with new technological entities. As R. Tańczuk (2018) writes, one of the essential elements of the fear of technology is the fear of losing humanity, the threat from machines that look more and more like us, and therefore the inability to distinguish between what is human and what is inhuman. Machines that are intelligent, make decisions, self-reproduce, can communicate, including expressing emotions, as well as learn and even behave creatively, requires asking questions about the limits of human subjectivity. Technological anxiety is based on the conclusion that technology can completely escape people's control, take over our everyday life, have a destructive influence on it, and as a consequence, strive to annihilate humans and a human-centered civilization (Ajlouni, Rawadieh, 2022).

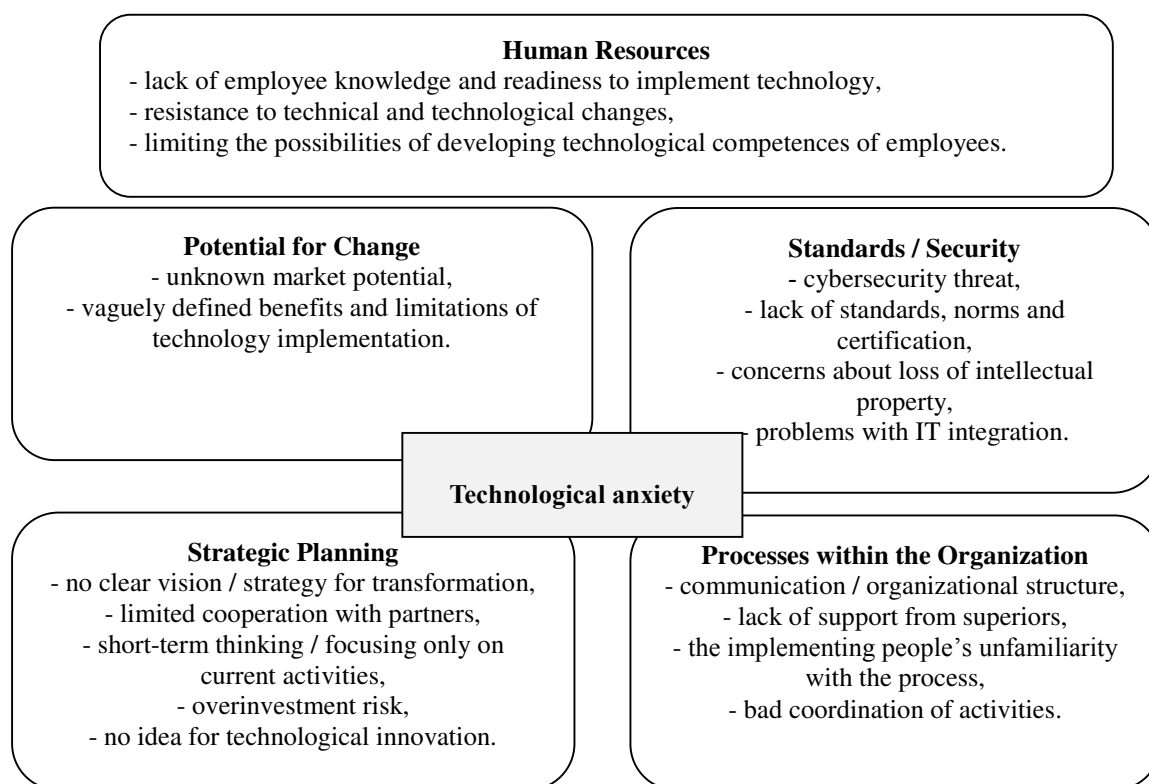
The key variables which influence experiencing technological anxiety are: personality predispositions (especially paranoid thinking tendencies) and age. Older people, compared to young people, known as digital natives, have significantly less experience in using advanced technologies (Liao, 2022; Wildenbos et al., 2018). Therefore, they also show a lower level of competence related to their understanding and operation. Older workers are often referred to as digitally excluded (both scientific and journalistic language includes other concepts reflecting

the analyzed problem, e.g. digital barrier, digital division, information disproportion, disconnection, information wealth versus information poverty) (Scheerder et al., 2017; Iwańczuk et al., 2017). In the first analyzes of this phenomenon, digital exclusion was treated as unequal access to the Internet, which was associated with a very simple division into people connected and not connected to the network. E-exclusion referred to the differences between those who have regular access to digital and information technologies and are able to use them effectively, and those who do not have such access (Czerski, 2020). Currently, the source of digital exclusion is rarely the lack of access to the network. Today, this phenomenon is treated as multidimensional, including access to information and communication technologies, the possibility of using digital technologies and the perception of the benefits of using digital artifacts. Psychological barriers are being emphasized more and more (Greer et al., 2019). In older people, new technologies cause uncertainty, stress and, consequently, reluctance to use these solutions. Already in the 1980s, within the Technology Acceptance Model, it was noticed that the behavior of an individual is directly determined by his or her intention and the belief that technology is easy to use. Both factors have a direct impact on the assessment of the usefulness of the technology and the user's attitude towards using it. Technological anxiety in the elderly triggers an attitude: I don't need it, I don't want to learn it. The so-called an anti-digital attitude may result in incomplete participation in social life. Low frequency of using technology largely affects the reduced autonomy and weaker self-esteem of one's own technological competences, which in turn leads to a feeling of social maladjustment, regression of the general development of cognitive, social and professional competences (Jamka, 2020).

Mental rejection of new technologies has a number of different consequences, e.g. it may be a deterioration of health due to resignation from using technologies supporting diagnostic and therapeutic services in a virtual way (medical teleconsultations, telemedicine) (Hou et al., 2017; McCabe et al., 2017). In the context of the topic discussed in this article, the potential effects of technophobia in the work environment are particularly important. The implementation of solutions typical for the 4.0 economy is tantamount to the spread of new technologies on an unprecedented scale. As a consequence, a special kind of pressure arises on employees to accept new technological solutions and to be able to use them in a short time. At the same time, many users cannot keep up with the understanding the essence of operation and the use of very modern and innovative machines and devices, therefore technophobia may cause a decrease in the effectiveness of the work performed and negatively affect the organizational climate (Khasawneh, 2018a, 2018b, 2023). The fear of "being unnecessary" (the phenomenon of technological unemployment) arises, on the other hand, employees feel a strong sense of mismatching competences with the needs of employers and the fear "if I am able to learn what I need to know" (Bader, Rahimifard, 2018). These phenomena and processes are also overlapped by the dematerialisation of work and employees, resulting in changes in the organizational structures of enterprises (e.g. e-enterprises, network organizations) and changes in the forms of work (remote work, teleworking), which intensifies



the feeling of social alienation. Even recruitment processes, which are increasingly dominated by machine learning algorithms, create a fear that the application documents submitted by the candidate will be rejected due to the lack of keywords or other pieces of information expected by the system (Jamka, 2020; Moczyłowska, 2023).



**Figure 1.** Potential sources of technological anxiety in the enterprise.

In line with the popular trend of anthropomorphic approach to organization, technological fear is described not only in the context of the experience of individuals, but also of entire enterprises. For example, M. Młody (2019) identifying technological anxiety as an organizational pathology, attempted to classify its key dimensions. These are: strategic planning, processes within the organization, the potential for change, standards and safety, and human resources (see Figure 1).

The potential sources of technological anxiety in the companies presented in Figure 1 focus on internal determinants. It should be emphasized that significant external barriers may appear in the process of development and implementation of new technologies, e.g. regulations, investment incentives or the lack of them, tax solutions. Therefore, a significant challenge for the theory and practice of management will be the development of fear measurement tools, and then the determination of the boundaries between the natural enterprise fear of new technologies, and the fear with pathological features.

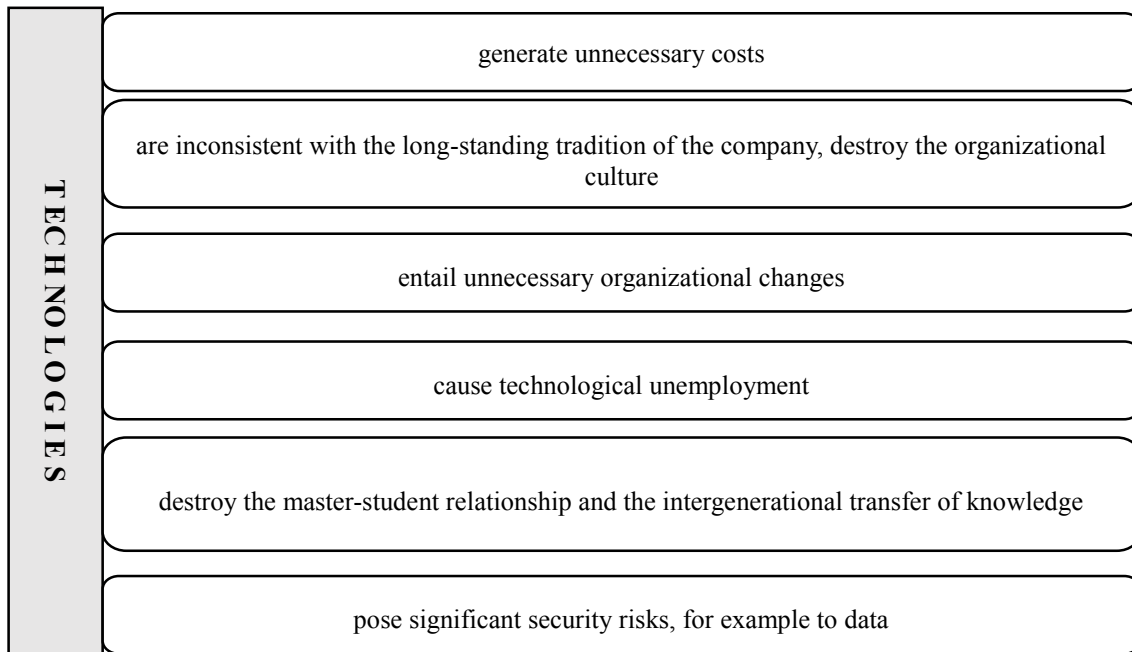
### 3. Methodology of own research

The subject of the research presented in this publication is the opinions of managerial staff (department/division directors) from the industrial enterprise sector on the intensity and manifestations of technological anxiety among employees. According to the FGI methodology, the research was conducted on a sample of 12 people. The following research problem was formulated: how do the managerial staff assess the scale, causes and effects of technological anxiety in the context of implementing technical and technological solutions specific to industry 4.0. In order to achieve the aim of the research, qualitative research was used. It is defined as empirical research, the primary purpose of which is to describe and analyze the causes, course, conditions, as well as the results of the occurrence or functioning of a given object, process or phenomenon in specific conditions and contexts. Qualitative research can be used to understand the phenomena better and deepen the current state of knowledge, although it is much more difficult to standardize the data obtained in this way. They are well suited to capturing the specificity of phenomena and taking into account the impact of unmeasurable or difficult to measure variables on management processes taking place in dynamic organizations (Bansal, Corley, 2011).

For the purposes of this article, interviews were conducted with the managerial staff representing the enterprise sector, in line with the principle that each manager should be an employee of a different enterprise. The condition for inclusion in the studied sample was work experience in a managerial position not shorter than 5 years. A proportional share of women and men was used, reflecting the proportions of representatives of particular genders in the professional group of managers in Poland. 4 out of 12 interviewees are women. The respondents represented medium-sized (3) and large (9) enterprises. The elimination of micro- and small enterprises resulted from the fact that most of these economic entities do not use technological solutions typical for industry 4.0 too much. The respondents' statements were recorded and then transcribed and analyzed using NVivo software (Bringer et al., 2004).

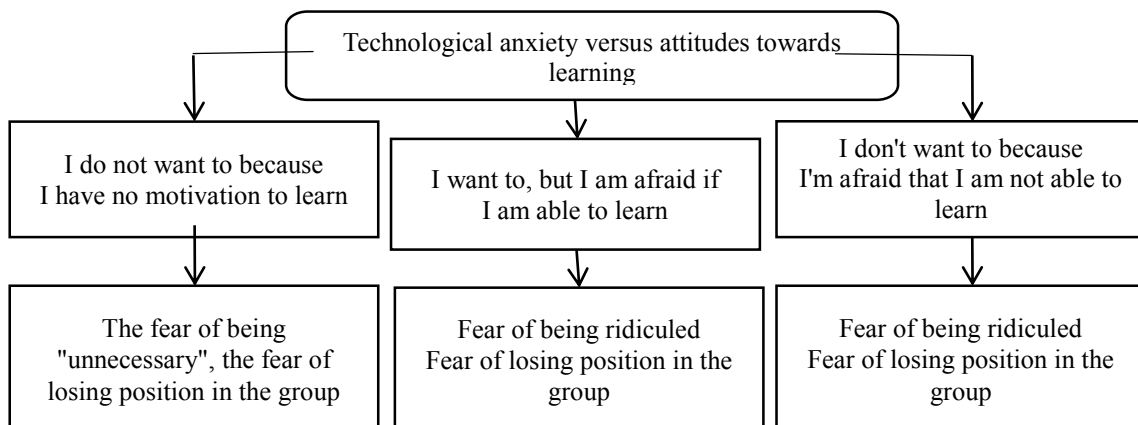
The vast majority of the study participants were students of Executive MBA studies at the Institute of Economic Sciences of the Polish Academy of Sciences in Warsaw and MBA Management at the Lazarski University. Conducting research among the participants of MBA programs gives the opportunity to access a relatively large sample of managers in a short time, but also limits its representativeness. It is made up of people with high qualifications only. Moreover, the share of managers aged 60+ who are less likely to undertake postgraduate studies is relatively low. Therefore, the conclusions drawn on the basis of the presented research require confirmation in quantitative research.





**Figure 3.** Technological anxiety rationalization.

In the opinion of the surveyed managers, the consequence of technological anxiety is primarily the low level of employee involvement in the process of implementing technical and technological changes and discouraging others from this process - those who have a positive attitude towards the digital transformation of the enterprise. Moreover, technological anxiety significantly influences attitudes towards learning (see Figure 4).



**Figure 4.** Technological anxiety versus attitudes towards learning.

The analysis of the respondents' statements allows for the conclusion that technological anxiety has a deeper psychological basis. New technologies cause deep concern because they require adaptive behaviors that some employees, especially in the 55+ age group, are not ready for. They are afraid whether they are able to acquire the competences necessary in the 4.0 enterprise or are not motivated to learn (for example due to the imminent retirement). It is easier for them to mentally reject changes than to deal with the fear of potential ridicule over the difficulty of acquiring new competences.

## 5. Summary and conclusion

Technological anxiety is a real problem in companies implementing technological solutions typical for industry 4.0. It mainly affects employees in the 55+ age group. It generates negative attitudes towards changes, and in particular to-wards the need to acquire new competences necessary for effective work in the conditions of digital economy. Employees experiencing technological anxiety rationalize it by looking for a justification for their emotions in the form of potential negative consequences of technological changes. Technological anxiety causes job dissatisfaction, a feeling of maladjustment and, consequently, social and health effects in the workers it affects. From the perspective of the company, it is a psycho-social barrier to the implementation of the concept of industry 4.0. The conclusions drawn from the research presented in this article have limitations. They are due to the qualitative nature of the research and the fact that the problem of technology anxiety was analyzed only from the perspective of managers. Therefore, it is advisable to continue research among different groups of employees and learn more about their attitudes toward new technologies typical of Industry 4.0 and the intensity, cause and manifestation of technology anxiety.

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## DEVELOPMENT DILEMMAS OF PUBLIC-PRIVATE PARTNERSHIPS

Janusz MYSZCZYSZYN

West Pomeranian University of Technology in Szczecin, Faculty of Economics; jmyszczyszyn@zut.edu.pl,  
ORCID: 0000-0001-9578-5741

**Purpose:** the purpose of this article was to assess the development of public-private partnerships (PPP) in Poland. The author identified the reasons for the still small number of projects, also carrying out and animating the available statistical data and the results of his research from the field of labor competencies.

**Approach/Methodology/Design:** a review of PPP literature, available statistics, and surveys of PPP projects in Poland were used.

**Findings:** the results of the study illustrate the prospects and dilemmas of PPP development in Poland, and in particular, the importance of competence and motivation of public sector employees. In order to develop the PPP market further, greater involvement of public institutions in promoting the development of employee competence and the need to use motivational factors becomes indispensable.

**Research limitations/implications:** the author conducted his research to a narrow extent; further research with a more significant number of respondents and the inclusion of private sector representatives implementing the PPP formula would be recommended.

**Practical implications:** public-private partnership in modern conditions, including the problems of financing public tasks by central and local authorities, can become an engine of economic development (including local), the basis of modernization, a factor in the growth of competitiveness, including improving the quality of life of citizens. It is reasonable to learn about the principles of public-private partnership in broad social circles in order to promote its development, both at the central, regional, and local (e.g., municipal) level. The results of the study can contribute to the identification of critical barriers inhibiting the development of PPP in Poland. In this regard, the leveling of low competencies among public sector staff may have an impact on the further development of PPP.

**Originality/Value:** public-private partnerships, despite the recording of nearly 175 projects, are still an unpopular form of implementing public tasks compared to leading European countries. One of the factors limiting the development may be low or insufficient labor competencies on the part of the public sector. An additional element emphasizing the originality of the work is the author's research and reference to previous results.

**Keywords:** public-private partnership (PPP), competence of employees, barriers to development.

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

## 1. Introduction

With the wide range of public goods on offer, both at the central and local levels, institutions and entities representing the public sector are looking for effective methods of implementing public tasks. Staff shortages, financial problems, and the multitude of tasks make the idea of public-private partnership (PPP) a remedy. In addition to the implementation of public tasks, PPP makes it possible to spend less on public funds and increase the availability of public services, affecting their quality as well.

As Wetenhall points out, history indicates that there has always been some degree of public-sector and private-sector cooperation, but an equally important determinant remains the definition of the tasks of such cooperation (Wettenhall, 2003; 2005).

PPP seems to be a good solution for both public and private partners, and the partnership allows mutual goals to be achieved with explicit sharing of risks.

Statistics on the development of PPPs around the world indicate an increase in the popularity of these projects, although there is a lack of precise statistics to report their number and value accurately (Załączna et al., 2021, p. 87).

According to the European Investment Bank (EIB), nearly 1850 PPP projects totaling nearly EUR 380 billion have been recorded in Europe since 1990. The most popular projects have been in the transportation sector (60.8% by value and 22.3% by number of projects), the health sector (13.8% and 22.06%, respectively), and education (10.35% and 25.6%).

In 2022 year, the aggregate value of PPP transactions that reached financial close in the European market totalled €9.8 billion, a 17% increase from 2021 (€8.4 billion). An increase in the value and the number of public-private partnership deals in 2022 shows that, despite uncertainty and volatility in construction prices, the public-private partnership market is recovering after the shock of the coronavirus pandemic (European Investment Bank, 2023). The PPP market is concentrated in a few countries – the United Kingdom, Spain, Portugal, Greece, Ireland, while the others have either a PPP policy but few projects France and Germany – or proved sceptical of both PPP policy and its implementation – the Nordic countries and some new accession countries. This means that the EU member states have responded differently to the PPP trend that has invested public management.

The UK remains the European PPP leader, where annually, up to 80 new agreements are signed for hundreds of millions of pounds, that offer up to 17% savings for the country's budget. Public-private partnerships have invested £56 billion in more than 700 infrastructure projects. These include new schools, hospitals, roads, housing, prisons, military equipment and accommodation PPP transfers delivery, cost risk and performance to the private sector - it protects the public sector from delays, cost overruns and poor performance. As noted by Calugareanu & Bulat The EU PPP market is mainly concentrated in the United Kingdom, France, Germany, Belgium, the Netherlands, etc., which have implemented projects worth 90% of the entire market in 2019 (Calugareanu, Bulat, 2022).

In the European Union, the most common type of PPP implemented is the contract from the category "design-build-finance-maintenance-management" (DBFMO), in which all phases of the project are assigned to the private partner, starting with the design stage up to the construction, management and maintenance of the infrastructure, including fundraising (Calugareanu, Bulat, 2022).

In 2022 France was the largest PPPS market in Europe not only in terms of value, with a total of €4.2 billion (€1.6 billion in 2021), but also in terms of the number of projects, with 21 deals closed (18 deals were closed in 2021). Turkey was the second largest of PPPs market in terms of value, with a total of €2.0 billion (€1.4 billion in 2021). In terms of the number of projects, Germany was the second largest PPPs market with four deals closed (seven deals were closed in 2021). Nine countries closed at least two deals (six countries in 2021) and 15 countries closed at least one public-private partnership transaction (compared to 14 in 2021). Over the past five years, France, Germany and the United Kingdom have led the European PPPs market in terms of the total number of deals closed (Market update Review of the European public-private partnership market in 2022, March 2023).

In Poland, PPPs are still an unpopular form of cooperation, with the total value of broadly defined PPP projects accounting for just 0.4% of total private sector fixed asset investment (Myszczyzyn, 2022).

The author's main objective was to determine the current pace of development of the PPP market in Poland and the main barriers to development, and in particular, to assess the importance of competence and motivation on the part of the staff of public entities.

The author, in order to achieve the stated research goal, established the following research hypothesis:

H1: The high level of competence and motivation of public sector employees is a critical factor in the further development of the PPP market in Poland.

The research goal mentioned above and the hypothesis stem from the desire for further research in the search for factors inhibiting the development of PPPs. Lack of sufficient knowledge and experience of public authorities to conduct PPP projects at the stage of initiation of proceedings and project preparation was indicated by respondents in a study conducted by the author in 2022 (Myszczyzyn, 2022).

In addition to a review of the literature, including reference to previous studies' available statistics of the PPP market, own research was conducted using survey questionnaires among public entities that have already implemented PPP projects.

## 2. Literature review - definition and directions of PPP development

In the available literature, one can come across various definitions of public-private partnerships, including the use of the terms P3, 3P, PFI (Private Finance Initiative), PF-PPP (Private-Finance PPP), PSP (Private Sector Participation), PfPPP (People first PPP), hybrid models, etc. (Lissowski, 2019; Myszczyzyn, 2022; Nikiforov et al., 2022). However, it should be noted that most European countries use the abbreviation public-private partnership (PPP) (Ball et al., 2007).

The subjects of public-private partnerships are, on the one hand, private partners and, on the other hand, public sector entities, which include not only public authorities but also local governments, non-profit organizations, NGOs, charitable foundations, etc.

As defined by the Organisation for Economic Co-operation and Development (OECD): public-private partnerships (PPPs) are long-term contractual agreements between the government and a private partner whereby the latter typically finances and delivers public services using a capital asset (e.g. transport or energy infrastructure, hospital or school buildings). The private party may be tasked with the design, construction, financing, operation, management and delivery of the service for a pre-determined period of time, receiving its compensation from fixed unitary payments or tolls charged to users. This definition includes both “pure” PPPs (where the main source of revenue is government payments) and concessions (where the main source of revenue is user fees) (OECD, 2018).

In World Bank documents, the term PPP is defined as a long-term contractual arrangement between one or more contracting authorities and a private partner for providing a public asset or service, in which the private partner bears significant risk and management responsibility and remuneration may be linked to performance (Guidance on PPP Legal Frameworks, 2022).

PPPs may be utilised as an opportunity to cater to investment requirements and invest over the government capital budget limits, also improving the quality of investment decisions and project delivery efficiency (Greve et al., 2013).

Krumm indicates that PPP arrangements are characterized by a relatively long, fixed duration of contract time or permanent (organizational) models of the relationship between the public and the private partner (life-cycle approach), often complex funding arrangements with the private sector bearing the initial costs and long-time responsibility for operation and maintenance, whereas the public sector is in charge of the long-time refinancing of the private partner either by (regularly) fixed direct transfers or by (shadow) tolls or user fees (Krumm, 2016).

The EPEC Guide to Public-Private Partnerships identifies the following features of a PPP contract:

- a long-term contract (the PPP contract) between a public contracting authority (the contracting authority) and a private sector company (the project company) for the delivery of a public service,
- the allocation of specified risks to the project company, typically with regard to designing, building, operating and financing the infrastructure asset used to deliver the public service,
- a focus on the specification of service outputs rather than inputs,
- the application of private financing (often involves a project finance loan) to underpin the risks transferred to the private sector,
- performance-based payments to the project company, based on the level and quality of the public services delivered (EPEC Guide to Public-Private Partnerships, 2021).

In their search for standardization of partnership terminology, Hodge and Greve list several types of terms associated with different types of PPPs: 1) inter-institutional cooperation to jointly implement projects and share risks, 2) long-term infrastructure contracts, 3) public policy networks based on loose relationships between stakeholders, 4) partnerships in civil society development, 5) partnerships in the area of renovation and revitalization of urban areas (Holdge et al., 2009).

Batra indicates that the UK has been an initiator in popularising the concept of PPP, as an alternative mechanism to traditional procurement that offered limited execution and financing. Other than the UK, PPPs have been widely adopted in countries like Ireland, Germany, Norway, Denmark and the Netherlands (Batra, 2022).

Cepparulo and others emphasize that even if the EU states share a general regulatory framework - the EU directives have established a very favourable uniform legislation for PPPs and imposed binding norms aimed at granting fair competition, PPPs are very unevenly distributed (Cepparulo et al., 2020).

In this context, in Poland, public-private partnership is based on, among other things, the Act of December 19, 2008 (Journal of Laws 2009, No. 19, item 100 as amended), the Act of October 21, 2016, on Concession Contract for Works or Services (Journal of Laws 2016, item 1920 as amended), the Act of September 11, 2019 - Public Procurement Law (Journal of Laws 2019, item 2019 as amended). The Polish government, in the document Government Policy for the Development of Public-Private Partnerships until 2030, defined, among other things, the strategic objective of the PPP policy, which is to popularize the PPP formula for ensuring efficiency, quality and sustainability of public investments with the assumption of long-term maximization of socio-economic benefits (Appendix to Resolution No. 177 of the Council of Ministers of September 25, 2023).

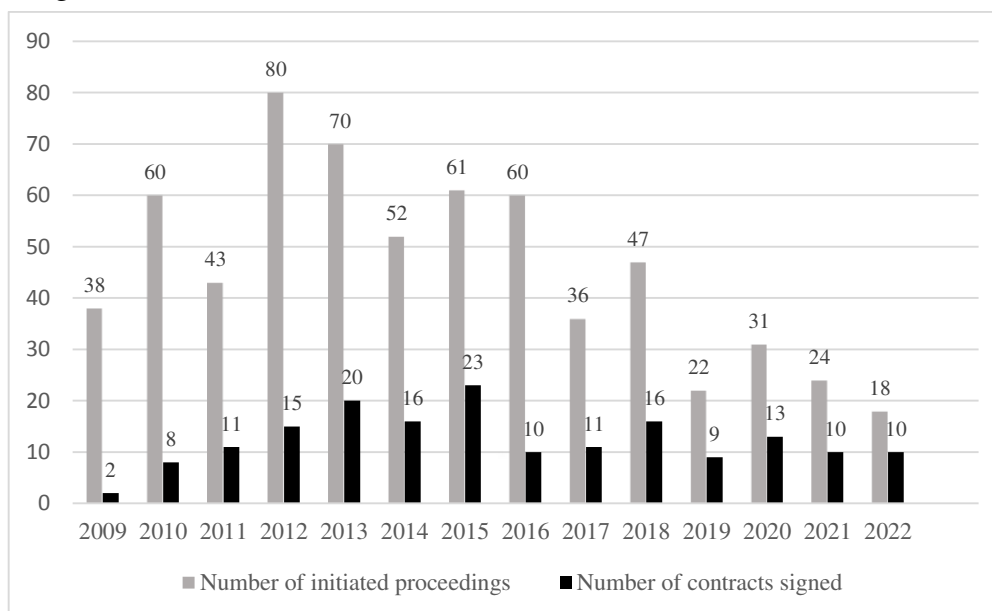
### 3. Development of PPP in Poland

The value of the Polish PPP market calculated by the cumulative value of completed and ongoing projects (from 2009 to the end of 2022) was about PLN 8.9 billion (ca. €2.02 billion), and a total of 174 agreements were signed. The average value of an agreement concluded between 200.9 and 2022 amounted to PLN 53 million (ca. €12.04 billion), which means that, as a rule, projects of relatively small value prevail.

Eighty PPP agreements are for projects under PLN 5 million (operator services), and 18 agreements exceed PLN 100 million. A few projects worth more than PLN 500 million have also been recorded - Thermal Waste Conversion Plants in Olsztyn and Gdańsk and the Fast Tram in Kraków.

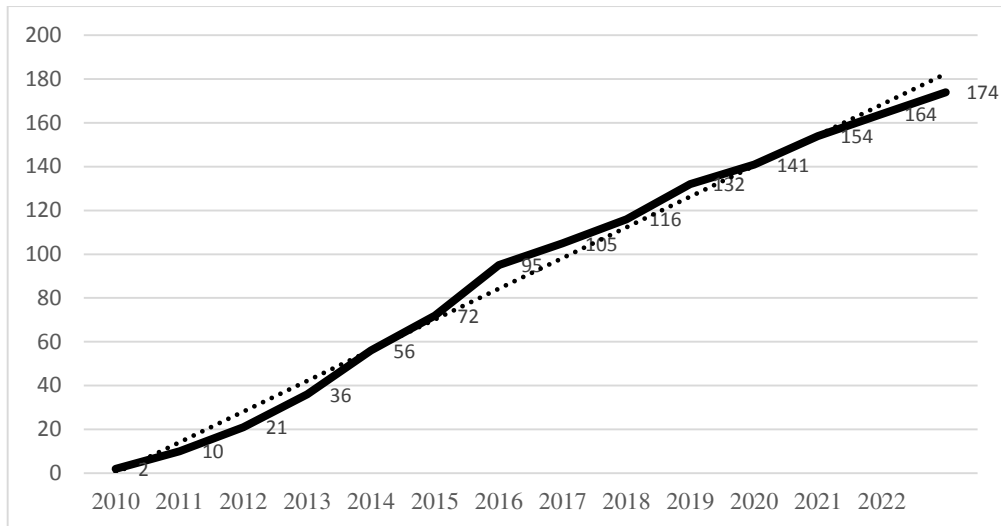
It should be noted that the ratio of initiated proceedings to proceedings with a signed contract remains relatively low. Between 2009 and 2022, a total of 642 PPP proceedings were initiated in Poland. At the same time, the number of signed PPP contracts was 174, which gives an efficiency of 27.1%. However, in recent years, the rate has increased significantly, and at the end of 2022, it was 39% (Government Policy for the Development of Public-Private Partnerships until 2030).

The cited data on the number of resolutions initiated and contracts concluded by year are shown in Figures 1 and 2.



**Figure 1.** The number of initiated proceedings and the number of signed PPP contracts in 2009-2022.

Source: Author's calculations based on: Raport rynku PPP 2009-2020, Ministerstwo Funduszy i Polityki Regionalnej, Warszawa 2022, p. 4; Raport rynku PPP 2009-2022, Ministerstwo Funduszy i Polityki Regionalnej, Warszawa 2022, p. 3; Raport rynku PPP 2009-III kw. 2023, Ministerstwo Funduszy i Polityki Regionalnej, Warszawa 2023, p. 3.



**Figure 2.** Number (cumulative) of PPP contracts signed 2009-2022.

Source: Author's calculations based on: Raport rynku PPP 2009-2020, Ministerstwo Funduszy i Polityki Regionalnej, Warszawa 2022, p. 4; Raport rynku PPP 2009-2022, Ministerstwo Funduszy i Polityki Regionalnej, Warszawa 2022, p. 3; Raport rynku PPP 2009-III kw. 2023, Ministerstwo Funduszy i Polityki Regionalnej, Warszawa 2023, p. 3,

Figure 2 contains a labelled linear trend line, which shows that, on average, the number of signed PPP contracts in Poland is increasing by almost 14 per year, which is far from expectations.

On a regional basis, one can see significant discrepancies in the number of contracts signed:

- in the eastern part, these are still isolated projects;
- the undisputed leader is the Masovian Voivodeship, which has undertaken 36 projects so far;
- a relatively large number concerns parts of the southern provinces of Poland (Silesia, (24) Lower Silesia (19), Lesser Poland (15)) and northern provinces (Pomerania (22), Warmia-Masuria (10));
- a high number is recorded by the Wielkopolska province (15);
- in other provinces, these are single projects.

Public entities in Poland most often implement PPPs in four sectors: energy efficiency (28 agreements), transport infrastructure (24), sports infrastructure (24), and water and sewage management (24).

In terms of value, the dominant sectors were transportation infrastructure, sports and tourism, telecommunications, waste management, water and sewerage, and revitalization.

Proceedings for the selection of a private partner were initiated most often by local government units (91%), including urban municipalities (31%), rural municipalities (25.8%), and rural-urban municipalities (14.4%); government administration accounted for only 4.6%.

At least 56 projects were planned for the end of 2022, including 12 for transportation infrastructure, public buildings – 12, sports and tourism – 8, revitalization – 6, and energy efficiency – 5.

As indicated in the PPP Market Report for Q3 2023, among the proceedings mentioned above, only four agreements with a total value of PLN 18.3 million were concluded (PPP Market Report 2009 – Q3 2023)

The author's previous research (2022) found that public sector employees generally gave a positive assessment of cooperation with the private partner during the implementation of the project (87% of respondents gave an upbeat assessment of cooperation, and 8.3% had no opinion).

Respondents assessed that the development of PPP in Poland is hampered by 1) lack of experience (54% of respondents), 2) complicated legal regulations (42% of respondents), 3) concern about ensuring the sustainability of the investment and excessive debt of the public partner (38% of respondents) (Myszczyzyn, 2022).

#### **4. Competence and motivation as a determinant of PPP development – results and discussion**

The planning and implementation of PPP projects require proper management, especially since the participants are public sector entities that are tasked with various public tasks and private sector entities that need to achieve the business objectives set. It makes it a complex process, both from a theoretical and practical point of view and success largely depends on how well the work is managed.

In this regard, it should be added that it is also necessary to take into account generational changes and the preparation of cadres in the future when implementing projects that have been planned for up to several decades.

PPP researchers stress that there are still gaps regarding the analysis of competency requirements, including management competencies necessary for the successful management of PPP projects. In this regard, there are both essential soft competencies and those traditional hard competencies.

Therefore, it can be concluded that due to the nature of PPP, one of the prerequisites for its successful implementation is the availability of specialized knowledge and skills.

In their study of management competencies in Jordan, they report that the following are critical to PPP implementation: technical experience, project management experience, negotiation and arbitration experience. Mistarihi et al. conducted a study based on two case studies and highlighted that public sector managers had fewer years of experience (both prior and project) compared to their private sector counterparts (5.6 and 4.2 versus 10.4 and 7.2 years, respectively). In addition, an important aspect was the realization that extensive knowledge of the project's financial aspects, monitoring, and planning techniques and methods is necessary. Other beneficial types of knowledge and qualifications that staff should have include



knowledge of policies and practices adopted by the partner, familiarity with the use of IT tools, and legal and contracting knowledge (Mistarihi et al., 2012).

Giving a list of critical success factors for projects, Geroniks & Lejniaks point out, among other things, the need to create favorable policies and the importance of the competence of all parties involved (Geroniks et al., 2015).

Similarly, in the case of Poland, past practice in the use of PPPs has revealed numerous shortcomings, including insufficient knowledge and lack of competence on the part of the public sector (Kania, 2021).

Also, in the resolution of the Government of the Republic of Poland titled Government Policy for the Development of Public-Private Partnerships by 2030, it is directly indicated that the most severe barrier to the development of PPP in Poland is the insufficient level of knowledge and competence in PPP among public entities (Government Policy for the Development of Public-Private Partnerships by 2030, p. 20).

In pursuit of the planned goal, the author surveyed public partners implementing the PPP formula. The electronic version of the questionnaire was made available to public partners, and the survey was conducted in the period 15.01–15.03.2023. Thirty-two completed questionnaires were received, which came from 20 public entities.

In the research group, the most considerable portion was micro-scale projects (PPP project did not exceed PLN 5 million, ca. €1.12 million).

Among the barriers hindering the development and popularity of PPPs, respondents indicated 1) complicated legal provisions (40.6%), 2) shortage of competence (31.2%), and lack of experience was indicated by 19.4% of respondents, while lack of state support was indicated by 9.7%.

In terms of PPP project preparation, almost half of the private institutions (53%) used a specialized institution (consulting offices), according to respondents. The data is similar to those reported in the PPP Market Report 2009 – Q3 2023 prepared by the Ministry of Funds and Regional Policy of the Republic of Poland (46%).

Respondents to the question of whether they were informed and trained on the specifics of PPP project implementation prior to the start of preparation and implementation answered affirmatively in only 9 cases (28% of respondents); as many as 72% negated this answer. Such a scenario means that employees were often surprised and not very familiar with the specifics of this type of project, which in turn negatively affected the effectiveness of tender proceedings for the selection of a private partner.

Respondents were also asked to assess their level of competence related to the preparation and implementation of PPP projects. They were asked to rate their level of competence on a scale of 1 to 5, with 1 meaning "definitely negative" and 5 meaning "definitely positive". The majority of the survey participants, 53.1% to be exact, rated their level of competence in this regard with a "3" (sufficient), 29% of the respondents opted for a "2" (mediocre) rating, while 9.7% of them chose the lowest rating of "1" (insufficient). It may be of concern that only

6.5% of respondents rated their level of PPP-related competence with a "4" (good), and none of them chose the highest rating of "5" (very good).

To the question of whether the respondents felt competence deficiencies during the preparation or implementation of the PPP project, they answered in the affirmative (answers "yes" or "rather yes") in 16 cases (50% of the respondents), with the opposite opinion (answers "no" or "rather no") also 50%. With the caveat that only 9.3% of respondents felt that they definitely did not respond to their competence deficiencies.

In this context, the surveyed employees evaluated the possibility of improving their competence in the position they work in. On a scale of 1-5, where 1 meant "definitely negative" and 5 meant "definitely positive. A lower rating (1) was selected by as many as five people and a rating (2) by nine people; together, these responses accounted for nearly 41% of the total. The most significant number of responses was marked off for rating (3); they accounted for 50%. Only two people (6.25%) considered that in a reasonable stipulation (4), they had the opportunity to improve their competence in the studied area. None of the respondents chose a rating (5).

Referring to the results obtained, it was reasonable to find out the opinions of respondents regarding the listing of the most critical competencies in PPP implementation. Respondents were allowed to choose from a list of competencies, up to three. Respondents also had the opportunity to add additional competencies to the list of answers that were not included. Respondents indicated knowledge of applicable laws, knowledge of risk identification techniques, and knowledge of negotiation techniques as the most critical competencies in this regard. There were far fewer indications of the following: ability to cooperate, the need for directional education, and competence in project management. One answer concerned foreign language competence.

An essential element influencing the development of PPPs besides competence was the motivations of public sector employees.

In general, respondents described their motivation at the lowest possible level of 1 or 2 - a total of 21 responses (65.6%), at a sufficient level (rating of 3) - a total of nine people (28.1%), at a good level - only two people (6.26%), at a very good level - no one.

Respondents also selected the three most important factors influencing their motivation to do their jobs. The most essential factors, in their opinion, were salary level (87.5% of respondents), family support (75%), and stability of employment (65.6%). A much smaller percentage of responses were: the opportunity to develop competence (31.3%), relationships and atmosphere in the workplace (18.8%), etc.

Respondents were also asked to assess the impact of their competencies on the professional preparation and implementation of the PPP project.

## 5. Conclusion

The development of public-private partnerships is an essential issue in political, economic, and social contexts and can positively affect macroeconomic as well as local development, leading to an increase in citizens' quality of life. Despite the tangible benefits associated with the implementation of public tasks in this formula, such cooperation requires adequate preparation, both in the institutional and personal sense.

The author's previous research has shown that PPP is an attractive method of implementing public tasks due to, among other things:

- limited resources of public institutions for investment;
- distribution of costs over time and their distribution among project participants;
- no impact on the current level of debt of the public entity;
- due to the lack of skills and experience (personnel) on the part of the public partner to build and manage projects, the private partner's contribution of innovative know-how;
- risk sharing, high quality of products provided by the private sector;
- sustainability of the project (Myszczyzyn, 2022).

In view of the various barriers to development, an important issue, which is the main objective of this study, was to examine the competence and motivation of the public partner's employees.

The vast majority of respondents indicated that they felt competency deficiencies during the PPP realization, and most of them rated their competencies as definitely not good.

The obtained research results allow us to verify the established research hypothesis H1 positively.

It is tangible evidence that public entities should take care to develop workforce competencies, which could positively affect PPP realizations in the future. It is consistent with other studies that the government's message of willingness to support PPP projects is clear, but the Polish PPP market does not show an upward trend - the government's declarations are, therefore, not directly translated into the development of the PPP market.

The survey results also report that the vast majority of respondents (71%) have not been trained on the functioning of PPPs prior to project preparation and implementation, which is alarming.

Public sector employees, in general, are lowly paid, and in this context, their incentives to work are quite low, which can only lead to a collapse in the further development of PPPs.

In summary, there are many factors affecting the smooth preparation and implementation of public-private partnership projects, but the competencies and motivations of public sector employees play a crucial role in them. Both hard and soft competencies affect the efficiency of work regardless of the position and lead to the achievement of the desired goals. Thus, it is worth pointing out that in order for public-private partnerships to develop at a faster

pace, those responsible for managing the public sector should pay more attention to the level of competence of employees while allowing them to grow, just as state action may prove to be a key factor.

Unleashing the potential of PPPs certainly requires comprehensive and multifaceted measures, both at the central and local levels.

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## FINANCIAL KNOWLEDGE AMONG MICRO-ENTREPRENEURS. A CASE OF KATOWICE CITY, POLAND

Magdalena OGÓREK

Uniwersytet Ekonomiczny w Krakowie; Magdalena.ogorek@phd.uek.krakow.pl,  
ORCID: 0000-0002-8212-4423

**Purpose:** This study aimed to enhance the understanding of the financial knowledge (FK) levels among micro-entrepreneurs in Katowice City, Poland and is a partial answer to the OECD's call expressed in 2022&23's reports regarding the need to investigate and diagnose financial literacy and FK in Poland (including a subpopulation of SMEs, micro-entrepreneurs) and the first steps towards a roadmap for designing National Strategy for Financial Education. This study analyzed the FK levels among micro-entrepreneurs, explicitly focusing on adapting the OECD/INFE Toolkit 2022 (OECD/INFE/T2022) to the local context.

**Design/Methodology/Approach:** The study employed an adjusted, fine-tuned questionnaire and methodology to evaluate FK based on the OECD/INFE/T2022 (methodology and questionnaires), tailored to the socio-legal, organizational, and economic conditions of the country and region. The paper also involved a comprehensive review of the existing literature on the importance of FK for micro-entrepreneurs and FK surveys among them.

**Findings:** The research fills a significant gap in the international academic literature and responded to the OECD's recommendations for Poland, shedding light on the FK status among micro-entrepreneurs locally. Likewise, sets the groundwork for future research on FK among micro-entrepreneurs, s.a., local cyclical evaluations, research on a regional or national level, providing valuable insights for policymakers and practitioners.

**Research Limitations/Implications:** While the study on Katowice micro-entrepreneurs provided crucial insights for local stakeholders, further research across regions, nation-wide, through time is necessary to ensure a comprehensive understanding of FK among micro-entrepreneurs. Additionally, the OECD/INFE/T2022 questionnaire can be further adjusted and translated to encompass remaining subsections (financial attitudes and behaviors) for a multidimensional examination.

**Originality/Value:** This research significantly contributes to the call by the OECD for a more in-depth understanding of FK among SMEs, particularly micro-entrepreneurs, in Poland. Its findings underscore the critical role of FK in fostering the well-being and sustainable growth of micro-entrepreneurs; it enables stakeholders to target problematic areas of FK identified in the study and to design financial education programs adequate for mitigating diagnosed deficiencies, thereby making a valuable contribution to the literature, and governmental and market practice.

**Keywords:** Financial Knowledge, Micro-Entrepreneurs, OECD/INFE, Katowice.

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

## Introduction

This study addresses a significant research gap identified in both the extensive literature on financial literacy and the OECD's 2022 and 2023 reports, which collectively underscore the need for a focused investigation into the financial knowledge (FK) levels among micro-entrepreneurs in Katowice City, Poland. The existing body of knowledge primarily centers on general FK, necessitating focusing on certain subpopulations such as SMEs and micro-entrepreneurs with a more localized examination tailored to the unique socio-legal, organizational, and economic conditions of the region (OECD/INFE, 2022a; 2022b). There are recommendations from the OECD that underscore the need for further research and engagement, particularly focusing on certain subpopulations such as SMEs and micro-entrepreneurs in Poland as to design the National Financial Education Strategies (NFES) (OECD, 2022b). G20 leaders emphasize the role of academia in designing effective NFES aligning with the OECD's call for research institutions and universities to assess FK in Poland (OECD, 2022b), as there is lack of NFES in Poland, however there are some steps that indicate progress in this regard, but necessitate further diagnosis of FK (OECD, 2023; European Commission, 2023b). Recognizing the unique challenges faced by micro-entrepreneurs, the literature emphasizes the importance of FK for their well-being and thriving, while the international literature emphasizes a research gap regarding diagnosing and investigating FK levels among micro-entrepreneurs on a national level (Brown et al., 2006; Hyder, Lussier, 2016; Sukurman, 2015; Jackson, 2021). This study analyzed the FK levels among micro-entrepreneurs, explicitly focusing on author's adaptation and fine-tuning of the OECD/INFE Toolkit 2022 (OECD/INFE/T, 2022) to the local context. To author's knowledge it is a first study regarding FK evaluation among micro-entrepreneurs in Katowice City, Poland with the OECD/INFE Toolkit 2022, especially with its national-context adjusted version. The paper also involved a comprehensive review of the existing literature on the importance of FK for micro-entrepreneurs and FK surveys among them.

Guided by the overarching need expressed by the OECD to delve FK in Poland, especially among SMEs and micro-entrepreneurs, this study seeks to answer two crucial research questions: What are the specific levels of financial knowledge (FK) among micro-entrepreneurs in Katowice City, Poland; and What is the extent of understanding of each basic FK concept, as established in the OECD/INFE Toolkit 2022 in the FK sub-section, among micro-entrepreneurs in Katowice City, Poland (OECD/INFE, 2022a; 2022b). The purpose of the article is as stated below: the primary purpose of this study is to contribute to the OECD's call for an in-depth understanding of FK among SMEs, with a particular focus on micro-entrepreneurs in Poland. It aims to enhance comprehension by analyzing FK levels in Katowice City, employing an adapted version of the OECD/INFE Toolkit 2022 (OECD/INFE/T, 2022) that is tailored to the local context (OECD/INFE, 2022a; 2022b). There are the following



intermediate objectives of the article: 1) employ a fine-tuned methodology and questionnaire, based on the OECD/INFE/T2022, to evaluate FK levels among micro-entrepreneurs in Katowice City, accounting for the socio-legal, organizational, and economic nuances of the region; 2) conduct a comprehensive review of existing literature, focusing on the relevance and significance of FK for micro-entrepreneurs, aligning with the specific conditions prevalent in Katowice City; 3) address the identified research gap in the international academic literature by responding to the OECD's recommendations for Poland, shedding light on the local FK status among micro-entrepreneurs, 4) lay the groundwork for future research on FK among micro-entrepreneurs, emphasizing the importance of local cyclical evaluations and research on regional or national levels. These insights will be invaluable for policymakers and practitioners alike (OECD/INFE, 2022a; 2022b).

This study assumes that an examination of FK among micro-entrepreneurs in Katowice City will reveal specific challenges and areas for improvement. The hypothesis posits that targeted financial education programs can be designed to address diagnosed deficiencies, thereby fostering the well-being and sustainable growth of micro-entrepreneurs (OECD/INFE, 2022a; 2022b). To achieve the study's objectives, an adjusted questionnaire and methodology, based on the OECD/INFE/T2022, will be employed. This approach ensures that the evaluation of FK levels is tailored to the socio-legal, organizational, and economic conditions specific to Katowice City. Additionally, a comprehensive literature review and FK surveys among micro-entrepreneurs will provide a multidimensional examination of the subject, aligning with the OECD's overarching recommendations (OECD/INFE, 2022a; 2022b).

The OECD/INFE (the OECD and its International Network on Financial Education) supports policymakers, institutions, public authorities, and academia in implementing national financial education (FE) strategies and targeted sub-population programs. They offer guidance, research, methodologies, and resources on financial literacy (FL), (FK), and FE, including measurement and evaluation tools (OECD/INFE, 2023b). The OECD is the EU's implementing partner for financial literacy projects, collaborating at both EU and country levels, with a recent focus on Poland (OECD/INFE, 2023a; 2023b), addressing Poland's lag in NSFE compared to other EU Members. Recently, the OECD, with the NWGFE (Polish National Working Group on Financial Education)<sup>1</sup>, presented a 2021 assessment report on NSFE development in Poland, emphasizing FL, FI, and FK issues in Polish society, with a focus on Project 21PL32 (OECD, 2022a, p. 3). Recommendations include further research and engagement, especially for vulnerable subpopulations and stakeholders like the private sector, SMEs, and micro-entrepreneurs (OECD, 2022a, pp. 6-10, 108-133; 2022b, pp. 8-9, 26-27, 57-60, 102-103). While not a dedicated FL study, OECD's research included an inventory questionnaire on FL,

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<sup>1</sup> Ministry of Finance (MF), the Ministry of Education and Science (MEiN), the National Bank of Poland (NBP), the Polish Financial Supervision Authority (UKNF), the Office of Competition and Consumer Protection (UOKiK), the Bank Guarantee Fund (BFG), the Warsaw Stock Exchange (GPW), the Central Securities Depository of Poland (KDPW) and the Financial Ombudsman (RF)) (OECD, 2023; 2022a; 2022b).

FE, and FI initiatives for public administration, private sector entities, and civil society organizations (OECD, 2022b, p. 9). The assessment report led to joint actions by the OECD and NWGFE for NSFE development in Poland, followed by an implementation roadmap (OECD, 2023). The OECD suggests future cooperation, encouraging research institutions and universities to assess FL and FE, understanding financial attitudes and behaviors in Poland (OECD, 2022b, pp. 10-11). The report recommends creating specific projects for FE, FK, and FL, considering the needs of target groups like SMEs, small businesses, and micro-entrepreneurs, to examine their current levels of FK, behaviors, attitudes, FL, and FI (OECD, 2022b, p. 11).

The OECD highlights three crucial points supporting this article: 1) SMEs play a critical role in Poland's economy, necessitating appropriate FK, FL, FE, and FI skills, 2) the absence of data on FE, FK, FL, FI needs in the SME sector in Poland, and 3) the recommendation for future research to understand specific FE, FK, FL, FI needs of SMEs in Poland (OECD, 2022b, p. 27; 2022a, pp. 24-25). Poland lacked a national FE strategy (NFES) or a policy for FL enhancement defining FL and recognizing the national importance of FE (OECD, 2022b, p. 122). However, a first-step roadmap for NFES in Poland has been recently published (OECD, 2023; European Commission, 2023b; OECD/INFE, 2023). While several organizations in Poland conducted FL surveys, the OECD recommends systematization for better coordination, using internationally acknowledged methodologies, and cyclical evaluation and monitoring (OECD, 2022b, pp. 130, 140-144). Region-specific methodologies, like OECD/INFE-based or globally recognized approaches, are recommended (OECD, 2022b, p. 21). Research using the globally acknowledged OECD/INFE 2022 methodology for studying FL, FK, and FI, especially among micro-entrepreneurs, is limited in the literature, particularly in the context of Katowice, Silesia region. Each region in Poland is unique due to historical, socio-demographic, and economic factors, with significant differences in economic and social development (OECD, 2022b, p. 21). G20 leaders emphasize academia's role in designing national and local government strategies and policies regarding FL, as academic research contributes significantly to shaping strategies and assessing effectiveness (Deutsche Bundesbank, 2017, p. 2). FK research among micro-entrepreneurs aids policymakers in establishing programs to support small business (SB) development in emerging markets (Hyder, Lussier, 2016).

Despite the significant role of small businesses (SBs) in various economies (Brown et al. 2006) (for their relevance in the EU and Poland, see (European Commission, 2020; 2023a; PARP, 2021; Witosz, Witosz, 2015, pp. 37-113), and in the UK (Brown et al., 2006), and in the U.S. (Jackson, 2021, p. 4), existing studies primarily focus on individuals and personal finance matters of the general public (OECD/INFE, 2016; 2017; Mitchell, Lusardi, 2011; 2015; Lusardi, Mitchell, 2011; Lusardi et al., 2010), creating a gap in investigating the FL levels of individuals who are also owner-entrepreneurs, owner-managers (a segment of the population simultaneously owning and managing their own SB, while remaining individuals in the general population) (Brown et al., 2006). FL among owner-entrepreneurs has consequences for SB

failure, with research revealing a significant correlation between financial illiteracy (FIL) and SB breakdown (Jackson, 2021, p. 4). FIL often leads to economic crises due to overspending, poor investment decisions, and high credit card use, contributing to social problems like excessive debt and business failure (Sukumaran, 2015). Pioneering research at Oxford Brooks University Business School on SBs ('owner-entrepreneurs') and FL indicates that varying degrees of FIL significantly impact the success or failure of this segment in the business community (Brown et al., 2006).

Despite entrepreneurs' particular need for FL, owner-managers, like the general population, exhibit low levels of FL, as evidenced by financial awareness and skills that may not enable them to confidently understand and analyze required financial information (Brown et al., 2006, p. 13). SBs must demonstrate competence and possess a specific blend of business skills, including a grasp of basic financial concepts, to survive and grow (Monk, 2000, p. 12). The term 'entrepreneur' refers to one who 'undertakes an enterprise' or 'owns and manages a business' (Boutillier, Uzunidis, 2013, p. 582). Small and Medium Enterprises (SMEs) in the EU (or more precisely, European Economic Area and Switzerland (European Parliament, 2023; Treaty on the Functioning of the European Union, 2016; 2020)) are defined based on staff headcount, turnover, or balance sheet total, with the 'micro' category having less than ten staff, turnover less than two million euros, or balance sheet total less than two million euros (European Commission, 2003; 2022; 2023a). SMEs are pivotal to Europe's economy, contributing to job creation, economic growth, and social stability endurance (European Commission, 2023a; 2020, p. 3). In 2023, SMEs constituted 99 pct. of all businesses in the EU, representing a major focus of EU policy to promote a conducive business environment (European Commission, 2023b). European Commission bodies actively address obstacles for SMEs through the recent SME Strategy (Directorate-General for Internal Market, Industry, Entrepreneurship and SMEs, 2021). SMEs contribute more than half of Europe's GDP and play a significant role in adding value across all sectors of the economy (European Commission, 2023a). Although SMEs are recognized as an 'engine of the European economy,' realizing their full potential remains an ongoing process (Verheugen, 2022, p. 3; European Commission, 2023c).

In Poland, SMEs contributed 49.1 pct. to GDP in 2018 (calculations performed by the Statistics Poland (GUS, 2023; PARP, 2021, p. 6), with sole proprietorship being a prevalent form of business activity (PARP, 2021, p. 6; Gajewska, 2012, p. 59). Self-employment in Poland exceeds the EU28 average (OECD, 2023, p. 26), and SMEs, especially micro-entrepreneurs, dominate the business landscape (OECD, 2023, p. 26). PARP, the Polish Agency for Enterprise Development (PARP, 2023; PFR Group, 2023), reported that up to 99.8 pct. of enterprises were SMEs, with micro-entrepreneurs comprising 99.7 pct. Medium enterprises constituted 0.7 pct., and large ones accounted for 0.2 pct. (PARP, 2021). According to their legal-organizational form, as much as 87 pct. were natural persons operating a business (i.e., sole proprietors) (PARP, 2021, p. 6) of which 98.9 pct. were micro-enterprises (PARP,

2021, p. 6). Research indicates that women own 37 pct. of enterprises, with women commonly being owners of small businesses (Dźwigoł-Barosz, 2016, p. 131).

Polish legal literature also sees sole proprietorship as most common legal-organizational form of entrepreneurship in Poland (Witosz, Witosz, 2015, p. 39). A sole proprietorship means that a 'sole person' is the owner (or proprietor or tenant) and an operator of the company; furthermore, such an individual bears an unlimited liability with their own private assets for the debts of the company they operate (Bundesministerium für Finanzen, 2023; Gzik, 2018, p. 6).

Thus, is also called 'owner-entrepreneur' and 'owner-manager' (Brown et al., 2006, p. 179; Ropęga, 2013, p. 67), or a 'sole proprietorship', a similar concept across the EU, e.g. (Witosz, Witosz, 2015, p. 49; Gajewska, 2012, p. 59; Bundesministerium für Wirtschaft und Klimaschutz, 2023; Bundesministerium für Arbeit und Wirtschaft, 2023; Witosz, Witosz, 2015, p. 39). For the Polish literature on sole proprietorship, see (Witosz, Witosz, 2015, pp. 38-53). The form has its own unique specificity and characteristics for numerous reasons, see (Gzik, 2018, pp. 10-12; Ropęga, 2013, p. 57). Sole proprietors make critical decisions about their businesses, with their traits and behaviors, including directly impacting management quality (Ropęga, 2013, p. 67). Management functions in sole proprietorships are self-performed, with knowledge and knowledge acquisition influencing entrepreneurial decision-making, especially FK (Roper, Love, 2018; Kheradmand, Jafari, 2015; Rachapaettayakom et al., 2020). FK is crucial for managing risks and returns in financial activities and decision-making (Deutsche Bundesbank, 2017, p. 1). Given the vital role of SMEs in the Polish economy, providing appropriate FK, FL, and financial skills is imperative, as recommended by the OECD (OECD/INFE, 2023, p. 27).

FL and FK gain recognition at the highest policy level, as underscored by endorsed high-level principles from G20 leaders (OECD/INFE, 2020b, p. 3; 2021, p. 3). FK plays a crucial role in budgeting, saving, managing payables, and handling credit commitments, enhancing the ability to navigate uncertainties and avoid adverse financial situations (OECD/INFE, 2016, p. 11). Effective decision-making necessitates fundamental knowledge of economics and finance (Mitchell, Lusardi, 2015, p. 107; Lusardi, Mitchell, 2023, p. 19). The imperative to teach FL to entrepreneurs is grounded in the need to empower them for sound financial decision-making, fostering business prosperity and contributing to sustainable development (Rahmandoust et al., 2011). The OECD defines Financial Literacy (FL) as the amalgamation of financial awareness, knowledge, skills, attitude, and behaviors necessary for sound financial decisions and individual financial well-being (OECD/INFE, 2012, p. 2; Atkinson, Messy, 2012). This understanding aligns with the World Bank's perspective on FL (Zottel, 2013, pp. 2-5). A financially literate individual possesses basic knowledge of key financial concepts (Atkinson, Messy, 2012, pp. 6-7) and avoids enduring long-term consequences resulting from suboptimal financial decisions (Yoong, 2011, p. 76).

FK empowers individuals to allocate resources effectively over time, utilize sophisticated financial products for increased returns on financial assets, and achieve better investment outcomes (Lusardi et al., 2013, p. 2; Lusardi, Mitchell, 2023, p. 9). FK levels, assessed globally by various entities, including the World Bank, OECD, FINRA, National Bureau of Economic Research (NBER), the U.S., Global FL Excellence Center at the George Washington University (GFLEC), Directorate-General Health and Consumer Protection of the European Commission's and others, are crucial in evaluating individuals' knowledge of basic financial concepts (Zottel, 2013, p. 8; Bolaji-Adio et al., 2013; OECD/INFE, 2018; GFLEC, 2023). Financial Illiteracy (FIL) is defined as a lack of skills and knowledge in financial matters, hindering effective actions toward achieving goals (National Financial Educators Council, 2023). FIL results in the incapability to manage monetary resources successfully, impacting business outcomes (Jackson, 2021, p. 8). The relationship between FL, entrepreneurial concepts, related knowledge, and competencies directly influences entrepreneurial success or failure (Jackson, 2021). Insufficient FL skills in entrepreneurs pose a systemic problem, impacting entrepreneurship growth, economic prosperity, and garnering the attention of governmental stakeholders and society (Dahmen et al., 2014). In the context of sole proprietorships, particularly in emerging markets, low FL and FK levels may lead to adverse effects on entrepreneurs (Sucuahi, 2013). The vital role played by micro-entrepreneurship can be maintained by owner-entrepreneurs' knowledgeable financial management, furthermore, the fundamental principle dictating the success of micro-enterprises posits that achieving success in business is contingent upon the effective application of FL (Brown et al., 2006; Sucuahi, 2013).

The literature emphasizes the essential role of FK for owner-entrepreneurs, particularly in small business (SB) success where the owner often serves as the manager (Rachapaattayakom et al., 2020). This extends to the context of emerging markets as well (Hyder, Lussier, 2016; Oyadomari et al., 2017). The literature also highlights the crucial role of FL in entrepreneurial success and overall sustainable development (Rahmandoust et al., 2011; Swiecka et al., 2020, p. 700). Managerial Inadequacy Factors are identified as primary causes for SB failures (Anderson, 2012, pp. 3-40). Effective financial management and controls are paramount for SBs, necessitating owners with fundamental familiarity in accounting and finance, as well as basic financial concepts (Cadden, Lueder, 2012). While financial and managerial accounting skills are crucial for any business, small and family micro-businesses often lack these competencies, with only a few individuals possessing accounting backgrounds (Barbera, Hasso, 2013, p. 273). FK holds particular relevance for SB owner-entrepreneurs, given their multifaceted responsibilities for the survival of their businesses (Rachapaattayakom et al., 2020, p. 1). As SB entrepreneurs are often responsible for various tasks, including record-keeping and accounting, the acquisition of FK becomes imperative (Rachapaattayakom et al., 2020, pp. 2-3). For a comprehensive model detailing the level of FK acquisition and existing FK elements among owner-entrepreneurs, refer to (Rachapaattayakom et al., 2020, pp. 9-10).

## Methods

The OECD, World Bank, and national governmental institutions and academia employ FK research toolkits (predominantly OECD's, World Bank's, GFLEC's), often utilizing surveys as diagnostic tools for FK assessment and the design of National Strategies for Financial Education (NSFE) (Zottel, 2013; Grifoni, Messy, 2012; Bolaji-Adio et al., 2013, pp. 8-9). For a comprehensive review of these tools, refer to (Bolaji-Adio et al., 2013, pp. 1-199) and for the review of NSFE status (Grifoni, Messy, 2012). The author adapted the widely acknowledged and globally employed OECD/INFE Toolkits (Methodology and Questionnaire) (OECD/INFE, 2015; 2018; 2022), specifically the most recent 2022 version (OECD/INFE, 2022), for surveying micro-entrepreneurs in Katowice, Silesian Region, Poland, focusing on the financial knowledge sub-section (FK) (OECD/INFE, 2022). These toolkits were developed iteratively through global stakeholder acknowledgment, with core questions centering on specific topics, including FK (OECD/INFE, 2018, p. 4; Kempson, 2009; Atkinson, Messy, 2012). The OECD/INFE Toolkits facilitate data collection for understanding FK and FL within a country, over time, across countries, and global and regional trends (OECD/INFE, 2018, pp. 4-5; 2022, pp. 6-7; 2016; 2017; 2020; 2021).

The methodology is versatile and can be applied to measure FL within specific subpopulations, such as regional or employed subpopulations (OECD/INFE, 2022, pp. 7-8), as done by the author. Adjustments to the toolkit are proposed based on research questions, sub-topics, or specific parts studied, considering the research form and purpose (OECD/INFE, 2022, pp. 7-8), while acknowledging research limitations on international comparability or national patterns extrapolation (OECD/INFE, 2018; 2022; 2015). The subsection on FK employed in the author's research has remained largely consistent across toolkit versions (OECD/INFE, 2018; 2022; 2015). Specific considerations regarding the author's use of the toolkit are detailed in (OECD/INFE, 2022, pp. 13-36), encompassing the core of the author's questionnaire. Additionally, the author followed guidelines on adapting and translating survey questions (OECD/INFE, 2022) and OECD/INFE surveys practice and Good Practice (OECD/INFE, 2018; 2022; 2015).

OECD/INFE Toolkits (OECD/INFE, 2018; 2022; 2015) prescribe a dual-format approach, encompassing both paper and digital versions, allowing for flexibility in questionnaire administration, including Face-to-Face (F-T-F), CAPI, and Online (Digital Format) interviews, aligning with the methodology and good practice standards (OECD/INFE, 2018, pp. 6-9). Survey sample sizes for FL research among sole proprietorships, specifically micro-entrepreneurs, vary across developed and emerging markets, such as Canada, the United Kingdom, the U.S., the Philippines, India, and Pakistan (Dahmen et al., 2014; Brown et al., 2006; Sage, 2012; Jackson, 2021; Guliman, 2015; Anshika et al., 2021; Sucuahi, 2013). Generally, these studies indicate insufficient FL levels among micro-entrepreneurs, suggesting

limitations in FK for effective decision-making (Dahmen et al., 2014; Brown et al., 2006; Anshika et al., 2021; Sucuahi, 2013; Guliman, 2015). Sample sizes are diverse, ranging from over a dozen up to three hundred, as dependent on the researched area's population and subpopulation of micro-entrepreneurs targeted by the study, i.e., above a hundred on the country-level (Sage, 2012; Brown et al., 2006; Anshika et al., 2021), on a state- or a regional-level fourteen subjects (Dahmen et al., 2014); and on a city-level from over a dozen up to hundred, as depending on the city's population (Sucuahi, 2013; Guliman, 2015). Some cities researched were estimated, e.g., to be approximately 1.63 million in 2015 and projected growth up to over 1.8 million (CPDO, 2019)), thus necessitating higher samples.

The Author's sample comprised fifty-one micro-entrepreneurs from Katowice (as the other sixteen questionnaires were excluded from the sample due to headquarters and area of business activity outside Katowice), utilizing Face-to-Face (Paper Format) and Online (Digital Format) interviews, aligning with OECD's recommendations (OECD/INFE, 2018, pp. 6-9). Face-to-Face interviews were personally conducted, adhering to the criteria of micro-entrepreneur status and Katowice-area business activity, and excluding questionnaires with missing information or technical faults. The final sample included twenty-eight Paper Format and twenty-three Digital Format questionnaires.

The Author employed purposive sampling, considering industry distinctions and adhering to the Polish Classification of Activities (PKD). This approach, necessitated by the formal status of micro-entrepreneurs and the voluntary nature of survey participation in Katowice-area businesses, provided targeted and relevant insights. A separate analysis of sixteen excluded digital questionnaires (from satellite cities) revealed comparable trends with minimal discrepancies in assessed metrics. Due to budget constraints and the academic nature of the survey, respondents did not receive any incentives for participation. Unlike commercial or well-funded market research practices, which often use gratification to ensure an adequate sample size (IQS, 2023, p. 1), the absence of incentives resulted in a relatively low response rate. Despite using mailing lists and conducting personal interviews over a two-month period (the entire project was carried out throughout the second half of 2023 until November), the author received a limited number of agreements from prospective participants. The co-authored project was titled 'Financial Knowledge and Financial Inclusion among Micro-entrepreneurs in Katowice City, Poland H2 FY 2023' authored by Lejman-Gaska A. and Ogórek M. and included other, separate elements and sections not discussed in this article. The primary qualifications for participation were a formal micro-entrepreneur status and business activity in Katowice City, Poland.

## Results

Results from the Author' study on FK of micro-entrepreneurs in the Katowice region, Silesia, Poland, performed with the adjusted OECD/INFE, 2022 Toolkit are presented in Table 1 and Table 2. Results are discussed in the Discussion section.

**Table 1.**  
*Correct Answers to The Selected Financial Knowledge*

Item	Understanding of Certain Financial Knowledge Concepts with an Adequate Question Code						
	interest paid on loan: QK4	simple interest: QK5	compound interest: QK6	simple and compound interest, as both: QK5 and QK6	inflation, as both: QK3 Q7c	risk-return relationship, as both: QK7a and QK7b	diversification Concept Q7d
Percentage of correct answers (pct.)	72.55	78.43	58.82	56.86	84.31	68.62	78.53

Note. Question codes: from QK2-QK7 a-d. Outcomes derived from MS Excel formulas were rounded to the second decimal place.

Source: Own research (Own Co-Authored Project: Lejman-Gąska, Ogórek, 2023).

**Table 2.**  
*Financial Knowledge Score (FKS) Distribution with Minimum Target Score (MTS)*

Item	Financial Knowledge Score (FKS) Distribution and MTS (Minimum Target Score)							
	Threshold Evaluation							
	0 points (FKS 0, that is below MTS)	1 point (FKS 1, that is below MTS)	2 points (FKS 2, that is below MTS)	3 points (FKS 3, that is below MTS)	4 points (FKS 4, that is below MTS)	5 points (FKS 5, that is above MTS)	6 points (FKS 6, that is above MTS)	7 points (FKS 7, that is above MTS)
the number of micro-entrepreneurs who received a given FKS (percentage in the brackets)	0 (0 pct.)	0 (0 pct.)	3 (5.88 pct.)	5 (9.8 pct.)	6 (11.76 pct.)	7 (13.73 pct.)	15 (29.41 pct.)	15 (29.51 pct.)

Note. The MTS is determined for each set of tools or subsections in the OECD/INFE Toolkits, typically at an approximate level of 71.43%, depending on the maximum number of points (OECD/INFE, 2018, 2016). For example, the OECD/INFE established the MTS for FK as achieving at least five correct out of seven points (OECD/INFE, 2016; 2020b). Outcomes derived from MS Excel formulas were rounded to the second decimal place.

Source: Own research (Own Co-Authored Project: Lejman-Gąska, Ogórek, 2023).

## Discussion

Global FL levels are notably low (OECD/INFE, 2017, p. 3; 2016), a concern echoed in the case of Polish (Katowice) micro-entrepreneurs, although they outperformed the overall Polish population (OECD/INFE, 2018; 2022). Utilizing the FK Score (FKS), a synthetic scoring measure, respondents' performance is assessed based on correct answers, revealing the



proportion with minimum acceptable elementary financial knowledge (OECD/INFE, 2017, p. 8). The creation and analysis of FKS are pivotal metrics (OECD/INFE, 2018; 2022, pp. 30-32). Financial illiteracy is identified through the Minimum Target Score (MTS), indicating the percentage with a minimal acceptable level of basic financial education (MTS is a threshold, a cut-off for FIL indication), set at approximately 71.43 pct. of connectedness (OECD/INFE, 2018; 2016). For FK, the MTS is, for instance, achieving at least five correct out of seven points (OECD/INFE, 2016; 2020b).

In the OECD/INFE 2020 study on FL, encompassing 26 economies, including Poland, only 65 pct. of Polish respondents met the MTS on FK (OECD, 2022b, p. 45), while Katowice micro-entrepreneurs surpassed this, with 72.55 pct. This data implies superior knowledge of basic financial concepts over general population, still nearly only three-thirds of surveyed micro-entrepreneurs exhibited a minimum acceptable level of basic FK, that cannot be regarded as a satisfactorily outcome adequate for entrepreneurial resilience and growth. The results highlight the ongoing relevance of the OECD's 2016 recommendation for Poland to focus on financial knowledge (FK). The OECD suggests that countries like Poland may need to prioritize knowledge to ensure their populations understand Financial Literacy principles (OECD/INFE, 2016, p. 7). None of the respondents scored zero or only one correct answer. However, one in four entrepreneurs obtained scores below the Minimum Target Score (MTS). Since all questions pertain to basic FK concepts, it is concerning that only about a third of surveyed micro-entrepreneurs could answer all questions correctly. This underscores that basic financial concepts' understanding cannot be taken for granted, even in regions like Katowice, known for micro-entrepreneurial activities (Lusardi, Mitchell, 2023, p. 5).

Globally, and especially in developed markets, there is limited knowledge about essential concepts, such as risk diversification (Lusardi, Mitchell, 2023). However, the Author's results reveal that other basic FK areas posed even greater challenges for micro-entrepreneurs. While 78.43% understood risk diversification, other fundamental concepts, such as risk-return relationships and understanding compound interest (both simple and compound), were less clear. Simple interest was relatively well understood (by over three-fourths of respondents), but the concept of compound interest was grasped solely by 58.82% of micro-entrepreneurs. The OECD, which measures understanding of both simple and compound interest, found that only 56.86% of surveyed micro-entrepreneurs exhibited such understanding. FK is crucial for understanding and managing finances (Sukumaran, 2015) and is indispensable for the success of entrepreneurship (Jackson, 2021, p. 7). It serves as a vital tool for business owners (owner-entrepreneurs), offering the necessary financial tools for informed decision-making that contributes significantly to micro-entrepreneurial success (Brown et al., 2006; Dahmen et al., 2014).

The absence of Financial Literacy is a common deficiency among small business (SB) owners (Rahmandoust et al., 2011, p. 62). Therefore, FK among Polish micro-entrepreneurs should be a target in the forthcoming National Strategy for Financial Education (NSFE),

with a focus on specific concepts and areas, such as risk-return relationships, compound interest, and loan interests. On the other hand, inflation was well understood by over 96% of micro-entrepreneurs, aligning with the OECD's previous assessments of the general public in Poland, where inflation was also very familiar (OECD/INFE, 2018). The results highlight the ongoing relevance of the OECD's 2016 recommendation for Poland to focus on financial knowledge (FK). The OECD suggests that countries like Poland may need to prioritize knowledge to ensure their populations understand Financial Literacy principles (OECD/INFE, 2016, p. 7). None of the respondents scored zero or only one correct answer. However, one in four entrepreneurs obtained scores below the Minimum Target Score (MTS).

Since all questions pertain to basic FK concepts, it is concerning that only about a third of surveyed micro-entrepreneurs could answer all questions correctly. Nonetheless, as literature evidenced, knowledge of basic financial concepts cannot be taken for granted, even in a country with well-developed financial markets (Lusardi, Mitchell, 2023, p. 5) and, accordingly, in Katowice region in micro-entrepreneurial circles it cannot be taken for granted as well. Globally and in developed markets, the knowledge is particularly low about essential and fundamental concepts, s.a., risk diversification (Lusardi, Mitchell, 2023); however, the Author's results show that other basic FK was even more problematic for micro-entrepreneurs. However, the Author's results reveal that other basic FK areas posed even greater challenges for micro-entrepreneurs. While 78.43% understood risk diversification, other fundamental concepts, such as risk-return relationships and understanding compound interest (both simple and compound), were less clear. Simple interest was relatively well understood (by over three-fourths of respondents), but the concept of compound interest was grasped solely by 58.82% of micro-entrepreneurs. The OECD, which measures understanding of both simple and compound interest, found that only 56.86% of surveyed micro-entrepreneurs exhibited such understanding. FK is crucial for understanding and managing finances (Sukumaran, 2015) and is indispensable for the success of entrepreneurship (Jackson, 2021, p. 7). It serves as a vital tool for business owners (owner-entrepreneurs), offering the necessary financial tools for informed decision-making that contributes significantly to micro-entrepreneurial success (Brown et al., 2006; Dahmen et al., 2014).

The absence of Financial Literacy is a common deficiency among small business (SB) owners (Rahmandoust et al., 2011, p. 62). Therefore, FK among Polish micro-entrepreneurs should be a target in the forthcoming National Strategy for Financial Education (NSFE), with a focus on specific concepts and areas, such as risk-return relationships, compound interest, and loan interests. On the other hand, inflation was well understood by over 96% of micro-entrepreneurs, aligning with the OECD's previous assessments of the general public in Poland, where inflation was also very familiar (OECD/INFE, 2018). FK empowers individuals for financial control, active saving, debt avoidance, and a nuanced comprehension of financial and economic risks (OECD/INFE, 2020, p. 3). Micro-entrepreneurs lacking insight into the risk-return relationship may make suboptimal financial decisions, leading to distress or

bankruptcy. Similarly, a deficiency in understanding compound interest hampers efficient fund management. The OECD recommends enhancing FL skills, especially in budgeting, interest understanding, and the advantages of compounding, inflation, and risk diversification, through formal systems (OECD/INFE, 2020, p. 8).

Macro-regional specificities, particularly in post-transitional economies, shape FK and FL survey results (OECD/INFE, 2020; 2021). Post-transitional countries exhibit low FL, elementary FK, and limited finance use (OECD/INFE, 2021, pp. 9-12), scoring lower than EU and OECD economies (OECD/INFE, 2020, p. 7). In the CIS region, the average FKS is 51.1% (3.6 out of 7 questions) (OECD/INFE, 2021, p. 9). In the SEE region, micro-entrepreneurs' FKS variability, with one-third scoring seven, contrasts with 27.44% below MTS. Those failing or barely meeting MTS constitute 41.17%, reflecting the survey results in Katowice. Policymakers in post-transitional economies like Poland need sustained policies for financial literacy (OECD/INFE, 2021, p. 12). Globally, FK is low, even in developed countries with advanced financial markets (Mitchell, Lusardi, 2015, p. 1). Thus, country-specific financial education programs and NFES are imperative. In the 2016 global FL Survey, Poland ranked lowest among thirty countries, significantly below the OECD average, and inferior to other CEE/CESEE post-transformational countries (OECD/INFE, 2016, p. 8). A nationwide survey of micro-entrepreneurs may further inform this data. Benchmarking against other CEE countries can validate trends in subpopulations like micro-entrepreneurs.

Testing individuals' knowledge of basic financial concepts holds the advantage of revealing their familiarity with more complex ideas, such as the risk-return relationship, the term structure of interest rates, and the compounding of interest over extended periods (Lusardi, Mitchell, 2023, p. 4). The author's survey underscores specific areas of financial knowledge (FK) and related concepts that demand attention in financial education (FE) policies in Poland. These targeted areas will be emphasized in the upcoming National Financial Education Strategy (NFES), currently under development by the NWGFE with OECD oversight.

Sole proprietorships, especially at smaller scales, demonstrate limited awareness of business and financial risks, underscoring the importance of risk management (Ropega, 2013, p. 171). Gzik (2018) explores risk types for sole proprietorships (pp. 13-16) and underscores the pivotal role of risk minimization for small enterprise success (pp. 16-18). Effective risk management relies on strong FK, essential for handling financial activities and decisions (Deutsche Bundesbank, 2017, p. 1). In small businesses (SBs), sole proprietors, or owner-managers, wield significant influence over critical decisions, and their traits and behaviors shape the company's management quality (Ropega, 2013, p. 67). Management functions in sole proprietorships are self-performed (Gajewska, 2012). Knowledge acquisition, particularly in FK, directly influences entrepreneurs' decision-making, supporting their activities (Roper, Love, 2018; Kheradmand, Jafari, 2015; Rachapaettayakom et al., 2020). Existing literature strongly emphasizes the direct contribution of FK to the success of small businesses (Hyder, Lussier, 2016; Oyadomari et al., 2017). Given the crucial role of Small and Medium-sized

Enterprises (SMEs) in the Polish economy, providing them with appropriate FK, financial literacy (FL), and financial skills becomes imperative, aligning with OECD recommendations (OECD/INFE, 2023a, p. 27).

## Summary

The author responded to the OECD's call for further research on financial education (FE), financial knowledge (FK), and financial literacy (FL) in Polish society, focusing on subpopulations like SMEs and micro-entrepreneurs (OECD, 2022a, pp. 6-10, 108-133; 2022b, pp. 26-27, 60, 102-103; 2022b, pp. 8-9, 57-59). The results align with OECD's recommendations, supporting the rationale behind the development of the National Strategy for Financial Education (NSFE) in Poland (OECD, 2023). Acknowledging the critical role of SMEs in the Polish economy, the article endorses the OECD's idea of providing them with suitable FK, FL, FE, and financial skills (OECD, 2022b, p. 27; OECD, 2022a, pp. 24-25). The publication addresses the OECD's identified data gap concerning the needs of FE, FK, FL in the SME sector in Poland (OECD, 2022b, p. 27; OECD, 2022a, pp. 24-25).

The article's results can be viewed as a partial response to the OECD's recommendation for additional research to understand the specific needs and levels of FE, FK, FL in SMEs in Poland (OECD, 2022b, p. 27; 2022a, pp. 24-25). Considering Poland's lag behind other EU countries in having an NFES or other FE policies and programs (OECD, 2022b, p. 122), the findings contribute to the Polish NFES roadmap, particularly in shaping NFES in the scope it is related to SMEs and micro-enterprises and dedicated, targeted FK projects for micro-entrepreneurs and SMEs on a local level. To address the FK diagnosis and identification of FK local specifics as recommended by the OECD for effective FE, FK, and FL initiatives (OECD, 2022b, p. 115), the paper diagnoses such FK specificities among micro-entrepreneurial groups in Katowice. However, this diagnosis is an initial step, urging further research to enhance micro-entrepreneurs' long-term financial well-being comprehensively and multidimensionally throughout the region (Silesia) and Poland, considering additional elements beyond FK, such as financial behaviors and attitudes. Research findings underscore the critical role of FK in fostering the well-being and sustainable growth of micro-entrepreneurs; it enables stakeholders to target problematic areas of FK identified in the study and to design financial education programs adequate for mitigating diagnosed deficiencies, thereby making a valuable contribution to the literature, and governmental and market practice.

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## USE OF INTELLIGENT TRANSPORTATION SOLUTIONS BY CITY RESIDENTS. THE CASE OF LODZ

Aldona PODGÓRNIAK-KRZYKACZ<sup>1\*</sup>, Justyna PRZYWOJSKA<sup>2</sup>

<sup>1</sup> University of Lodz, Faculty of Economics and Sociology; aldona.podgorniak@uni.lodz.pl,  
ORCID: 0000-0003-0029-0418

<sup>2</sup> University of Lodz, Faculty of Economics and Sociology; justyna.przywojska@uni.lodz.pl,  
ORCID: 0000-0002-1125-2225

\* Correspondence author

**Purpose:** The purpose of the paper is to examine the opinions of the residents of the city of Lodz on the innovativeness of the city's transportation system and to assess the extent to which residents use intelligent transportation solutions. The paper analyzes 3 groups of solutions: (1) digital solutions that facilitate individual car trip planning; (2) digital solutions that facilitate public transportation planning and use; (3) shared mobility applications.

**Design/methodology/approach:** The article presents the results of a survey conducted in 2022 on a sample of 250 residents of Lodz.

**Findings:** Survey participants perceive the city's transportation system and available transportation services as relatively innovative. The adoption of modern digital transportation solutions varies by type. Residents are predominantly inclined to utilize applications that facilitate the planning and execution of individual car trips, with shared mobility systems being employed to a lesser extent. Among the solutions supporting public transportation trip planning, electronic passenger information displays at bus stops have gained more popularity than mobile apps. Ticket machines are also more frequently utilized than mobile apps for ticket payments. The frequency of using these solutions is influenced by respondents' gender and car ownership.

**Practical implications:** The results obtained can be used to determine the directions of intervention in the field of urban transport policy, as well as strategies for popularizing intelligent transport solutions among residents.

**Originality/value:** This study seeks to contribute to the current body of literature on the adoption of three categories of digital transportation solutions among urban residents. The article targets researchers and practitioners in the field of smart city development, particularly those engaged in the implementation and promotion of digital solutions within urban transportation systems.

**Keywords:** smart mobility and transportation, smart transportation solution, Intelligent Transport System, transportation mobile application, smart city.

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

## 1. Introduction

Contemporary cities play a crucial role in the digital twin transformation towards sustainability. Specifically, significant efforts are currently focused on reducing the carbon dependence and enhancing energy efficiency of urban transportation. These endeavors rely on the implementation of innovative technological solutions as part of the broader framework for developing sustainable smart cities (Bokolo, 2023; Müller-Eie, Kosmidis, 2023; Wolniak et al., 2023). A smart city (SC) can be characterized as a city that collaborates with its residents, leveraging modern technologies to provide innovative solutions across various domains, including mobility, economy, administration, environment, and quality of life (Dzupka, Horvath, 2021; Toli, Murtagh, 2020; Eremia et al., 2017). Notably relevant to the article's focus, smart mobility is defined as a cohesive set of activities aimed at enhancing the efficiency, effectiveness, and environmental sustainability of cities. A key aspect of smart mobility is connectivity, which, in conjunction with extensive datasets, enables real-time transmission of traffic information for users, while local government officials can concurrently engage in dynamic traffic management (Paiva et al., 2021; Pinna et al., 2017; Tomaszewska, Florea, 2018).

In recent years, intelligent transportation solutions have also gained popularity among urban residents. These innovative technologies aim to improve transportation efficiency and reduce traffic congestion. Intelligent Transportation Systems (ITS) refer to the integration of advanced technologies into transportation systems to increase their efficiency (Anedda et al., 2023; Boukerche, Wang, 2020). These technologies include real-time traffic management, smart parking, public transportation applications, ticketing solutions, smart traffic lights and ride-sharing platforms, among others (Tasgaonkar et al., 2024; Din, Rehman, 2019). These are supported by in-vehicle transportation systems that offer a communication framework for vehicles, road infrastructure and pedestrians (Hernández-Jiménez et al., 2019).

By leveraging data and connectivity, Intelligent Transportation Systems (ITS) contribute to optimizing transportation networks and enhancing the commuting experience for urban residents (Waqar et al., 2023; Angelidou et al., 2022; Šurdonja, 2019). This is particularly significant in the context of urban quality of life and residents' well-being, as research indicates that prolonged commute times have adverse effects on mental health, job satisfaction, and leisure time contentment (Lampkin et al., 2023). Smart solutions play a pivotal role in addressing this issue by reducing travel time through the provision of real-time traffic updates and suggesting alternative routes. These solutions are designed to offer citizens more sustainable, efficient, and convenient transportation options, thereby minimizing environmental impact through the promotion of electric vehicles and ride-sharing. Furthermore, ITS contributes to enhanced safety by facilitating improved traffic management and a reduction in accidents. Through the effective utilization of these solutions, city managers can strategically

plan transportation systems, alleviate congestion, enhance public transportation operations, and offer convenient and sustainable mobility choices for both residents and visitors.

Technological solutions in urban transportation, are effective only when they find acceptance among users. In other words, technologies are considered useful and intelligent only when they are used intensively by people and when people do not experience inconvenience while using them (Popova, Zagulova, 2022). Studies of the degree of use of modern transportation solutions by users are basically not conducted. Contemporary research focuses primarily on analyzing the feasibility of implementing digital solutions in cities' transportation systems and related management systems. Our article fills the research gap in this area.

The aim of this article is to discern the perceptions of Lodz residents regarding the innovativeness of the city's transportation system and to evaluate the extent of their utilization of intelligent transportation solutions. The study scrutinizes three categories of solutions: (1) digital tools facilitating individual car trip planning; (2) digital solutions supporting public transportation planning and usage; (3) shared mobility applications. In the subsequent section, we conduct a literature review on these groups of intelligent transportation solutions and their functionalities. The next section outlines the availability of these solutions in Lodz and delineates the survey's assumptions regarding their adoption by city residents. The presentation of survey results incorporates sociodemographic characteristics such as gender and car ownership.

## **2. Literature review**

Research conducted by Baldauf and Tomitsch (2020) leads to the conclusion that urban mobility apps provide residents with useful solutions in the areas of Intermodal Route Planning, Advanced Ticketing, and Real-time Information. Some of these apps are supported by local authorities and/or can be accessed through their official websites.

One of the key applications of intelligent transportation solutions in urban areas is trip planning. With advanced algorithms and real-time data, travel planning applications can offer personalized routes and transportation modes, taking into account factors such as road conditions, public transportation schedules and individual preferences. Through the analysis of diverse data sources, including GPS data from public transportation vehicles and historical traffic patterns, these apps have the capacity to suggest the most efficient and time-saving routes for commuters. This not only results in time savings and stress reduction for individuals but also contributes to the broader goal of mitigating traffic congestion.

Digital travel planners, including those for public transport travel, address users' needs for real-time access to information, saving pre-trip search time and travel time itself. The literature indicates that time savings through access to real-time information can range from 5 to 15%

(Bian et al., 2022; Li et al., 2021). Lopez-Carreiro et al. (2020) in their study showed that the areas of information most desired by travelers were specifically travel time, mode of transportation, itinerary, cost of travel and service incidents. Caulfield and O'Mahony (2007) conducted a study to collect data on public transportation passenger preferences and describe the methods of providing information that a passenger requires at each stage of the trip. The authors defined the stages before traveling to the destination, at the stop, on board and before traveling to the origin (return trip). A key finding was the importance of real-time information. The lack of certainty about passengers' arrival time at their destination emerged as a major factor causing frustration in public transportation use. Furthermore, passengers engaged in intermodal travel (involving multiple modes of transportation) were more likely to use public transportation information. Grotenhuis et al. (2007) further found that passengers were most concerned about timely arrival at interchanges. Real-time knowledge of estimated arrival times diminishes the uncertainty associated with waiting and increases user satisfaction due to its enhanced reliability (Bian et al., 2022).

Utilizing public transportation in cities is facilitated by various smart solutions beyond digital trip planners. These encompass functionalities like real-time tracking of buses and obtaining information about their arrival times at bus stops, digital ticket purchase via electronic ticketing systems, and automated fare collection. The Real-Time Monitoring and Tracking System for Vehicles enables travelers to monitor the location of public transportation vehicles through an app and access information about the anticipated arrival time at a specific stop from passenger information boards installed at bus stops. This functionality is enabled by GPS modules installed in public transportation vehicles, transmitting the vehicle's location in real time to receiver boards (Sharif et al., 2018). Electronic ticketing systems enable the purchase of digital tickets through various channels, including: 1) Smartphone apps: users can buy digital tickets through dedicated applications on their smartphones. 2) In-vehicle and bus stop ticket machines: these machines, besides printing physical tickets, offer the option to store digital tickets on the traveler's payment card. This allows for greater flexibility in ticket management. 3) Traveler payment cards, smartphones with NFC, smart QR codes, or apps: these methods facilitate check-in and check-out on the vehicle, supporting the pay-as-you-go concept. Users can use payment cards, smartphones with Near Field Communication (NFC) capabilities, smart QR codes, or specific apps to record their journey and enable seamless payment based on actual usage (Ferreira et al., 2017; Joshi et al., 2023).

Public transportation trip planning apps that provide real-time information contribute to the attractiveness of public transportation. Some authors claim that more than 30% of public transportation app users increase bus use (Bian et al., 2022). Also Bielińska-Dusza et al. (2021) indicate that certain implemented smart solutions contribute to enhancing the appeal of public transportation. However, they highlight that measures such as prioritizing public transport vehicles at intersections or adjusting traffic signals based on traffic volume do not positively influence the perception of public transport among users as a reliable means of navigating the city.



Another prominent domain within smart transportation solutions in cities revolves around the concept of shared micromobility services (Reck, Axhausen, 2021). The development of the sharing economy (SE) contributes to the realization of sustainable development goals (Boar et al., 2020; Sadiq et al., 2023) in various areas, including transportation (Standing et al., 2019; Arias-Molinares et al., 2021). This is exemplified by diverse low-carbon urban initiatives encompassing bicycle programs, ride-sharing systems, scooters, and cars (Pereira, Silva, 2023; Shaheen et al., 2020; Oeschge et al., 2020). In general, mobility sharing entails innovative transportation services designed to optimize vehicle use and reduce the reliance on private cars. These services enable users to access transportation on a short-term, "as-needed" basis (Machado et al., 2018). Most of the shared services scrutinized in our article, particularly scooters and bicycles, fall under the category of shared micromobility. Micromobility aims to cover short distances, as well as the first or last miles (Hosseinzadeh et al., 2021). Vehicles used for micromobility are lightweight, small and do not reach speeds above 45 km/h. Both human-powered and electric-powered bicycles and scooters fall into this micromobility category (Krauss et al., 2022). On the other hand, carsharing, another mobility form analyzed in our study, allows for longer-distance travel and provides access to a variety of vehicles with different functionalities. Similar to shared micromobility services, carsharing operates on an access-based model rather than ownership, contributing to the development of sustainable urban transportation systems (Vanheusden et al., 2022). This solution is appealing to customers due to its flexibility, allowing them to choose the right car for each purpose, lower costs, and reduced maintenance efforts. A carsharing operator that ensures an adequate fleet size, equitable distribution of cars, and sufficient available parking spaces for its vehicles in response to urban parking space shortages presents an attractive option for residents navigating through urban spaces (Jian et al., 2020; Jochem et al., 2020).

Smart parking is emerging as another crucial aspect of smart urban mobility, gaining popularity as cities strive to become more intelligent and sustainable. With the increasing number of vehicles, smart parking is becoming a strategic concern for urban development (Al-Turjman, Malekloo, 2019). It is estimated that in urban areas, up to 30% of traffic is attributed to vehicles searching for available parking spaces. This often involves slow-moving vehicles, negatively impacting overall efficiency and contributing to increased transport pollution (Yang, Lam, 2019; Zhang, Li, 2018). Furthermore, driver distraction caused by the search for parking spaces is a contributing factor to collisions in parking lots. Individuals are often too preoccupied to pay attention to traffic or pedestrians (Kumar et al., 2023). Intelligent parking guidance systems that rapidly provide drivers with accurate information about parking availability can significantly reduce the time spent searching for parking spaces and alleviate traffic congestion (Xiao et al., 2023). Parking Guidance and Information Systems (PGI) play a key role in providing drivers with information about the nearest parking lots and the number of available spaces. Vision-based solutions are increasingly being deployed in cities as a cost-effective alternative to traditional PGI systems relying on hardware sensors installed on each

parking space. Vision-based systems utilize cameras to capture images of the parking lot, providing information about space occupancy (Grbić, Koch, 2023).

Smart transportation solutions are consistently recognized by residents as one of the most crucial components of people-centered smart cities (Del-Real et al., 2023; Ji et al., 2021; Wei et al., 2023). Thompson (2016), on the other hand, points out, that among city-related mobile applications, by far the most popular are those related to travel (car, bus, bicycle, parking, etc.) in cities. Since the concept of smart mobility is relatively new, there are limited studies on the use of specific technologies and user behavior (Wang et al., 2021).

Most research in this area focuses on factors influencing the acceptance of digital solutions in urban transportation (Ferreira et al., 2017; Wang et al., 2021). The adoption of digital transportation services depends on factors such as digital competence, attitude (Ahmed et al., 2020), intention to use, accessibility to and operation of shared mobility systems (Turoń, 2022), trust, income, gender (Lenz, 2020; Singh, 2020), or age (Battarra et al., 2018; Docherty et al., 2018; Sourbati, Behrendt, 2021). Groth (2019) notes that access to smart mobility services is constrained for certain demographics, including the elderly, unemployed, and individuals with lower incomes.

### **3. Methods**

#### **3.1. Characteristics of digital transport solutions to support travel in Lodz**

The study investigates 3 groups of digital transportation solutions dedicated to individual users of the city of Lodz:

1. digital tools to facilitate individual car trips planning - navigation apps that offer route planning and real-time traffic information, variable message signs, parking space available signs, parking meters and apps for parking payments,
2. digital tools to facilitate planning and use of public transport - dynamic passenger information displays at bus stops, apps for navigating public transport offering information on public transportation routes, schedules, and real-time updates, ticketing system (applications, Open Payment System and ticket machines),
3. shared mobility applications – car-sharing, e-moped sharing, scooter sharing, bikesharing.

Solutions in each of these groups can be classified in terms of the required user interaction as well as the type of provider (Table 1).

**Table 1.***Smart transportation solutions in Lodz by type of provider and required user interaction*

Item		Smart transportation solutions		
		Digital tools to facilitate individual car trips planning	Digital tools to facilitate planning and use of public transport	Shared mobility applications
Required user interaction	yes	<ul style="list-style-type: none"> <li>- navigation apps</li> <li>- parking meters and apps for parking payments</li> </ul>	<ul style="list-style-type: none"> <li>- apps for navigating public transport</li> <li>- apps for ticket payments</li> <li>- ticket machines</li> <li>- digital ticket purchase system assigned to a payment card (Open Payment System)</li> </ul>	<ul style="list-style-type: none"> <li>- apps for renting a car by the minute</li> <li>- apps for renting a e-moped by the minute</li> <li>- an app for renting a scooter by the minute</li> <li>- an app for renting a bicycle by the minute</li> </ul>
	not	<ul style="list-style-type: none"> <li>- variable message signs</li> <li>- parking space available signs</li> </ul>	<ul style="list-style-type: none"> <li>- dynamic passenger information displays at bus stops</li> </ul>	-
Supplier type	public	<ul style="list-style-type: none"> <li>- parking meters</li> <li>- variable message signs</li> <li>- parking space available signs</li> <li>- apps for parking payments</li> </ul>	<ul style="list-style-type: none"> <li>- dynamic passenger information displays at bus stops</li> <li>- apps for navigating public transport</li> <li>- apps for ticket payments</li> <li>- ticket machines</li> <li>- digital ticket purchase system assigned to a payment card (Open Payment System)</li> </ul>	<ul style="list-style-type: none"> <li>- an app for renting a bicycle by the minute</li> </ul>
	private	<ul style="list-style-type: none"> <li>- navigation apps</li> <li>- parking space available signs</li> <li>- apps for parking payments</li> </ul>	<ul style="list-style-type: none"> <li>- apps for navigating public transport</li> <li>- apps for ticket payments</li> </ul>	<ul style="list-style-type: none"> <li>- apps for renting a car by the minute</li> <li>- apps for renting a e-moped by the minute</li> <li>- an app for renting a scooter by the minute</li> </ul>

Source: own elaboration.

Solutions supporting individual travel planning by car in Łódź encompass various types of digital tools, both requiring interaction from travelers and not necessitating such activity. Providers of these solutions include both the municipal government and private operators. Travel planning in Łódź is aided by navigation applications provided by the private sector, which drivers can access via smartphones (e.g., maps.google) or, using appropriate devices, within vehicle navigation systems. These solutions involve user interaction. Support for travel planning also includes variable message signs (9 VMS boards), constituting the driver information subsystem—a component of the city's intelligent transportation systems (Sprint, 2023). The boards provide information on road incidents, repairs and detours. They are positioned on major streets throughout the city and do not require user interaction. Digital transportation solutions also apply to the city's parking system. Using the municipal parking system in Łódź requires payment for parking, which can be done through applications (currently 8 apps: AnyPark, CityParkApp, ePARK, FlowbirdParking, Karta Łodzianina, moBILET, MobiParking, mPay) or parking meters located in the paid parking zone, equipped with touchscreen displays (Urząd Miasta Łodzi, 2023). Additionally, a municipal parking space

information system based on 30 signs was implemented in 2014. In addition to the city's system, a parking information system is implemented at one of the central locations in Łódź, the Manufaktura shopping center. This system includes sensors installed at each parking space, determining the current occupancy status. The processed information is then collectively displayed on boards at the entrances to the parking lots surrounding Manufaktura. Consequently, drivers receive information about the number of available and occupied spaces before entering the parking lot. If all parking spaces are occupied, the information enables the driver to bypass a specific parking lot and proceed to another one with less congestion (Barwiński, Kotas, 2015).

The use of public transportation in Łódź is supported by interactive and non-interactive digital solutions provided by both the public and private sectors. One implemented solution is the Real-Time Information Display System at Bus Stops, comprising 130 boards installed at 65 stops managed by the Bus Stop Information Subsystem. The system provides arrival times and information about the bus or tram, including whether it is low-floor and wheelchair-accessible. The Mobile Information Subsystem allows passengers to access vehicle routes, departure times, and plan their journeys through the website [www.rozklady.lodz.pl](http://www.rozklady.lodz.pl). The system is supported by 88 CCTV cameras installed at 82 intersections (Borowska-Stefańska et al., 2021). Additionally, the city has implemented a Public Transport Management Subsystem and a well-equipped Traffic Control Center. The software implemented was the Sydney Coordinated Adaptive Traffic System (SCATS), which manages traffic lights phases. The ITS system is complemented by the Sensor and Video Device Subsystem, automatically registering vehicle characteristics using ANPR (Automatic Number Plate Recognition) and collecting data on vehicle types and license plates at measurement points. The visual monitoring system consists of high-speed HD cameras at major intersections (Sprint, 2023). Despite the introduction of these ITS solutions, Łódź still remains the most congested city in Poland (Podgórnjak-Krzykacz et al., 2022).

For accessing passenger information related to public transportation, mobile applications such as Jakdojade, myBus, and WatchLine Lodz are available. The myBus application allows users to check departures from a specific bus stop, the current location of the vehicle on its route, and whether the bus or tram is equipped with air conditioning, a ticket vending machine, or space for bicycles. Interchanges on the map are marked, displaying departures from all stops within the intersection in chronological order.

Passengers can purchase tickets at 24-hour ticket machines, located in most districts of Łódź. There are approximately 50 of these machines, and they are also installed in all vehicles. Digital tickets for local public transportation in Łódź can be obtained through mobile applications such as banking apps, Karta Łodzianina, zbiletem, moBilet, SkyCash, Jakdojade, mintmobile, or mPay (MPK-Łódź Spółka z o.o., 2023). In selected public transportation vehicles, the "Entry-Exit" fare in the Open Payment System (OPS) can be utilized, enabling payment for the traveled route. Modern ticket terminals are installed at all doors of trams, where

passengers need to tap their payment card upon entering the vehicle and again when disembarking, ensuring payment is only collected for the traveled route. (Kowalska, 2020).

The available shared mobility systems in the city include (Podgórnjak-Krzykacz et al., 2022; Podgórnjak-Krzykacz, Przywojska, 2022):

- Bikesharing: the Łódzki Rower Publiczny system is organized by the city, with Homeport as the current operator. It currently provides 1,500 bicycles, and bike rentals are possible through both applications and terminals at bike stations;
- Scooter sharing: currently offered by two operators - Bolt and Lime;
- E-moped sharing: until 2022, the service was provided by the operator Blinkee.city;
- Car sharing: currently provided by three operators - Easysshare, Traficar, and Panek - these services collectively offer around 600 cars for rent in the city.

These systems utilize mobile applications for accessing vehicle rental services, location services, and payment for the ride.

In 2023, a mobile point was launched in one of the Łódź neighborhoods called Zenit. Echo Share, a neighborhood mobility point, offers residents the opportunity to rent electric vehicles such as scooters, bicycles, or cars. This point also serves as an eco-friendly charging station, obtaining energy from photovoltaic panels located within the neighborhood (ECHO Residential by Archicom, 2023).

### 3.2. Method and research sample

The study focuses on the perception of the innovativeness of Łódź's urban transportation system by city residents and the extent to which they use intelligent transportation solutions. Additionally, the study aimed to determine whether the availability of digital solutions in public transportation influences its usage. Analyses took into account control variables such as respondents' gender and car ownership. The online survey was conducted in 2022 with a sample of 250 respondents who are users of the city's transportation system. The characteristics of the sample are included in Table 2.

**Table 2.**  
*Sample structure*

Category		Respondents	
		n	%
Total		250	100.0
Gender	Woman	132	52.8
	Man	118	47.2
Car ownership	Yes	157	62.8
	No	93	37.2

Source: own elaboration.

### 3.3. Measurement

Assessment of the modernity of the city and its transportation system was measured using the variables in Table 3. Respondents used a 7-point Likert scale: from "strongly disagree" to "strongly agree".

**Table 3**

*Measuring the modernity of the city and its transportation system*

Question	Items	Scale
Assessing the innovation of the city and its transport system	1. Łódź is a modern city 2. Łódź has modern transport infrastructure and systems 3. Modern transportation services are available in Lodz	strongly disagree, disagree, somewhat disagree, undecided, somewhat agree, agree, strongly agree

Source: own elaboration.

The use of intelligent transportation solutions assigned to 3 groups (1) digital tools to facilitate individual car trips planning (2) digital tools to facilitate planning and use of public transport (3) shared mobility applications was measured in terms of frequency. The variables are presented in Table 4. Respondents used a 7-point scale: from "never" to "always".

**Table 4**

*Measuring the use of smart transportation solutions and services by Lodz residents*

Area	Items	Scale
Digital tools to facilitate individual car trips planning	(1) Frequency of using websites/apps for route planning including information about possible traffic jams, collisions, and road congestion (2) Frequency of using variable message signs informing about traffic intensity and road difficulties (3) Frequency of using apps/boards/systems informing about available parking spaces	never, very rarely, rarely, moderately, often, very often, always
Digital tools to facilitate planning and use of public transport	(1) Frequency of using electronic dynamic passenger information displays for public transportation (2) Frequency of using apps for navigating/planning public transportation trips, e.g., jakdojade (3) Frequency of using ticket machines at stops (4) Frequency of using ticket machines in vehicles (5) Frequency of using digital tickets in apps (6) Frequency of using digital tickets assigned to a payment card	never, very rarely, rarely, moderately, often, very often, always
Shared mobility	(10) Frequency of using of shared city bikes (11) Frequency of using of shared scooters (12) Frequency of using of shared e-mopeds (13) Frequency of using shared cars	never, very rarely, rarely, moderately, often, very often, always

Source: own elaboration.

The variables used to measure the impact of the availability of digital solutions in public transportation on its usage are presented in Table 5. Respondents utilized a 7-point Likert scale, ranging from "definitely not" to "definitely yes".

**Table 5.**

*Measuring the impact of accessibility to digital public transport solutions on public transport use*

Question	Items	Scale
Impact of availability of digital solutions in public transport on more frequent use of public transport	(1) Impact of the availability of digital ticket assigned to a payment card (2) Impact of ticket availability in the app (3) Impact of ticket machine availability (4) Impact of public transportation navigating app availability (5) Impact of electronic dynamic passenger information displays availability	Definitely not, rather not, I have no opinion, rather yes, definitely yes

Source: own elaboration.

## 4. Results and discussion

### 4.1. Assessment of the city's transport system in terms of modernity

The evaluation of the city and its transportation system in terms of modernity, based on respondents' opinions, appears quite favorable (Table 6). The availability of modern transportation services received the highest rating. Slightly over 65% of respondents agreed or strongly agreed with this opinion. In the second place was the statement that Łódź is a modern city, with just over 63% of respondents fully or partially agreeing with it. The lowest ratings were given to the presence of modern transportation infrastructure and systems. Just under 60% of respondents held this opinion. Women and respondents without a car were more likely to agree with opinions about the city's modernity, infrastructure, and transportation services. Car owners and men were more critical. The obtained results align with the findings of other authors' research. For example, research by Borowska-Stefańska and others (2020) on the quality of public transportation services in Łódź paints a positive picture—the current policy regarding fleet and transport organization is heading in the right direction. However, a clear recommendation is the popularization of ITS systems displaying information about the arrival time of the next vehicle. According to other researchers (Fajczak-Kowalska et al., 2017) the introduction of the new transportation system in Łódź slightly improved the quality of public transportation services. Visible improvement occurred primarily in the information sphere, including dynamic content boards providing information about the vehicle's location, upcoming stops, transfer possibilities, as well as voice announcements in buses, information at stops, and on the Internet.

**Table 6.**

*Respondents' opinions of Lodz and its transportation systems in terms of modernity by gender and car ownership (N = 250) (%)*

Agreeing with the statement		strongly disagree	disagree	somewhat disagree	undecided	somewhat agree	agree	strongly agree	Total
<b>Lódź is a modern city</b>									
Gender	Woman	7.6	3.0	18.2	2.3	49.2	12.9	6.8	100.0
	Male	3.4	11.0	26.3	1.7	39.8	14.4	3.4	100.0
Owning a car	Not	5.4	4.3	19.4	2.2	48.4	18.3	2.2	100.0
	Yes	5.7	8.3	23.6	1.9	42.7	10.8	7.0	100.0
Total		5.6	6.8	22.0	2.0	44.8	13.6	5.2	100.0
<b>Lódź has modern transport infrastructure and systems</b>									
Gender	Woman	6.8	4.5	22.0	2.3	42.4	14.4	7.6	100.0
	Male	0.8	14.4	28.8	4.2	33.1	16.9	1.7	100.0
Owning a car	Not	4.3	7.5	21.5	2.2	46.2	18.3	0.0	100.0
	Yes	3.8	10.2	27.4	3.8	33.1	14.0	7.6	100.0
Total		4.0	9.2	25.2	3.2	38.0	15.6	4.8	100.0
<b>Modern transportation services are available in Lodz</b>									
Gender	Woman	6.1	4.5	15.2	6.1	42.4	18.2	7.6	100.0
	Male	0.8	4.2	22.9	6.8	39.8	22.0	3.4	100.0
Owning a car	Not	3.2	3.2	20.4	5.4	45.2	20.4	2.2	100.0
	Yes	3.8	5.1	17.8	7.0	38.9	19.7	7.6	100.0
Total		3.6	4.4	18.8	6.4	41.2	20.0	5.6	100.0

Source: own elaboration.

#### 4.2. Use of modern transportation solutions

The first group of digital solutions that facilitate individual car trip planning in Łódź, which we analyze, includes: (1) websites and route planning applications that consider information about traffic jams, accidents, and congestion on roads, (2) variable message signs providing information about traffic intensity and road disruptions in the city, (3) applications/boards/systems providing information about available parking spaces. The frequency of using these tools by respondents when planning and driving in Łódź is presented in Table 7. Respondents used a 7-point scale, ranging from 'never' to 'always'. Among respondents, the most popular are applications enabling route planning, with over 60% of respondents often, very often, or always using them. Women tend to use them more frequently than men, and non-car owners more than car owners. Sociodemographic variables have been identified in many studies as factors influencing residents' transportation behaviors, including those related to the use of digital solutions (Prieto et al., 2017). The lower popularity of such tools among car owners may result from drivers having in-vehicle navigation systems at their disposal. Conversely, non-car owners who travel as passengers and use these applications can inform drivers about current congestion on the route. Additionally, the information provided by these applications is useful for individuals using other means of transportation, such as public transport.

Variable message signs are used significantly less frequently by respondents (approximately 35%). Every fourth respondent uses them with moderate frequency. Over 46% of individuals without a car rarely or never use them. Applications and systems providing information about available parking spaces in the city are the least popular solution.



Every fifth respondent has never used them. This solution is least popular among women and individuals without a car. It can be assumed that the low popularity is a result of the weak organization of the system in Łódź. The city has not implemented an intelligent parking system accessible through an application in the paid parking zone. Only parking space availability counters are available on selected streets in the city center. Counters also operate in some private parking lots located near large shopping centers. Furthermore, research by Borowska-Stefańska and Wiśniewski (2019) indicates that parking organization issues in Łódź are not limited to the city center alone (mainly the Śródmieście district). Areas along the main communication arteries of the city running parallelly (e.g., Piłsudskiego Avenue) or meridianally (e.g., Kościuszki Street, Zachodnia Street) deserve special attention.

**Table 7.**

*Respondents' use of modern services to plan individual car trips by gender and car ownership (n = 250) (%)*

Frequency of use		never	very occasionally	rarely	moderately	often	very often	always	Total
<b>Websites/apps for route planning including information about possible traffic jams, collisions, and road congestion</b>									
Gender	Woman	6.1	5.3	12.1	12.9	27.3	22.7	13.6	100.0
	Male	6.8	5.9	11.0	16.9	30.5	22.9	5.9	100.0
Owning a car	Not	8.6	5.4	7.5	7.5	26.9	26.9	17.2	100.0
	Yes	5.1	5.7	14.0	19.1	29.9	20.4	5.7	100.0
Total		6.4	5.6	11.6	14.8	28.8	22.8	10.0	100.0
<b>Variable message signs informing about traffic intensity and road difficulties</b>									
Gender	Woman	11.4	9.8	13.6	25.0	21.2	14.4	4.5	100.0
	Male	9.3	14.4	22.0	24.6	19.5	9.3	0.8	100.0
Owning a car	Not	7.5	14.0	21.5	25.8	14.0	10.8	6.5	100.0
	Yes	12.1	10.8	15.3	24.2	24.2	12.7	0.6	100.0
Total		10.4	12.0	17.6	24.8	20.4	12.0	2.8	100.0
<b>Apps/boards/systems that inform about free parking spaces</b>									
Gender	Woman	22.0	9.1	10.6	22.7	20.5	12.9	2.3	100.0
	Male	18.6	9.3	15.3	23.7	20.3	8.5	4.2	100.0
Owning a car	Not	25.8	5.4	15.1	21.5	17.2	10.8	4.3	100.0
	Yes	17.2	11.5	11.5	24.2	22.3	10.8	2.5	100.0
Total		20.4	9.2	12.8	23.2	20.4	10.8	3.2	100.0

Source: own elaboration.

The second group of modern solutions, examined in terms of frequency of use by respondents, pertains to digital tools supporting public transportation and includes two types of functionalities: the ability to plan public transportation journeys (applications and electronic dynamic passenger information displays) and the ability to purchase tickets (four available modern options were considered: ticket vending machines on vehicles and at stops, ticket payment through applications, and assigning it to a payment card, including the Open Payment System). Among the solutions supporting public transportation journey planning, electronic passenger information displays at stops gained more popularity than applications with similar functionality (Table 8). Every fourth respondent has never used such applications, almost 40% are men, and nearly 30% own a car. These data may be related to the nature of the passenger's

interaction with the tool. In the case of applications, installation on a smartphone is necessary, and providing data is also required, which may be a discouraging factor. On the other hand, electronic passenger information displays do not require additional activity from the user. This conclusion thus confirms the findings of other researchers regarding the significance of perceived ease of use in using solutions (Haldar, Goel, 2021). Women more frequently use both solutions compared to men. Additionally, both solutions are more popular among individuals without a car, which is likely linked to more frequent use of public transportation.

Among the modern ticket purchasing options, respondents most frequently choose ticket machines in public transport vehicles (used often or always by approximately 47% of respondents), followed by purchasing a digital ticket in a mobile app (42% of respondents often or always buy a digital ticket). In third place is the purchase of a ticket at a ticket machine at the bus stop (about 23% of respondents often or always buy tickets this way), and the least popular option is the Open Payment System or buying a digital ticket at a ticket machine and assigning it to a payment card (used often or always by only 13.5% of respondents). For the option of saving a digital ticket on a payment card, the highest percentage of individuals who never use this solution was recorded (almost 60%). Once again, women more frequently use every analyzed ticketing method compared to men. Ticket machines are more commonly used by individuals who own a car; on the other hand, non-car owners prefer digital tickets through the app, which may be attributed to the frequency of public transportation use. It can be assumed that car owners use it occasionally, opting not to install an app and instead using a ticket machine. For those who use public transportation more regularly, installing an app is more justified. Thus, our results support the findings of other researchers who argue that the perceived usefulness and benefits of a mobile ticketing service are perceived differently in different usage situations, and the usage situation significantly influences usage intention (Mallat et al., 2006).

**Table 8.**

*Respondents' use of modern public transportation solutions by gender and car ownership (n = 250) (%)*

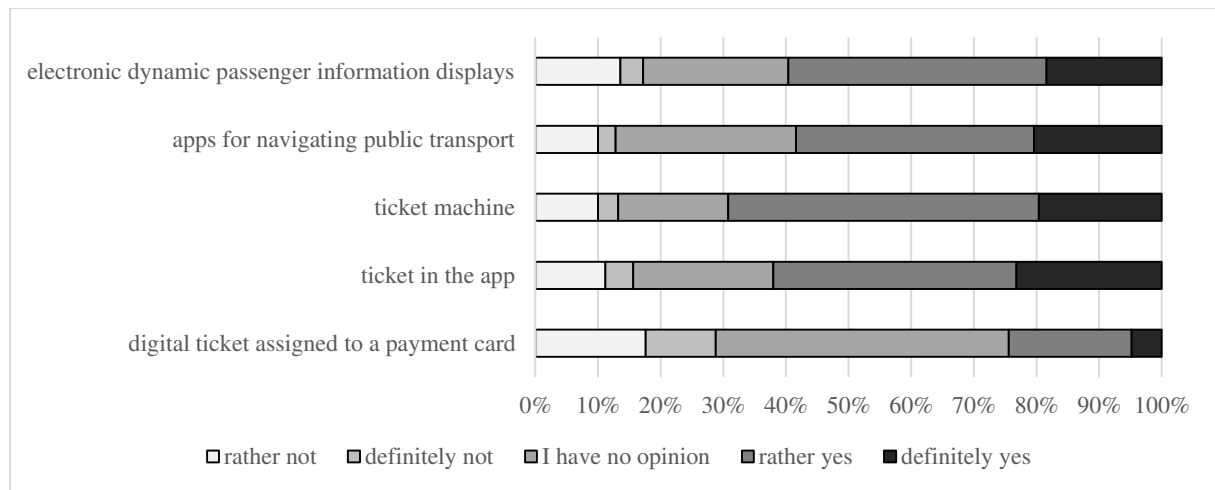
Frequency of use		never	very occasionally	rarely	moderately	often	very often	always	Total
		<b>TRIP PLANNING, CONNECTION INFORMATION</b>							
		<b>Electronic dynamic passenger information displays for public transport</b>							
Gender	Woman	11.4	8.3	9.8	26.5	19.7	17.4	6.8	100.0
	Male	9.3	15.3	12.7	28.0	22.9	7.6	4.2	100.0
Owning a car	Not	7.5	5.4	8.6	29.0	23.7	15.1	10.8	100.0
	Yes	12.1	15.3	12.7	26.1	19.7	11.5	2.5	100.0
Total		10.4	11.6	11.2	27.2	21.2	12.8	5.6	100.0

Cont. table 8.

		<b>Public transportation navigating/trip planning apps (e.g. Jakdojade)</b>							
Gender	<i>Woman</i>	13.6	10.6	12.9	15.9	15.9	13.6	17.4	100.0
	<i>Male</i>	38.1	7.6	12.7	16.9	10.2	7.6	6.8	100.0
Owning a car	<i>Not</i>	19.4	10.8	12.9	12.9	8.6	14.0	21.5	100.0
	<i>Yes</i>	28.7	8.3	12.7	18.5	15.9	8.9	7.0	100.0
Total		25.2	9.2	12.8	16.4	13.2	10.8	12.4	100.0
		<b>MODERN TICKET PURCHASING OPTIONS</b>							
		<b>Ticket machines at bus stops</b>							
Gender	Woman	22.7	25.8	20.5	9.8	11.4	8.3	1.5	100.0
	Male	32.2	18.6	13.6	8.5	18.6	6.8	1.7	100.0
Owning a car	Not	23.7	24.7	23.7	7.5	12.9	6.5	1.1	100.0
	Yes	29.3	21.0	13.4	10.2	15.9	8.3	1.9	100.0
Total		27.2	22.4	17.2	9.2	14.8	7.6	1.6	100.0
		<b>Ticket machines in vehicles</b>							
Gender	Woman	6.1	13.6	14.4	15.9	19.7	24.2	6.1	100.0
	Male	16.9	10.2	14.4	14.4	24.6	13.6	5.9	100.0
Owning a car	Not	8.6	15.1	14.0	17.2	20.4	17.2	7.5	100.0
	Yes	12.7	10.2	14.6	14.0	22.9	20.4	5.1	100.0
Total		11.2	12.0	14.4	15.2	22.0	19.2	6.0	100.0
		<b>Digital tickets in the app</b>							
Gender	Woman	23.5	10.6	11.4	9.1	18.2	15.9	11.4	100.0
	Male	32.2	7.6	11.9	10.2	16.9	10.2	11.0	100.0
Owning a car	Not	18.3	5.4	8.6	9.7	18.3	19.4	20.4	100.0
	Yes	33.1	11.5	13.4	9.6	17.2	9.6	5.7	100.0
Total		27.6	9.2	11.6	9.6	17.6	13.2	11.2	100.0
		<b>Digital tickets assigned to a payment card</b>							
Gender	Woman	50.0	15.2	8.3	6.8	7.6	7.6	4.5	100.0
	Male	57.6	12.7	11.0	11.9	3.4	3.4	0.0	100.0
Owning a car	Not	47.3	17.2	8.6	9.7	4.3	8.6	4.3	100.0
	Yes	57.3	12.1	10.2	8.9	6.4	3.8	1.3	100.0
Total		53.6	14.0	9.6	9.2	5.6	5.6	2.4	100.0

Source: own elaboration.

The survey results reveal that respondents are more inclined to use public transportation due to digital solutions (Figure 1). The most substantial positive impact is associated with ticket machines, as almost 70% of respondents believe that they are more likely or definitely more likely to choose public transportation because of this payment option. The purchase of tickets through the app also holds significant importance, with 62% of respondents indicating a positive correlation. In contrast, respondents consider the system of saving a digital ticket on a payment card to have the least influence on their attitudes. Our findings align with those of other researchers; for instance, a study by Shaheen et al. (2016) demonstrated that respondents using transportation multimodal apps were motivated by the goal of making less energy-intensive trips and relying on public transportation.



**Figure 1.** Respondents' opinions on the impact of innovations in Lodz public transport on their willingness to use it ( $n = 250$ ) (%).

Source: own elaboration.

The third category of contemporary transportation solutions included in the survey comprises shared mobility services such as bikesharing, scooter sharing, e-moped sharing, and car-sharing. The frequency of utilization of these services by respondents is presented in Table 9. These services exhibit considerably lower popularity compared to all previously analyzed solutions. Approximately 60% of respondents have never utilized any of these vehicles, with the figure rising to almost 88% in the case of scooter sharing. A small percentage of respondents use these systems frequently, with car-sharing recording the highest frequency (more than 15.5% of respondents), followed by bikesharing (10%), scooter sharing (8%), and e-moped sharing, which is used less frequently. These results contradict the findings of other researchers regarding the increasing popularity of shared mobility systems (Bokolo, 2020). Men and non-car owners more frequently rent bicycles and scooters, while women and car owners prefer car sharing. Previous research suggests that these services are predominantly used by men (Singh, 2020), however our analysis indicates the need for further research to explain the higher acceptance of car sharing in Lodz among female respondents than among men.

**Table 9.**

*Respondents' use of shared urban mobility by gender and car ownership ( $n = 250$ ) (%)*

Frequency of use		Never	Very rarely	Rarely	Moderate	Often	Very often	Always	Total
		<b>Bike</b>							
Gender	Woman	63.6	13.6	6.8	8.3	3.8	3.0	0.8	100.0
	Male	55.1	13.6	13.6	5.1	8.5	4.2	0.0	100.0
Owning a car	Not	60.2	16.1	6.5	6.5	7.5	2.2	1.1	100.0
	Yes	59.2	12.1	12.1	7.0	5.1	4.5	0.0	100.0
Total		59.6	13.6	10.0	6.8	6.0	3.6	0.4	100.0

Cont. table 9.

		<b>Scooter</b>							
Gender	Woman	65.9	7.6	7.6	13.6	1.5	1.5	2.3	100.0
	Male	54.2	16.1	16.1	2.5	7.6	3.4	0.0	100.0
Owning a car	Not	62.4	8.6	8.6	10.8	8.6	0.0	1.1	100.0
	Yes	59.2	13.4	13.4	7.0	1.9	3.8	1.3	100.0
Total		60.4	11.6	11.6	8.4	4.4	2.4	1.2	100.0
		<b>E-moped</b>							
Gender	Woman	88.6	5.3	3.8	2.3	0.0	0.0	0.0	100.0
	Male	86.4	5.9	2.5	3.4	1.7	0.0	0.0	100.0
Owning a car	Not	89.2	5.4	1.1	3.2	1.1	0.0	0.0	100.0
	Yes	86.6	5.7	4.5	2.5	0.6	0.0	0.0	100.0
Total		87.6	5.6	3.2	2.8	0.8	0.0	0.0	100.0
		<b>Car-sharing</b>							
Gender	Woman	62.1	12.1	3.0	4.5	6.1	8.3	3.8	100.0
	Male	62.7	11.0	9.3	4.2	4.2	6.8	1.7	100.0
Owning a car	Not	65.6	10.8	7.5	6.5	5.4	3.2	1.1	100.0
	Yes	60.5	12.1	5.1	3.2	5.1	10.2	3.8	100.0
Total		62.4	11.6	6.0	4.4	5.2	7.6	2.8	100.0

Source: own elaboration.

## 5. Summary

Smart transportation solutions have revolutionized travel planning in cities, providing real-time information about road conditions, alternative routes, public transportation schedules, and the integration of different transportation options. This empowers users to make informed decisions about travel routes and modes, ultimately reducing travel time and alleviating road congestion. Intelligent transportation solutions also contribute significantly to enhancing public transportation systems, making them more competitive and appealing compared to individual modes of transportation.

City residents are actively embracing smart transportation solutions to enhance the efficiency and effectiveness of urban travel. The increasing popularity of public transportation apps and ride-sharing platforms reflects their openness to innovative technologies. Our survey results reveal that residents utilize smart transportation solutions with varying frequencies, depending on the type of solution. The most commonly used solutions are those supporting trip planning and execution for individual transportation, followed by public transportation, and least frequently for shared mobility systems.

Among solutions supporting public transportation trip planning, electronic passenger information displays at bus stops enjoy greater popularity than mobile apps. Ticket machines are also more commonly used for ticket purchase compared to mobile apps. Moreover, differences in the usage of all analyzed solutions were observed between men and women, as well as car-owning and non-car-owning individuals. These findings underscore the necessity of promoting modern transportation solutions among city residents, particularly applications

related to public transportation. This can be achieved through marketing campaigns, educational initiatives, and promotional efforts targeting diverse social groups and individuals of varying ages. Such endeavors are justified by the confirmed positive impact of these solutions on the inclination to choose public transportation for urban travel.

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## ESG RISK MANAGEMENT IN THE CORPORATE LENDING PROCESS IN POLAND

Irena PYKA<sup>1\*</sup>, Jan PYKA<sup>2</sup>

<sup>1</sup> University of Economics in Katowice; i.pyka@ue.katowice.pl, ORCID: 0000-0001-5524-3550

<sup>2</sup> Katowice Business University; jan.pyka@gwshl.com, ORCID: 0000-0001-8127-7076

\* Correspondence author

**Purpose:** The fundamental objective of the study is to characterise the features that accompany ESG risk management processes in Polish companies financing green investments with a bank credit.

**Design approach:** The study focuses on the observation of changes occurring in the concept and processes of ESG risk management following the so-called Paris Agreement of 2015. The EU regulations standardising the ESG risk management process in companies and banks have been analysed, indicating the differences resulting from them. The inclusion of ESG risks both in creditors and credit recipients is achieved through various channels, determining the extent, and expected outcomes of green investments. Without a doubt, the issue has been receiving considerable research attention in many papers since the energy crisis caused by Russia's aggression against Ukraine. However, in light of EU regulatory changes and the increased interest of business entities in green financing, uncertainties, and research problems are on the rise in this area. An evident limitation of the conducted research is the lack of empirical data completing the knowledge on the effects of ESG strategies both domestically and in EU member states. Therefore, the paper draws on questionnaire surveys conducted by the authors, as well as on the findings of various reports published on the subject.

**Findings:** The research shows that EU regulations increase the security of financing green investments in both companies and banks. The concept of sustainable development and ESG risk management associated with it have been severely curtailed through their introduction. Nevertheless, there is a fairly substantial area of uncertainty associated with the process of financing green investments. The study analyses its determinants indicating that internal ESG risk management procedures of companies and banks do not eliminate the external risks of financing corporate green investments.

**Originality/value:** The conducted research undoubtedly broadens the knowledge about the role and significance of ESG risk in the green investment financing process. The analysis of studies relating to ESG risk, taking into consideration EU documents, contributed to exposing unexplained, debatable, and unsolvable issues. The questionnaire survey as well as the secondary data obtained made it possible to verify the number of common opinions and statements, along with the main hypothesis of the paper.

**Keywords:** bank lending, credit risk management, ESG financing, ESG risk, ESG strategy, ESG disclosure, EU taxonomy, non-financial reporting, greenwashing, financially sustainable credit.

**Category of the paper:** viewpoint.

## 1. Introduction

ESG risk, which constitutes the research subject of this paper, is increasingly widely considered and analysed in numerous studies, papers, and strategies of business entities. In the ESG (Environmental, Social, Governance) concept, which is currently replacing the CSR (Corporate Social Responsibility) strategy in companies, ESG risk is a broadly defined notion. It is identified by indicating the negative consequences caused by all the factors, both environmental (E), social (S), and governance (G), which severely affect the financial standing and hinder the activities of business entities (more broadly business entities and organisations). In such circumstances, it is extremely difficult to make it tangible and thus to measure and monitor it. The extensive measures in the European Union regulating corporate sustainability, including ESG risk, identify the risks and procedures needed to manage these risks in an almost enumerative manner. Non-financial and financial companies undertaking operations in Poland have been obliged, like those in other EU member states, to strictly comply with EU sustainability standards and modify their business strategies. The relatively brief period of intensification of the introduced changes, and the extended period of standard-setting obligations along with the energy crisis of recent years make Polish companies notice a range of benefits resulting from green financing of their investments. They accept the administration of sustainable development viewing it as increased security against the tangible negative effects of ESG. The study focuses on the observation of changes in the concept and processes of ESG risk management taking place after the so-called Paris Agreement of 2015. An in-depth analysis of ESG risk management strategies and procedures was conducted drawing on the SFDR, the EU taxonomy and the CSRD emphasising the resulting standard-setting differences concerning companies and banks. The identification of ESG risk in the process of green financing is carried out in line with EU standards, but separately in each of the analysed business entities conditioning not only the process of its management but also the effectiveness of green investment. Given that the ESG risk inclusion in both banks and credit recipients takes place through different channels, the research hypothesis was aimed at demonstrating that credit risk management associated with green investment financing is a complex undertaking requiring the co-responsibility of banks as well as companies to comply with EU regulatory standards at great risk to their reputation and financial performance. The paper draws on the questionnaire surveys published in various ESG reports, assessing corporate expectations

towards sustainability strategies, green financing of corporate investments, and ESG risk management. The section focused on financing green investment in banks includes the results of the authors' research conducted in the Polish banking sector. The research was conducted in Q1 2023. The research sample involved the 10 largest commercial banks in Poland, including PKO BP S.A., Bank Pekao S.A., Santander Bank Polska S.A., ING Bank Śląski S.A., mBank S.A., BNP Paribas S.A., Bank Millennium S.A., Alior Bank S.A., Citi Handlowy S.A., and Velo Bank S.A. A total of 101 representatives of commercial banks in Poland participated in the research, of which 46.06% held managerial positions, and 53.94% represented risk management departments. 82.12% of the respondents had at least 10 years of experience working in a bank. However, the paper is of a **cognitive** nature due to the divergence of formulated views on ESG risk, as well as the lack of empirical data completing the knowledge on the results of ESG strategies within the country and in EU member states. The conducted theoretical research, complemented by the analysis of EU documents associated with the ESG concept, as well as the questionnaire research used, certainly adds to the knowledge about the role and significance of ESG risk in the process of green investment financing.

## 2. Materials and Methods

### 2.1. ESG risk in Polish companies

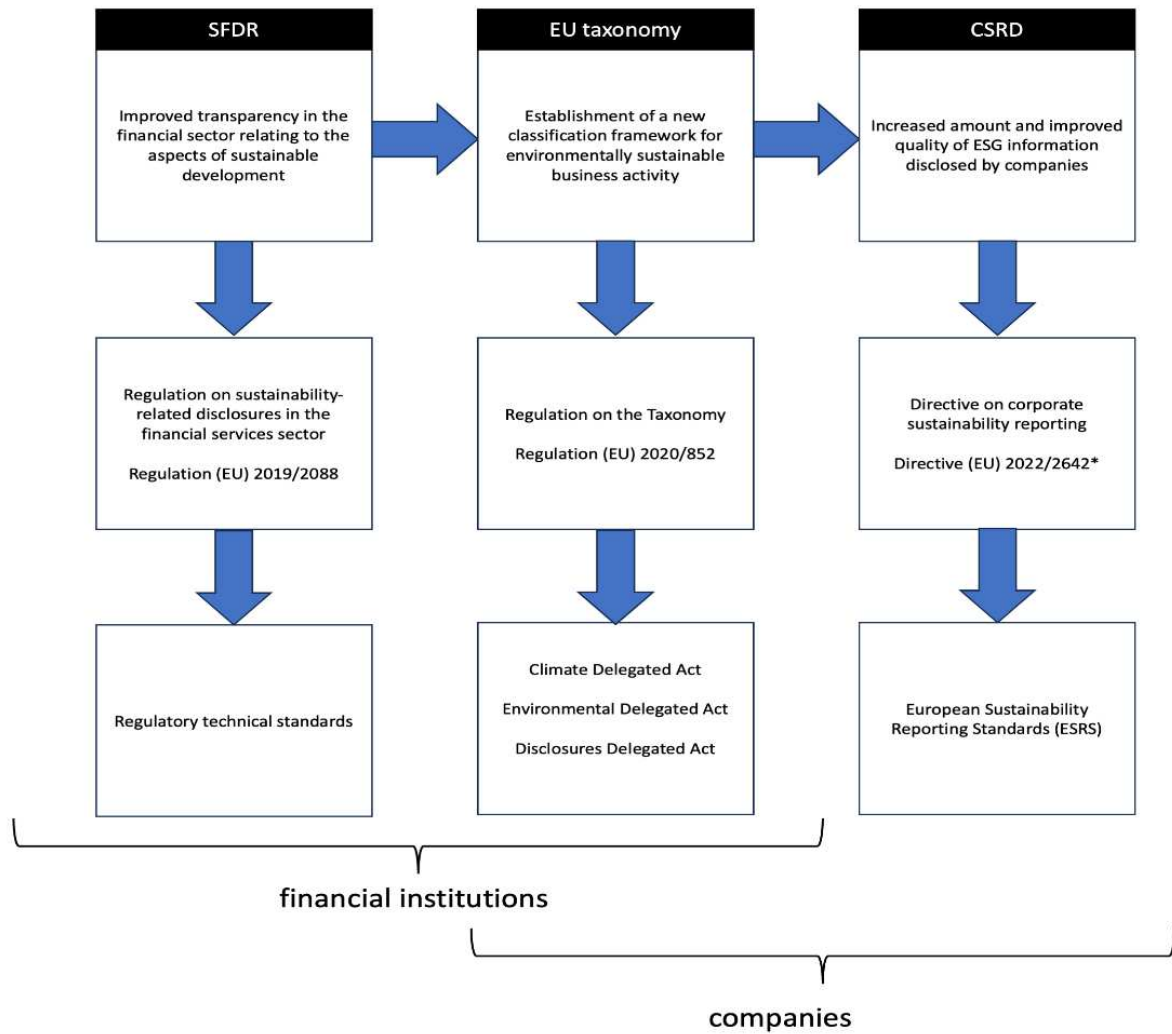
The concept of ESG risk is multidimensional, difficult to identify, and heterogeneous (Marcinkowska, 2022, p. 37). It is undoubtedly related to the idea of sustainable development, whose concept has been discussed and modified for many years now (Alberti, 1996, pp. 381-424; Bocian, 2009, pp. 75-81; Borys, 2011, pp. 75-81; Forrester, Górka, pp. 15-21; Kistowska, 2009, pp. 20-30). By revealing its core characteristics, ESG risk can be defined in a relatively straightforward manner by recognising that it is influenced by environmental, social, and governance factors, which can significantly impact the financial standing and hinder the operations of companies (more broadly, business entities and organisations). Unquestionably, the concept of ESG risk is extensive in such an approach, for it relates to all areas of sustainable development (Environmental, Social, Governance - ESG), which is synonymous with the diversity of the occurrence of the factors of its materialisation and entity, industry, geographical, time or spatial diversification. Indeed, the observed climate change, concomitant degradation of the environment, and related catastrophic phenomena resulting in social conflicts are distributed unevenly and stimulate different environmentally sustainable economic solutions. The research conducted indicates that there are serious environmental differences in the perception of the significance of ESG in further economic development. In the highly developed countries of the global economy, the motives for pursuing ESG are becoming stronger.

In less economically and socially developed countries, there is still not enough information and arguments for the implementation of ESG standards as tools for effective business management (Raport koszty). Environmental risks including the physical impact of global warming on the economic development of countries in the global economy are also the reason for the varying approaches to ESG risk. ESG risk is clearly higher in certain geographical areas and lower in others. Business entities that need to build their resilience to ESG risk across various time horizons, through a comprehensive and future-oriented approach, as well as early and proactive actions under constant scrutiny and supervision, diversify their business and investment decisions. In this way, they undoubtedly reduce ESG-related transition risks and technological risks arising from green investment financing. Therefore, various legal acts, strategy documents, and policy materials give ESG risks a spectacular nature that usually corresponds to the manners in which business entities engage in the green economic deal. In this approach, it is made more specific by attributing features to particular institutions and business entities. ESG risk analysed in the study was aimed at the area of interaction between companies and banking institutions financing green investments. There is a growing belief in the business world that companies that fail to adjust to ESG may suffer from negative consequences affecting their operations and financial standing. As a result, they are increasingly relying on ESG for their corporate governance, including green investments that favour sustainability. However, the company's internal governance system, i.e., corporate governance, in the new environmental and climate conditions requires modification of procedures, standards, and control mechanisms for effective ESG risk management. Regulatory standards applicable in the European Union require the integration of ESG risk into business strategy and processes, internal governance, and risk management (Raport koszty, p. 80 et seq.). However, in lending institutions and companies, this is a heterogeneous process driven by existing European and Polish legal principles and international sustainability reporting standards and frameworks. The acceleration of the process came with the Paris Agreement of 2015. The agreement obliged all countries to present long-term scenarios for the reduction of greenhouse gas emissions by 2020. In 2018, for the first time in the European Union, the Sustainable Finance Action Plan emerged addressing the energy transition referred to as the Fit for 55 package (Action Plan). The Action Plan is part of a broader sustainable finance agenda, drawing on new and revised legal regulations requiring companies and financial institutions to be more transparent about their sustainability impacts and how they manage ESG risk, which is significant as its adoption by EU member states has greatly accelerated the emergence of new EU regulations relating to sustainability. The regulations include in particular:

- the CSRD and its complementary ESRS,
- the EU taxonomy establishing a common classification system for the identification of environmentally sustainable business activity,
- the SFDR aimed at financial market participants and advisers, which seeks to increase transparency and sustainability aspects in the financial sector.



Regulations and directives setting the general regulatory framework are usually complemented by delegated acts that specify how the aspects discussed therein are to be implemented in practice (cf. Figure 1). To varying degrees and extent, they apply to companies pursuing a sustainability strategy, including those undertaking green investments, and to financial institutions. By implementing the ESG strategy, companies commit themselves to respecting the EU taxonomy and the CSRD, whereas financial institutions, on the other hand, the SFDR and the EU taxonomy. However, the regulations indicated do not exhaust the complexity of the procedures needed for their implementation. This is because, in the process of financing green investments, there is a need for a far-reaching collaboration between companies and financial institutions, especially when implementation projects require green financing. Moreover, it should be noted that ESG strategy, in line with the indicated regulations, requires reporting. ESG reporting is a public disclosure of data relating to the operations of a given entity in three areas: environment, social issues, and corporate governance. Its objective is to make it possible to assess and compare entities in non-financial terms. The standard reporting method is to present indicators containing quantitative or qualitative data for each of the three categories. However, many reporting standards require their own elaboration to be standardised for entities implementing ESG. The process is seen as extremely complicated and thus conducive to increasing greenwashing. It is also difficult to consider EU regulation of ESG strategies as final. Firstly, because new ones are constantly being created, and secondly, because the implementation of EU regulations is frequently spread out. The largest Polish companies must disclose non-financial information from 2016 onwards, under the EU NFRD (Non-financial Reporting Directive) of 2014 (2014/95/EU). However, for it to be implemented in Poland, the Accounting Act (Journal of Laws of 2017, item 61) had to be amended. The introduction of mandatory non-financial data reporting has had an important impact on the development of ESG reporting in Poland and has contributed to an increase in the amount of ESG information released by companies. Nevertheless, the reporting process of companies implementing ESG is continuously being improved. On 28 November 2022, the Council of the European Union approved the Corporate Sustainability Reporting Directive, whose primary purpose was to strengthen and complement the NFRD. The ensuing reporting obligation was extended to include more companies, is broader in scope, and the entry into force of the directive was spread over four stages (figure 2).



**Figure 1.** EU regulations on the implementation of ESG.

Source: own elaboration.

<b>STAGE 1 in 2025</b> (i.e., in reports for 2024)	the new regulations will apply to companies already subject to the non-financial reporting directive
<b>STAGE 2 in 2026</b> (i.e., in reports for 2025)	the new regulations will apply to all large companies, i.e., those which exceed two of the three criteria: balance sheet total over EUR 20 million, net revenue over EUR 40 million, average annual number of employees over 250
<b>STAGE 3 in 2027</b> (i.e., in reports for 2026)	the new regulations will apply to small and medium-sized listed companies, i.e., those which exceed two of the three criteria: balance sheet total over EUR 4 million, net revenue over EUR 8 million, average annual number of employees over 50
<b>STAGE 4 in 2029</b> (i.e., in reports for 2028)	the new regulations will also apply to companies from third countries provided that they generate more than EUR 150 million in net revenue from sales and have at least one subsidiary here

**Figure 2.** Steps in the implementation of mandatory reporting.

Source: own elaboration.

According to new ESG regulations, the reporting system will be standardised, which will be based on the EU reporting standards of the European Financial Reporting Advisory Group (EFRAG) (Nowa rada...). The first set of guidelines called European Sustainability Reporting Standards (ESRS) was presented at the end of 2022. Simultaneously, the second set of standards is being developed. The EFRAG is expected to publish it by the end of 2023. The scope of regulation will apply to industry standards and listed small and medium-sized companies. Along with them, the requirement for certification conducted by an independent auditor of reports containing non-financial information will appear. Therefore, the latest regulations on ESG reporting will change the process of preparing and publishing reports on non-financial information. However, this is not the only and major problem of Polish companies implementing ESG strategies. The review of published ESG reports exemplifies, above all, the continued strong need for the education of business as well as other sustainability stakeholders. This is because a substantial proportion of them are not prepared to act on implemented ESG changes. Few Polish companies are familiar with ESG issues, and only one in five has developed a sustainability strategy, with the highest percentage in trading companies (25%) and large companies (24%). Of these, about 20% have developed the strategy themselves (47%), while the rest have been supported by the services provided by law firms, consulting firms, and even universities. One in three Polish companies that have implemented ESG principles decided to do so due to perceived opportunities for growth, better perception by customers, and out of concern for their image. Financial institutions awarding grants and EU funds (33%) have also proved to be a significant factor in activating companies about ESG. On the other hand, in Polish practice, ESG was seldom asked about by creditors (Raport koszty..., p. 8). Therefore, Polish companies recognising the potential of implementing ESG strategies, fail to prepare EU procedures for ESG risk management. They recognise instead the cumulative ESG risk factors in the global economy, which usually include:

- the impact of extreme weather phenomena on manufacturing and service activities,
- disruptions to energy supply and price increases for raw materials and supplies,
- disruption of supply chain,
- high legal liability,
- limited capacity to finance green investments.

Climate risk is the risk that is relatively best diagnosed in companies nowadays. It is much more difficult to identify ESG risk resulting from tensions and expected geopolitical changes. These undoubtedly include business decisions changing supply lines, or price disruptions in energy, raw materials and consumables markets. There is also a conviction that there are no significant barriers to financing green investments of companies. Indeed, the volume of this financing is steadily increasing. Moreover, any financial instrument can prove to be sustainable provided that there is a proper clause in the contract specifying how the funds are supposed to be used or the dependence of the financial terms on the achievement of particular non-financial objectives. Companies can therefore use green loans and bonds. They can also draw on

substantial fund resources accumulated in mutual investment institutions. Financing green investments is also facilitated by the intentionally generated SLL formula (Sustainability Linked Loan), as it can also be applied to companies encumbered by a “carbon footprint” (due to, for instance, inherited production processes) or declaring and implementing so-called “best efforts policy”, which is taken into consideration by financial institutions when providing support (WorldwideSpending...). The individualisation of companies’ approach towards ESG risk is therefore significant, which is why they are diversifying their business strategies and ESG risk management. EU regulations requiring compliance with a large number of rules and standards are a serious problem that undermines the sustainability motives of companies. Breaches of these can result in fines or damages, which have a direct impact on corporate liquidity. Various consulting and legal entities are frequently involved in the process, facilitating the development of ESG risk management processes. The reason for this is that plenty of companies find it difficult both to properly develop an ESG strategy and modify corporate governance. Solutions that emerge in this area change the negative approach of companies towards sustainability but increase financial costs and may breach the confidentiality of a range of business data. Moreover, for companies, ESG risk mitigated through the implementation and compliance with certain procedures does not guarantee ESG success. The reason for this is that interactions with company stakeholders cannot be reduced to information and reporting obligations. These only reduce in the short term the number of external risks in implementing an ESG strategy. Meanwhile, it is estimated that expenditure on ESG business services will increase to USD 158 billion in 2025, with a fivefold compound annual rate of return of 32.3% (Raport..., p. 7 et seq.). Such a “trump card” overrides any risk in large transnational corporations at least. A new momentum is therefore emerging in the global economy for the development of green companies that “must not fail”.

## **2.2. ESG risk in the corporate lending process**

In Polish companies, bank credit is the main source of corporate financing. Therefore, it is to be expected that it is this financial instrument that constitutes the main source of green investment in companies. However, the research conducted to date shows that when companies undertake green investments, they expect external support from public entities which, by implementing ESG regulations, ought not only to help companies learn about them but also to finance them. This issue in Poland is typically addressed by the largest corporations, including mostly listed companies and/or companies operating on an international scale with large investment projects. Therefore, their demand for green financing can be met with capital of diverse origins. Investment financing for these companies has always been easier than for smaller companies and bank credit has been a supportive source of financing investment. Most companies are also not able to precisely estimate the cost of their green investments. Companies are afraid of uncertainty and costs that are difficult to calculate at present (Raport..., p. 9). Therefore, while recognising the benefits of an ESG strategy, they remain passive towards

green investments. Thus, it is difficult to determine how high the demand for credit financing of green corporate investments will be and what its share of the ESG financing pool will be, including both other forms of private financing and public financing. Nevertheless, the experience of the companies surveyed remains invaluable. ESG risk, including risk arising from financing green investments, is extremely difficult to quantify. Therefore, extensive questionnaire-based research and established forums for the exchange of ideas and experiences are necessary and valuable. If the expectation of companies that in the near future the actual acquisition of funds may depend on carbon footprint reporting (Raport...) is met, financing green investments with a lower carbon footprint will become problematic. The concern about sufficient resources to finance corporate green investment projects, increasing capital costs and thus high investment risk is becoming a real issue. The process is already accompanied by increasing requirements of financial institutions towards credit recipients resulting from EU regulations. An important document for banks operating in Poland is the Regulation of (EU) 2019/2088 of the European Parliament and of the Council of 27 November 2019 on sustainability-related disclosures in the financial services sector called the SFDR (i.e., Sustainable Finance Disclosure Regulation) that has been in force on the territory of the European Union since 10 March 2021 (Regulation EU 2019/2088...). Another document aimed at banking institutions is the Regulation (EU) 2020/852 of the European Parliament and of the Council of 18 June 2020 on the establishment of a framework to facilitate sustainable investment ("Taxonomy Regulation") (Regulation EU 2020/852...). It includes a uniform classification system for green activity for all investors, companies, and financial institutions allowing them to determine their impact on the environment. What is more, banks in their ESG risk management process must take into consideration the issues legally regulated in the so-called Banking Package adopted in 2019 (Journal of Laws...). The implementation of these directives was planned for December 2020, meanwhile, the European Commission amended it already in October 2021, which took into consideration the demand for banks to continually analyse and manage ESG risk (Banking package...) Thus, ESG risk management became an integral part of operations of lending institutions forcing the need to implement risks related to climate change and promotion of sustainable finance in strategic decisions on bank risk management. From the perspective of the bank client, including especially the corporate client, it is critical how EU regulations will affect bank lending. Credit risk is the major regulatory risk that requires banks to comply with prudential standards. The obligation under EU regulations to manage this ESG risk will therefore force a change in bank lending conditions in many aspects. In May 2020, the EBA published the Guidelines on loan origination and monitoring (EBA/GL/2020/06), and on 30 June 2021 the final version appeared (EBA/GL/2020/06) (Wytyczne...). Under the guidelines, banks are required to meet supervisory expectations in terms of standards for taking, managing, and monitoring credit risk, as well as providing appropriate practices in the areas of client protection and prevention of money laundering. The guidelines refer to lending, managing, monitoring, pricing, and pricing policies in

EU lending institutions and have an impact on existing bank lending and their refinancing, but also apply to new lending. The guidelines also introduce the notion of “environmentally sustainable credit”. Granting such credit is related to the financing of environmentally sustainable business activities and requires the development of specific rules for their granting by banks. Banks that plan to grant environmentally sustainable credits should develop detailed policies and procedures for granting environmentally sustainable credits relating to their granting and monitoring. Banks should also specify transparently the criteria for regarding a credit as environmentally sustainable, as well as monitor the advisability of its use. While remaining in line with the EBA report (EBA Report...), banks are obliged to integrate ESG risk in a timely manner into their business strategies, governance, and risk management, as well as supervision. This process requires the preparation of their green financing strategy, defining qualitative and quantitative objectives supporting environmentally sustainable lending, and assessing the extent to which such lending is in line with or contributes to climate and environmental sustainability objectives. Therefore, banks are changing the terms and conditions of corporate lending in its classic form as well as ESG. Therefore, the costs of banking activities, both those directly related to bank lending and administrative and transaction costs, are increasing. It is also pointed out that banks expect an increasing demand for insurance services relating to ESG risk, which requires the preparation of special procedures for insurance providers who implement them. The probability of greenwashing occurring at the interface between two entities - banks providing green finance and companies financing green investments - is high. Disclosure, proper reporting, and a transparent taxonomy are in fact insufficient measures to mitigate ESG risks. The proper analysis of the risks arising from green financing of new techniques and technologies by various stakeholders in this process remains significant. Therefore, it is undoubtedly important to prepare ways and principles for the payment of compensation or liability of the parties for these damages, as well as to develop credit-rating institutions. A complicated credit risk management process in banks does not rule out their positive approach towards green lending. The conducted questionnaire survey indicates clearly that the stance of banks on green investments is changing. More than 50% of respondents point out a declining interest in financing investment projects that have a negative impact on the environment (fig. 1).

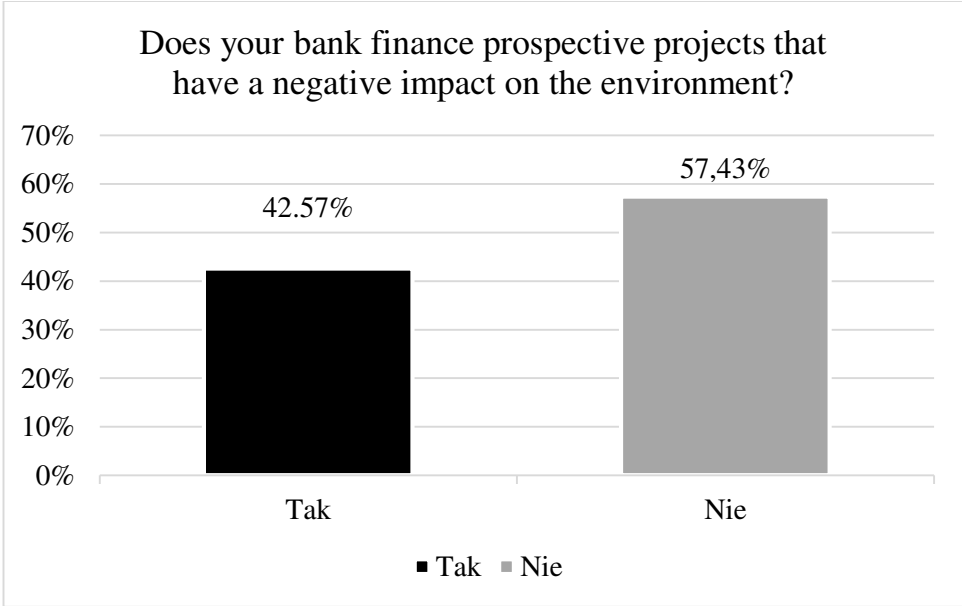


Figure 1. Survey results on the impact of bank finance prospective projects on the environment.

Source: own elaboration.

Over 62% also confirm the increase in bank financing of ESG investment projects (fig. 2).

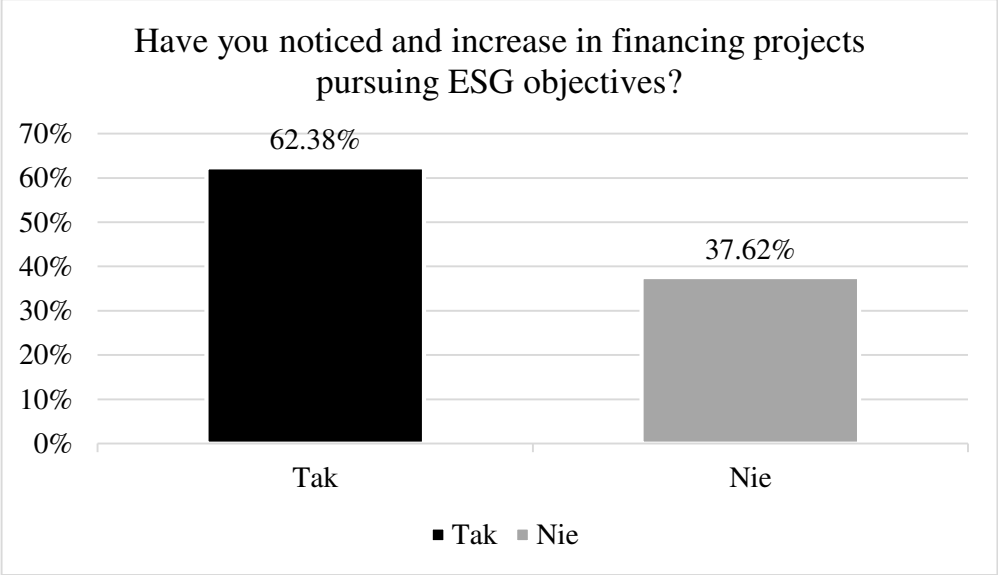
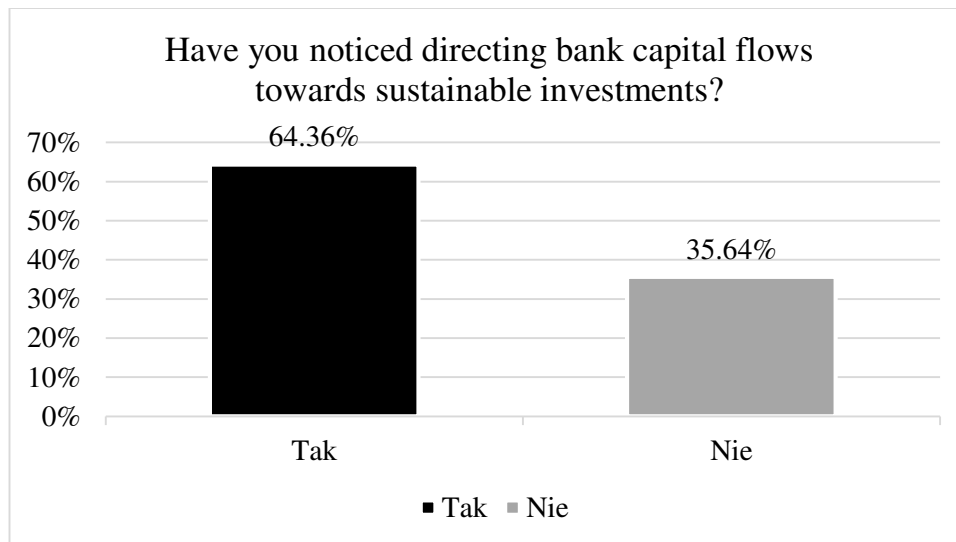


Figure 2. Survey results on the increase in financing projects pursuing ESG objectives.

Source: own elaboration.

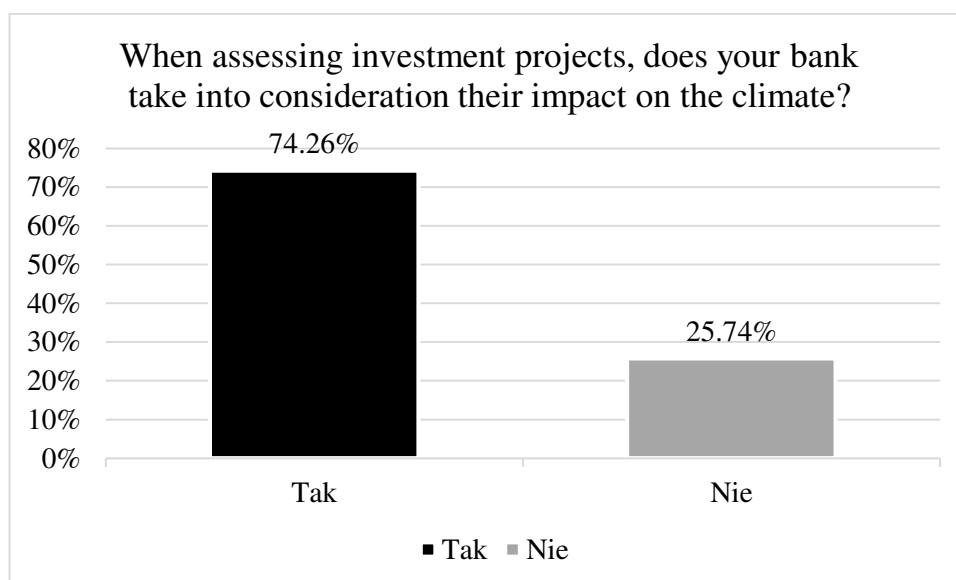
Simultaneously, as many as 64.36% of respondents notice a redirection of bank capital flows towards sustainable investments (fig. 3).



**Figure 3.** Survey results on directing bank capital flows towards sustainable investments.

Source own elaboration.

The study also confirmed the growing financing of investments in ecology. More than 74% of respondents are motivated by this criterion in financing investments with green loans (fig. 4).

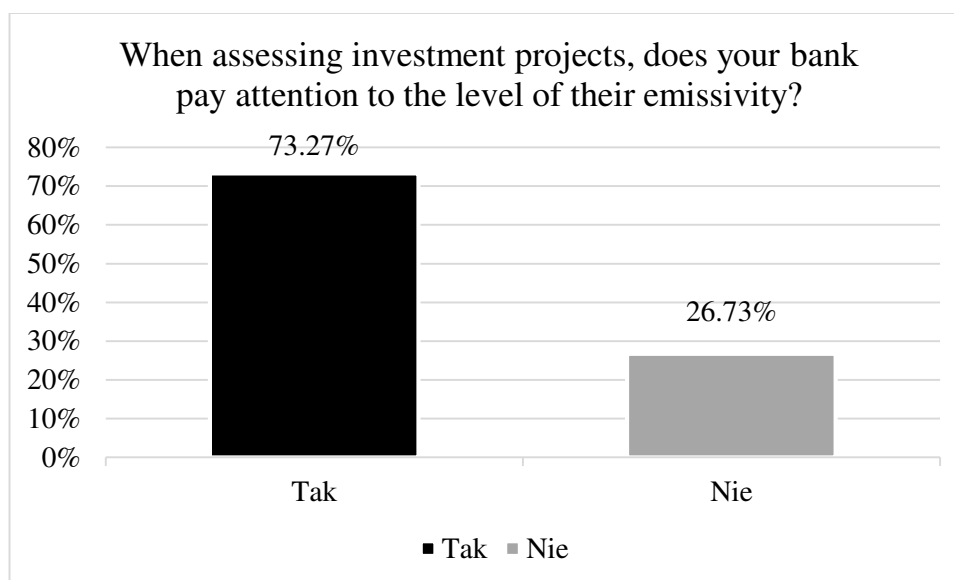


**Figure 4.** Survey results on the impact of climate considerations during bank's investment projects assessment.

Source: own elaboration.

The concerns of companies regarding the criterion of the carbon footprint of the investments financed were also positively verified (fig. 5).





**Figure 5.** Survey results on the impact of emissivity level during bank's investment projects assessment.

Source: own elaboration.

The presented research results refer only to those oriented towards green financing of investments in banks. Conducted in the Polish banking sector, the research verifies several common sustainability-oriented opinions and doubts. They show a significant eagerness of banks to undertake green financing initiatives and to change the existing structure of the bank credit portfolio. However, the conducted survey indicates that financing of investment in the so-called classic energy sector is not changing as intensely as could be inferred from the approach of banks towards green loans.

### 3. Results

The research conducted has shown that the enthusiasm of the Polish economy to switch to green financing through bank credit is affected by several distinct factors. The first problem is related to a serious lack of capacity to identify ESG risk, estimate its level, and monitor and assess both its short- and long-term consequences. Another fundamental problem results from the increasing pressure from public authorities in the broad sense to accelerate the implementation of sustainability in companies, financial institutions, and households. Although the implemented EU regulations stabilise the conditions for raising capital for financing green investments and increase the financial security of business entities, they do not, however, eliminate all ESG risk factors. Corporate governance and the development of ESG risk management procedures standardised across all EU member states constitute a key area of its mitigation. It is assumed that only a proper ESG risk assessment creates opportunities for business growth and makes it possible to avoid potential risks. Proper ESG risk management

that takes into consideration non-financial reporting consistent with EU guidelines expands corporate operational capabilities, reduces the financial costs incurred by companies, and makes it possible to increase their net profit. It also contributes to increased business prospects, increases access to capital and financing, improves customer relations, and enhances the company's reputation. According to the survey, companies, while recognising the positive aspects of green investments, are not coping with the plethora of EU regulations in the ESG risk management process. Their sustainability is therefore related to the increasing demand for advisory or insurance services, and perhaps other ones yet unrecognised. Moreover, as ESG becomes increasingly integrated into business strategies, companies recognise the increasing number of risks associated with the loss of their market value. Thus, they may feign various sustainability measures (greenwashing phenomenon). On the other hand, according to the study, the use of bank credit to finance green investments is subject to special scrutiny. This is because bank credit is an instrument for financing green investments subject not only to EU regulations but also to strict prudential standards. Therefore, banks are better protected against ESG risks than other financial institutions in the process of financing green investments. However, ESG risk accumulates at the level of the interaction between companies and banking institutions financing green investments usually not standardised due to their spectacular features. The banks surveyed, however, explicitly declare financing green investments, shifting their strategies and risk management systems towards sustainable development. The discrepancy noted has its justification that requires further research. Indeed, a bank credit is merely an option to finance green investments. Its application to alternative options for financing green investments, from public capital resources, remains a great unknown. Therefore, by looking at companies seeking capital to finance green investments, it is possible to analyse further resulting research problems. They are certainly an indication of the lack and low transparency of information on corporate sustainability.

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## READINESS FOR CHANGE AND EFFECTIVENESS IN POLISH HOSPITALS

Ewa RACZYŃSKA

Uniwersytet Ekonomiczny w Katowicach, Wydział Ekonomii, Katedra Przedsiębiorczości i Zarządzania  
Innowacyjnego; ewa.raczynska@ue.katowice.pl, ORCID: 0000-0002-7834-1353

**Purpose:** The aim of this paper is to attempt to analyze how readiness for change affects effectiveness in the Polish health sector. Theoretical and practical aspects of readiness for change, effectiveness, and determinants of the hospital system will be presented and research results will be published.

**Design/methodology/approach:** The survey study Likert scale-based with a telephone-assisted was conducted in a group of 100 Polish hospitals. Factor analysis, summary scales and regression calculations were performed.

**Findings:** The level of readiness to change positively influences hospital effectiveness. The level of readiness for change and effectiveness are independent of the level in the hospital network.

**Research limitations/implications:** Questions were provided by heads of medical administration, medical managers, and independent administrative specialists answered questions. The subjective opinions of medical and administrative staff may differ.

**Originality/value:** The article is addressed to researchers interested in the health care sector, as well as those interested in the relationship between readiness for change and effectiveness. For practitioners, hospital management may provide management guidance regarding organizational support.

**Keywords:** effectiveness, readiness for change, hospital, health care.

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

### 1. Introduction

The healthcare sector is subject to many changes, ranging from regulatory, structural, technological and funding changes to the dramatic functioning of a pandemic or workforce crisis. Changes in healthcare are often rapid and implemented overnight without adequate implementation. Progressive crises, such as the shortage and ageing of medical staff, the impact of Covid-19 on the health of the population and the trauma of medical staff due to overwork, and the uncertainty of the system can create considerable resistance to change in the health care

system. It is therefore important to understand both personal and organizational readiness for change. This article presents the results of empirical research on the impact of readiness for change on effectiveness in Polish hospitals and examines how the level of the hospital network affects the level of readiness to change. The research is designed to answer 3 research hypotheses developed from the literature review. The aim of the article is to investigate whether there is a positive relationship between readiness for change and effectiveness and between level of hospital network, readiness for change and effectiveness in Polish hospitals.

The article is aimed at health care researchers and practitioners, as well as those interested in the relationship between readiness for change and effectiveness. The results of the conducted research are a contribution of management and quality science, but may also be of interest to health sciences due to the sector in which the research was conducted. To date, no similar research has been conducted in Poland and the results may shape further research into hospital network eligibility and readiness for change.

## **2. Hospitals in Poland**

A hospital is a medical entity defined in Ustawa o działalności leczniczej, whose task is to provide medical services, health promotion, teaching and research. However, most often it provides hospital services consisting in providing 24/7 and comprehensive health services, i.e. diagnosis, treatment, care and rehabilitation (Ustawa..., 2011). Most hospitals are public, highly politicized institutions, and the rules of their operation are strictly defined by laws, regulations and orders of the President of the Narodowy Fundusz Zdrowia. Hospitals perform a social function by securing the health needs of the population, which often results in their lack of profitability (Raczyńska, 2023). Hospitality is the most cost-intensive element of the public health care sector - in the assumptions for 2023, expenses in this area are to constitute 50% of the National Health Fund's budget (NFZ Plan Finansowy, 2022). In response to many problems in the hospital system, the so-called hospital network reform was introduced, dividing them into first-, second- and third-degree hospitals, pediatric hospitals, pulmonology hospitals, oncology hospitals, nationwide hospitals and non-network hospitals (Ustawa..., 2017). First-level hospitals in simple terms correspond to district, second-level provincial, third-level clinical hospitals and institutes - it is assumed that the higher the level, the more extensive and specialized the structure and the more complex the procedures (Rabiej, 2020). In 2022, the qualifications of hospitals were revised, but without major changes for facilities. This reform was the last systemic change in the health care sector.

### 3. Effectiveness

Effectiveness is a difficult concept to define, although colloquially it is easy to understand its essence. It is worth quoting here a simple definition by E. Głodziński, who defines effectiveness as the relation of achieved results to used inputs. As M. Kulikowska-Pawlak points out, effectiveness can be analyzed in quantitative terms that are reflected in the relation of effects to satisfied needs in a given period, taking into account the relation of resources to effects (Kulikowska-Pawlak, 2010). P.A. Samuelson and W.D. Nordhaus also point to a soft factor relevant to the level of effectiveness which is satisfaction (Samuelson, Nordhaus, 2012). Relating efficiency strictly to the health care sector, it can be defined as a set of coordinated activities taking place at different levels of reference bringing about an improvement in the health of patients through the provision of medical and preventive services (Raczynska, 2020). Effectiveness in health care is a perplexing concept because it will be understood differently by the doctor, differently by the patient, for whom the medical effect is the most important (medical case effectiveness), and for hospital managers, the micro effectiveness (of the treatment entity) will be crucial, while globally the whole system is assessed (macro level). These levels interpenetrate and are strongly dependent on each other (Rudawska, 2011). Methods of measuring effectiveness in the health sector can be divided into indicative, parametric and non-parametric (Sekula, Julkowski, 2017). A common method of assessing the effectiveness of healthcare entities is to use only financial measures, but it is very important here to also consider indicators specific to hospitality such as average length of stay, occupancy of hospital beds, operating theatre, stock of medicines, excess workload, etc. (Kujawska, 2017). Based on a study in the Netherlands, entities should use between five and ten key performance measurement indicators in order for the measurement itself to be effective (Dyduch, Kozłowska, 2011). On the other hand, there are multi-criteria evaluation methods available, for example, the model proposed by K. Dubas based on M. Bielski's multi-criteria evaluation of effectiveness, which contains five dimensions of effectiveness and nine criteria, taking into account financial, technical, qualitative, behavioral and developmental dimensions (Dubas, 2011). Parametric methods for the health sector usually distinguish between SFA (stochastic frontier analysis) and DEA (data envelopment analysis). SFA analyses are usually applied to economic aspects, while DEA is linked to operational research (Lampe, Hilgers, 2015). Assessing system efficiency dedicated measures are QALYs, DALYs and CEAs - these measures are translated from medical cases to the system and allow for macro-level comparisons (Feng et al., 2020). So many effectiveness measurement methods provide a full range of options for managers making it impossible to identify a universal tool. The choice of performance measurement method should be tailored to the entity being evaluated, as well as the purpose of the analysis being performed.

#### 4. Readiness for change

Change is common in the turbulent environment the health sector is no doubt. Change sometimes occurs too quickly and adaptation is required within an unrealistic timeframe (Beasley et al., 2021). Properly managing the change process requires treating it as an opportunity, not just a threat (Walas-Trębacz, 2009). Organizational change is defined as the transition of an organization from one state to another that is different from the previous one. It means making adjustments and modifications between goals, objectives and resources over a period of time. Change can be a consequence of an internal or external situation. A well-conducted change process should bring benefits to the organization and its stakeholders (Szeliga-Rudzka, Mazurkiewicz, 2018). Change can involve a range of issues from external circumstances (e.g. legal changes) to internal (equipment, work organization, etc.), but it always involves people. The capacity for organizational change depends on the individual attitudes of the employees involved in the change, their individual behavior, group behavior, resistance and commitment (Nowak, 2013). High readiness for change is possessed by organisations with a unique organizational culture created by top management that is open to continuous change, accepts risk and sees it as an opportunity for success, uses appropriate management methods and concepts, supports and works together with the rest of the team (Skalik, 2018). Among the factors cited as significantly influencing change readiness in the health sector are transparent communication, resource availability, lack of skill and training, reward system, recent trends in health care, top management and decision making, state of affairs, clarity of organizational mission and goals, interdependence among departments, technology advancement, organizational culture, and stress level and job security (Vaishnavi et al., 2019). Extremely important in terms of the above factors is leadership, with transformational leadership playing a key role (Shannon, 2021) and a supportive organizational culture characterised by trust, collaboration, safety, teamwork, supportive and motivating leadership, and employee participation in decision-making (Ellis et al., 2023). The properly managed change will be effective change with the potential to increase organizational effectiveness (Gilley et al., 2009). A high level of change readiness should therefore potentially result in higher efficiency for an organization operating in a changing environment. This hypothesis will be verified by the author's empirical research.



## 5. Research methods

The research questionnaire was developed on the base of the Hospital Change Readiness (HCR) Questionnaire tool (Pomare et al, 2020) and the effectiveness scale proposed by Jones and Van de Ven (Jones, Van de Ven, 2016) was modified for the Polish conditions. The questionnaire contained 10 questions about readiness for change and 5 questions about effectiveness, in addition to a metric. The questions in the metric related to qualification for the hospital network. The research sample was hospitals in Poland with a contract with the NFZ. According to the Główny Urząd Statystyczny, there were 899 general hospitals in Poland in 2021. The survey, the results of which will be discussed, was conducted from October 2022 to February 2023 and a sample of 100 hospitals was obtained. The survey was preceded by a pilot in 2021, where the number of hospitals surveyed was 11. The research was conducted in order to prepare a dissertation. The research method was a telephone-assisted survey addressed to hospitals, random sampling. The respondents were heads of medical units (so-called heads of departments), heads of administrative units and employees in independent non-medical positions. Level I hospitals accounted for 37% of the respondents, level II 27%, level III 13%, non-network hospitals 8%, and nationwide, oncology, pulmonology and paediatric hospitals a total of 15%. 94% of the hospitals surveyed were accredited representing a large over-representation to reality. 73% were ISO 9001 certified. 47% of the surveyed population was financially loss-making. The following research hypotheses were adopted:

H1: The higher the level of readiness for change the higher the level of performance.

H2: The higher the place in the hospital network the higher the level of readiness for change.

H3: The higher the place in the hospital network the higher the level of effectiveness.

The traditional approach, factor analysis, summed scales and regression (Ferguson, Takane, 2009) were used to verify the hypotheses. This approach allowed the assessment of relationships between variables.

## 6. Findings

Factor analysis indicates that both the constructs of readiness for change and effectiveness are consistent. Cronbach's alpha in readiness for change has a high reliability on the summative scale, while effectiveness has an acceptable level. Table 2 indicates test values where eigenvalue  $>1$  and cumulative proportion  $>0.6$  indicating 2 factors. LR test: independent vs. saturated:  $\chi^2(45) = 540.00$  Prob $>\chi^2 = 0.0000$  Table 3 reports that factor loadings for Factor 1 are always greater in absolute value than Factor 2, meaning that all questions form a single construct. Tables 4 and 5 refer to the effectiveness construct. LR test: independent vs. saturated:  $\chi^2(10) = 134.59$  Prob $>\chi^2 = 0.0000$

**Table 1.***Measures to assess the quality of the measurement part of the model*

Item	Index	
	Readiness for change	Effectiveness
Cronbach alpha	0,889	0,745

Source: own development.

**Table 2.***Principal-component factors for readiness for change*

Factor	Factors			
	Eigenvalue	Difference	Proportion	Cumulative
1	5.07788	3.61560	0.5078	0.5078
2	1.46228	0.64763	0.1462	0.6540
3	0.81465	0.22274	0.0815	0.7355
4	0.59191	0.04096	0.0592	0.7947
5	0.55095	0.11182	0.0551	0.8498
6	0.43914	0.08773	0.0439	0.8937
7	0.35141	0.02555	0.0351	0.9288
8	0.32586	0.09782	0.0326	0.9614
9	0.22804	0.07016	0.0228	0.9842
10	0.15788	.	0.0158	1.0000

Source: own development.

**Table 3.***Factor loadings (pattern matrix) and unique variances for readiness for change*

What about	Factors		
	Factor1	Factor2	Uniqueness
Hospital will benefit from change	0.7225	-0.4886	0.2393
Legitimate reason for change	0.6637	-0.5706	0.2339
Change will improve	0.7957	-0.4436	0.1701
After change will be better	0.7883	-0.1350	0.3603
Adaptation after	0.7073	0.1165	0.4861
Will handle	0.6434	0.5422	0.2920
Personal relationships in work	0.6975	0.1036	0.5027
Long run	0.7435	0.2583	0.3805
After easier	0.7313	0.2934	0.3792
Better communication	0.6103	0.4604	0.4156

Source: own development.

**Table 4.***Principal-component factors for efectivness*

Factor	Factors			
	Eigenvalue	Difference	Proportion	Cumulative
1	2.69058	1.88659	0.5381	0.5381
2	0.80399	0.14089	0.1608	0.6989
3	0.66310	0.19637	0.1326	0.8315
4	0.46672	0.09111	0.0933	0.9249
5	0.37562	.	0.0751	1.0000

Source: own development.

**Table 5.***Factor loadings (pattern matrix) and unique variances for effectiveness*

What about	Factors	
	Factor1	Uniqueness
quality	0.8137	0.3379
quantity	0.5359	0.7129
costs	0.7240	0.4758
health	0.7722	0.4036
competition	0.7878	0.3793

Source: own development.

To verify the relationship between readiness for change and effectiveness, regression calculations were applied. Based on its results, there is a positive significant relationship (\*\*\*)  $p < 0.01$ ) between readiness for change and effectiveness thus confirming hypothesis H1. The control variables were hospital types and other metric questions - in most cases the relationships are not statistically significant.

**Table 6.***Regression*

VARIABLES	Ef_summ
Rfch_summ	0.291*** (0.110)

Note. The resistant standard error is indicated in brackets.

Source: own development.

To verify hypotheses H2 and H3, a T-Score was used. Table 8 compares the p-values and t-values - their results for the study conducted indicate that no pair has a significant difference, which means no significant relationship. Thus, the calculations allow us to refute H2 and H3 - the level in the hospital network does not affect either readiness for change or effectiveness.

**Table 6.***Descriptive statistics*

variable	RfCh			EF		
	N	średnia	odch. St.	N	średnia	odch. St.
I level	37	4.762	0.980	37	4.919	0.791
II level	27	4.548	0.786	27	5.067	0.642
III level	13	4.808	0.717	13	5.385	1.139
pediatric	5	4.580	1.307	5	5.040	1.389
pulmonology	3	4.600	0.608	3	5.467	0.462
oncology	2	5.050	2.333	2	5.600	0.849
nationwide	5	4.220	0.622	5	5.400	0.283
no network	8	5.275	1.050	8	5.375	0.910
Together	100	4.716	0.922	100	5.116	0.829

Source: own development.

**Table 7.**  
*T-Score*

Tests	RfCh		EF	
	t	p	t	p
I vs II	0.969	0.336	-0.824	0.413
I vs III	-0.178	0.860	-1.364	0.191
II vs III	-1.001	0.321	-0.938	0.363

Source: own development.

The results of the study allow H1 to be confirmed, while H2 and H3 were refuted. The assumptions of readiness for change that resulted from the literature studies were confirmed in the policy conditions. In contrast, the assumptions derived from the hospital network are not reflected in the light of the study. The place in the network does not influence either the effectiveness or the readiness for change of the surveyed group of Polish hospitals.

## 7. Discussion

Referring to H1 the higher the level of readiness to change the higher the efficiency, the results of the study can be considered to be in line with similar studies in the literature (Negm et al., 2021). Here, however, one should look for articles that understand the concept of effectiveness broadly, i.e. referring to productivity, outputs, outcomes rather than strictly efficiency. While there is not always a straightforward translation of the type the higher the level of readiness for change the better the effect, according to some researchers this is U-shaped (Helfrich et al., 2018). Readiness for change is often referred mainly to employee attitudes (Hameed et al., 2017), especially research in this area was conducted in health care during the covid-19 pandemic (Roemer et al., 2021). Readiness for change in research is often used as a mediator of the relationship between a given construct and effectiveness (Hariadi, Muafi, 2022). It is often associated with psychological research and the translation of readiness to change into organisational effectiveness is rarely reported in the literature, although the theoretical literature suggests the above conclusion. The hospital network is dedicated to the Polish health care system and its evaluation is carried out by the Ministry of Health. In the literature, it is usually assessed in terms of ensuring access to services (Mikos, Urbaniak, 2017) or funding (Sierocka et al., 2020). Similar results to the relationship between hospital location in the network and readiness for change were also obtained when comparing the level of maturity for change depending on the location in the hospital network. Process maturity and placement in a hospital network are not related (Raczyńska, 2023). The study shows that readiness to change influences the effectiveness of Polish hospitals, while the level in the network is not significant for readiness for change. On this basis, it can be concluded that it should be important for hospital managers to maintain a high readiness for change. At the same time, this is an option available to all hospitals regardless of their location in the system,

as it does not affect the level of readiness for change or efficiency. It is therefore possible to universally apply tools to strengthen readiness for change regardless of the type of hospital. It is also a basis for further research, i.e. how to influence the level of change readiness in hospitals and how to keep it high. The research was limited by the number of hospitals and the limited number of respondents. These research can be repeated after a new classification into the network or a change in the system.

## 8. Final conclusions

The article highlights the importance of readiness to change in hospital efficiency indicating a positive relationship between readiness to change and efficiency. The research provides guidance for management practitioners as the findings may have practical application. The conducted research fits into the research gap being a basis for further research in the field of readiness for change in the health sector also at lower referral levels. The research on hospital networks can be further used for evaluation of the healthcare system.

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## SMART WORKING IN ORGANISATIONS OPERATING ON THE POLISH MARKET – OPPORTUNITIES AND LIMITATIONS

Małgorzata SIDOR-RZĄDKOWSKA

Warsaw University of Technology, Faculty of Management; m.sidor.rzadkowska@pw.edu.pl,  
ORCID: 0000-0003-3826-9382

**Purpose:** The aim of this study is to reflect on the essence of smart working and analysis of the possibilities of applying this concept in organisations operating on the Polish market.

**Design/methodology/approach:** The study undertakes to review literature in order for consider the definition of smart working. Various forms of work that embrace this model and the provisions of Polish labour law that are important for its implementation in organisations have been analysed.

**Findings:** The article indicates challenges connected with adapting solutions to the provisions of the Polish Labour Law and educating management staff.

**Originality/value:** The article characterises smart working - a work model responding to the needs of the 5.0 economy. The elements constituting this model have been described. Moreover, the conditions that must be fulfilled in order to implement smart working in organisations operating on the Polish market have been indicated.

**Keywords:** Smart working, economy 5.0, Polish Labour Law, nomadic work, smart office.

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

### 1. Introduction

Over recent years, we have seen a complete change in the approach to remote work. Before 2020, i.e., in what could be called *pre-pandemic times*, remote work was a privilege available only to a selected few. Millions of employees forced to commute to the office every day looked with a mixture of admiration and envy at those who were allowed to perform their duties remotely. During the COVID-19 pandemic, remote work became a necessity. Sanitary requirements and lockdown left offices empty; employees were not allowed to come to offices. That ban was a fairly painful experience for many people; There were many comments about the feeling of being trapped at home. Currently, in what we all wish to believe can be called *post-pandemic times*, remote work has become a choice. This choice, as evidenced

by many studies cited in this article, most often takes the form of hybrid work. This hybrid is usually understood in a superficial way and is limited to considering how many days (weekly) an employee should spend in the office and how many at home. It is time to change this approach, taking another step towards shaping a modern work model. It is smart working - a work model adapted to the needs of both the employer and the employee. The presented article characterises this concept and analyses the opportunities and limitations related to the implementation of smart working in organisations operating on the Polish market.

## 2. What is smart working?

In short, smart working implies selecting a way of working tailored to the needs of both the employee and the employer (Bednar, Welch, 2020). It may take the form of remote work and office work - the office should also be *intelligent*. Not only does *smart office* positively impact the comfort of performing tasks, but it also stimulates creativity and cooperation between onsite and remote employees. This is currently one of the most critical challenges to be resolved. Research conducted in numerous organisations reveals that people working remotely feel as though they were becoming second-class employees (Sidor-Rządkowska, 2021, p. 78). Smart working eliminates these concerns by offering a range of various forms: office work, remote work (both at home and nomadic), coworking and the so-called hybrid work, which is a combination of these forms. Smart working is based on the belief that the choice of where to perform professional duties should not be limited to the alternative: working from home or working in the company's office (headquarters). One should consider other options in order to provide all employees with the workplace that is most conducive to the effective implementation of their tasks (Iannotta et al., 2020).

Remote work is essentially working from anywhere in the world. As Szapar (2021, p. 18) notes: "Everyone whose main work tool is a computer has a unique opportunity to re-evaluate their everyday life." This re-evaluation increasingly takes the form of nomadic work. The term "nomad" is used today to refer to people who work remotely and live in many different places without having a permanent address. It is estimated that by 2035, up to one billion people around the world will be considered digital nomads (Hatańska, 2022).

Nomadism is not a homogeneous phenomenon as its degrees vary. We can distinguish at least three basic types here (Szapar, 2021, pp. 56-57). The first one is the so-called *workationist* – a person who is away for no longer than a few weeks. During the trip, they work full-time, and after work may indulge in typical holiday pleasures in "beautiful scenery". In Poland, the most popular places among workationists are, obviously, the mountains (with particular emphasis on the Bieszczady Mountains), Masuria and seaside towns. A person who moves to a chosen place for a long time (usually to warm countries) is called a *slowmad*. They usually

want to change the environment for a while or escape from winter, while maintaining a permanent foothold. *Digital nomad* is an employee who completely resigns from the aforementioned foothold. With the so-called one backpack (in practice-several suitcases), they embark on the voyage around the world, stopping for longer in selected places. They are usually a freelancer, although this is not a necessary condition - more and more companies allow their employees to perform their professional duties in a nomadic manner. However, they are usually not obliged to have daily contacts with the employer; the working time of a digital nomad is most often determined by the deadline for completing the project.

Reports show that nomadic work is developing dynamically, especially in the IT industry where it has had long tradition. It is believed that effects of work are crucial rather than the place and time of performing particular tasks.

### **3. Smart working and economy 5.0**

The modern economy is sometimes referred to as the 4.0 economy. It is the economy that responds to the needs of the Fourth Industrial Revolution. One should explain why the technical revolution in which we (more or less consciously) participate is called the Fourth Industrial Revolution. Where does the number in this concept come from? The First Industrial Revolution was the breakthrough that resulted in the age of steam. The symbol here is the weaving loom invented in 1782. It initiated the development of craft production supported by the power of water and steam. The beginning of the Second Industrial Revolution dates back to 1913 - the world's first production line was introduced at the Ford factory. The period of this revolution was crucial for the development of management theory. A large number of contemporary researchers refer to scientific studies performed during the Second Industrial Revolution, and the names of Frederic Taylor, Karol Adamiecki and Edwin Hauswald are known (or at least should be known) to all graduates. 1969 is considered the beginning of the Third Industrial Revolution - it was then that a programmed logic system was invented as computers became popular. The current breakthrough - the Fourth Industrial Revolution (its beginning dates back to 1989) is associated with the invention of the Internet, which led to the explosion of innovative solutions (Kosieradzka, Zawila-Niedzwiecki, 2018, p. 10).

This fourth breakthrough is happening at the fastest pace in history and has the widest reach - it affects every aspect of our lives - work, health, interpersonal relationships, etc. (Blichacz 2023, p. 15). Recently, the concept of a fifth revolution has emerged - for several years now 5.0 economy has been discussed, the essence of which involves building sustainable relationships between increasingly intelligent technologies and people (Akundi et al., 2022; Weiner, 2022).

As Joanna Moczydłowska (2023, p. 164) observes, the 5.0 economy model is based on three basic pillars, that is ecology, man, and crisis resistance. Let us try to describe these pillars in the context of smart working.

**I. Ecology.** The pandemic has made everyone who did not understand it yet realise what a tragic condition our planet is in and how urgent actions are required to stop the degradation process. Smart working addresses this need as it helps to eliminate the need to travel to the workplace every day and thus significantly reduces exhaust emissions. It was the very concern of Jack M. Nilles, an American physicist and engineer, widely considered the father of remote work. When introducing this concept, Nilles writes: “One morning I was driving (alone, like most highway users) from home to university. As usual, the traffic on the Santa Monica Freeway was moving in spurts: forward and stop, forward and stop. That morning I was stuck helplessly on the highway, staring at the almost endless string of red brake lights of the cars in front of me. (...) The proverbial light went on in my head. Revelation. It was an extremely simple, yet powerful idea. One that could change the world” (Nilles, 2003, pp. 6-7). Research conducted in 2020-2023 clearly shows that the ability to avoid commuting to the workplace is generally considered to be the greatest advantage of remote work.

**II. Man.** Economy 4.0 put technology at the centre, while Industry 5.0 is developing under the slogan that people must be at the centre of all processes. People employed in an organisation are its main stakeholders; concern for their well-being is a condition for the effective operation of the company. Since the COVID-19 pandemic, much attention has been paid to building well-being programmes (Mołek-Winiarska, Mikołajczyk, 2022). One of the most important benefits of these programmes is the ability to choose where and how to work.

**III. Crisis resilience.** The COVID-19 pandemic and the outbreak of the war in Ukraine have shown how important crisis management is. One of the fundamental elements of such management is building resilience at the level of individuals, teams and entire organisations. Smart working and the ability to respond with flexibility to the unpredictable events will definitely help to build such resilience.

#### **4. Smart working and work hybrid**

The term "hybrid" relates to a work model in which some duties are performed at the company's headquarters, while some - remotely (usually in the home office system). Creating an effectively functioning hybrid is not an easy task - the belief that hybrid work somehow automatically combines the best of both remote and stationary work may be a manifestation of wishful thinking rather than the real experience of employees and managers (Sidor-Rządkowska, Sienkiewicz, 2023, p. 184).

In order to better understand the scale of the challenges, one should remember that behind the broad term "hybrid work" there are dozens of solutions applied in practice. When trying to organise these solutions, we should consider this issue from two points of view, that is a) the employee, b) the company as a whole.

Ad a) As regards the employee's point of view, we can distinguish three basic models of hybrid work:

1. **Classic hybrid work** – that is a specific balance between the number of days spent working in the office and the number of days one works remotely (the proportions are 2:3 or 3:2 assuming a five-day working week). It is assumed that the term "hybrid work" without any additional adjectives or terms refers to this work model.
2. **Hybrid office work first** – involves the advantage of onsite work; most often 4 days in the office and 1 day of remote work.
3. **Hybrid remote work first** – involves the advantage of performing duties remotely; most often 4 days of remote work and 1 day in the office.

Ad b) From the point of view of the company as a whole, we can distinguish two basic solutions for hybrid work:

- I. Everyone (or almost everyone - the exception may be e.g., security staff) performs some of their duties in the office and some remotely. Previously, we distinguished three basic types of such work: classic, office first and remote first. Each of them may apply to all employees or be different for various groups.
- II. Some employees of a given company work in the office, some remotely. Such solutions are typical especially for manufacturing companies where technological requirements force the constant presence of certain groups of employees at the company's headquarters. Here, the proportions regarding the number of people are usually expressed in percentages: 30%: 70%, 80%: 20%, 60%: 40%, etc. This is still a simplified variant - it does not consider those who work in the hybrid mode, performing some of their duties remotely, and some - onsite.

In practice, the situations presented above overlap. For example, in one company, approximately 35% of employees work 3 days in the office and 2 days at home, 25% - 2 days in the office and 3 days at home, 15% - 4 days in the office, 1 day at home, 10% – 4 days in the office, 1 day at home. It should be added that 8% of people work only in the office, while 7% - only at home. The scale of management problems that such a company's operation entails is enormous.

The hybrid work model (in all the varieties presented here) has become widespread; Research conducted among management staff (presidents, board members and directors of corporations operating on the Polish market) shows that hybrid work operates in 89% (!) of organisations. Only 6% allow only work in the office, while 5% - only remote work (Hybrid, Beyond, 2022). All the mentioned types of hybrid work are used (with a huge advantage of the classical model).

## 5. Smart office – an office for all or an office for everyone?

The idea of a smart office is to adapt office space to the contemporary market needs, which revolve around reducing business costs while increasing efficiency. Modern offices are intended not only to have a positive impact on the comfort of work itself, but also to stimulate creativity and provide space that will meet the needs of various groups of employees.

The importance of smart office is growing with increasing digitisation. Jeremy Myerson and Catherine Greene (cited in: Dudek, 2019a, pp. 216-221) assume that the mobility of knowledge workers (understood as performing professional duties outside the office) is a fact; individuals differ only in the degree of this mobility. From this point of view, the authors distinguish four groups of employees, giving them figurative names: *the anchors*, *the connectors*, *the gatherers*, *the navigators*. Let us try to describe them in more detail.

**The anchors** – this group includes people who need an office routine for their daily operations. They want to come to work at the same time every day, meet co-workers, complete their tasks and leave the company with a sense of duty well fulfilled. This group includes both those who are motivated by the presence of other people and those who do not have the conditions to work at home and/or do not like working there. *Anchors* wish to have their own room in the office (or at least a clearly separated area that ensures uninterrupted work), their desk, and a place to store documents and personal items. People belonging to this group play an important role in the organisation - for other employees they are both a source of information and a symbol of the company's continuity.

**The connectors** are employees who thrive on *the exchange of information* and knowledge. They spend no more than half of their working time at their desk; in the remaining time they move around the company, working with different people and putting them in contact with each other. It is easy to adapt to changes in the organisation of office space, but they like to have a lot of space at their disposal. This allows them to freely present to their colleagues what they are currently working on, listen to their opinions, seek advice and guidance.

**The gatherers** – this group includes highly mobile employees who spend most of their time outside the office. Their role is mainly to represent the company externally. They usually spend their working time meeting clients and making new contacts. They generally do not feel the need to have their own desk; Space shared with other employees of the organisation is sufficient for them.

**The navigators** - a characteristic feature of the discussed group of employees is "sailing on seas and oceans" with various duties and only occasionally calling at the port of the company. This mode is used, for example, by salespeople performing their duties in various parts of the country. They expect that during their (rare) visits to the company, they will be treated as full staff members and will be met with kindness, a friendly atmosphere and good working conditions.

Another classification divides modern office workers into four main groups, these are:

**Residents** – employees spending over 70% of their working time at a desk. Only in exceptional situations do they work remotely and rarely participate in meetings. The type of tasks they perform requires a lot of concentration. Therefore, they need to be provided a space enabling concentration, offering acoustic and ergonomic comfort. A valuable convenience may be, for example, high-class armchairs and desks with adjustable top height.

**Networkers** – on average, they spend 40-70% of their working time at their desks. They sometimes perform their duties remotely and often work in teams. For networkers, the most important thing is a comfortable meeting place with colleagues that allows for open communication.

**Nomads** – this group of employees spends no more than 30% of their working time at their desk. The remaining time passes in constant motion. They appreciate unrestricted access to spaces where they can quickly start working with a laptop or conduct a conversation.

**Field workers** – they only appear in the office occasionally. However, they expect that there will be a comfortable, easily accessible workplace waiting for them (2017).

The experience of the pandemic period led to the belief that the office should primarily perform activating and social functions. It is supposed to provide what remote work does not, that is the need to "leave home" and maintain direct contact with colleagues. Experts from Antal and Cushman & Wakefield wrote already in the fifth month of the epidemic: "Remote work will probably stay with us for a long time, thus office space will have a new function - it will be an inspiring place that will build and support the culture of the organisation, facilitate the learning process, encourage building bonds between colleagues and clients and foster creativity and innovation" (Elasticity of specialists and managers..., 2020, p. 8).

The previously described spread of the hybrid model, combining work in the office with remote work, poses particular challenges to the concept of smart office. New classifications are emerging, taking into account employees' expectations towards office space. One of the most interesting is the proposal of Colliers researchers, who in 2020-2022 conducted a study to answer the question of how the behaviour of different people is shaped in hybrid work conditions (Osiecka, 2022). This research led to the identification of three styles, which were given the following names: *Analytical Albert*, *Collaboration Claire*, *Varied Victor*. Let us try to briefly describe the characters behind these styles:

*Analytical Albert* - the working day of a person characterised by this style is dominated by focused individual tasks. Individuals representing this style focus predominantly on the ability to concentrate on the tasks at hand. They prefer working from home (assuming they have appropriate conditions for this). The purpose of coming to the office is to hold direct meetings with colleagues, deal with matters requiring paper documentation, and use a workstation equipped with modern tools. In the office, *Analytical Albert* becomes the life of the party, wishing to make the most of the time spent in this space.

- *Collaboration Claire* – this style of work is the opposite of Albert's style. The dominant part of *Claire's* working day consists of various types of meetings and social interactions. Despite the differences mentioned above, the basic purpose for which *Claire* comes to the office is similar to Albert's - it is to hold direct meetings with colleagues. *Claire* starts their day at the office by drinking morning coffee, treating this activity as an opportunity to have a whole series of spontaneous meetings. Then, *Claire* starts scheduled meetings. They are very diverse in nature - one-to-one conversations, meetings in small teams, workshops and discussion groups. The latter are often attended by a large group of people - some onsite, some remotely. Thus, *Claire* expects access to meeting rooms of various sizes and types, conducive to both individual conversations and videoconferencing. They need to be able to check who will be in the office on a given day - such information is crucial.
- *Varied Victor* - a characteristic feature here is the inability to indicate dominant tasks; meetings, individual work, telephone calls, work with documents, and other activities play an important role. It is also worth emphasising that this style of working in the office does not differ significantly from that of working remotely, which makes it difficult to clearly determine the purpose for which *Victor* comes to the office. On the one hand, it is - as in the case of the previous styles - the desire to hold direct meetings with colleagues and the desire to use devices that facilitate work. On the other hand, going to the office allows one to access documents, many of which are still paper and waiting for *Victor's* signature (a person who often holds managerial positions). There is also a third side - going to the office is for *Victor* an important (although they are not always fully aware of the fact) element of shaping their professional career. It builds a sense of proper image management and allows one to avoid the situation of "being unnoticed".

There could be many divisions and classifications. Regardless of the names used, one thing is certain - various types of employee activity result in different expectations regarding office space. The demands formulated more and more often by both architects and people managing organisations may be reduced to the following slogan: it is time to move away from designing offices for all and start designing an office for everyone. Therefore, it is necessary to recognise and consider the needs of various groups of employees. The smart office concept addresses this need.



## 6. Smart working and Polish labour law

From April 2023, the amended Labour Code, which includes provisions on remote work has been in force. According to these regulations, one may work outside the company's headquarters on a full or partial basis. The latter option involves, in practice, hybrid work (the concept of hybrid, as the concept of smart working, does not appear in the document in question).

However, the place of work must always be reported to the employer. In addition, the employee must be within reach of means of direct distance communication, i.e., have access to the Internet.

Remote work may take place either on the basis of an agreement between the employee and the employer or on the basis of previously defined organisational regulations. If the company does not have an agreement or regulations regarding remote work, this mode of work may be performed at the request of the interested employee. There are groups of employees for whom the employer (if the specificity of the tasks performed allows it) is obliged to positively consider the application in question. These groups are:

- pregnant women,
- parents raising children up to 4 years of age,
- parents raising children with a disability or having an opinion on the need for early support for the child's development,
- people caring for immediate family members with a disability certificate who live in the same household.

The Labour Code in force from April 2023 also introduces the concept of remote work on demand. If the nature of the duties performed allows it, the employee has the right to use 24 days a year to work remotely. All they need to do is submit an appropriate application and the employer will accept it. The legislator's intention was to take into account various situations in the employee's life that make it difficult for them to be present at the company's headquarters. On-demand remote work is sometimes referred to as occasional remote work.

## 7. Conclusions

The analyses conducted indicated that smart working in organisations operating on the Polish market has great opportunities for development. This is facilitated by the following factors:

- Remote work experience accumulated over recent years.
- Expectations of employees for whom the possibility of combining work in the office with remote work is becoming one of the main criteria for choosing an employer.
- The amendment to Polish Labour Law made in 2023.

However, there are also many limitations, such as:

- Organisational difficulties related to managing units and teams combining work in the office with remote work.
- The belief that remote work always means working from home;
- Lack of experience in creating office space in hybrid working conditions;
- Tendencies to justify reluctance to take action with (imaginary) legal barriers.

In order to eliminate these limitations, it is necessary to disseminate good practices and conduct educational activities aimed at the managerial staff of organisations operating on the Polish market.

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## ASSESSMENT OF THE IMPORTANCE OF ORGANIZATIONAL LEADERSHIP IN THE CONDITIONS OF INDUSTRY 4.0 BASED ON RESPONDENTS' ANSWERS BY GENDER

Damian SKÓRNÓG<sup>1\*</sup>, Paulina MAJOR-KALINOWSKA<sup>2</sup>

<sup>1</sup> Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; damian.skornog@polsl.pl, ORCID: 0000-0001-6357-4261

<sup>2</sup> Silesian University of Technology, Organization and Management Department, Department of Management; paulina.major@polsl.pl, ORCID: 0000-0002-8281-642X

\* Correspondence author

**Purpose:** The article discusses the assessment of perceptions of organizational leadership under Industry 4.0 conditions among the surveyed group based on 17 questions. The statements in the survey were formulated to allow respondents to express their opinions on the impact of leadership on various aspects of organizational performance, including financial performance, employee productivity, customer satisfaction, innovation, organizational culture, employee engagement and turnover. The article also outlines differences and similarities in perceptions of the importance of organizational leadership between women and men.

**Design/Methodology:** A survey was conducted on a targeted group. When analyzing the results obtained, the authors focused on descriptive statistics, in particular, the interpretation of the results of the percentage frequency of responses obtained, a comparison of responses among selected groups of respondents was carried out.

**Findings:** Based on the survey, a description was drawn up of the similarities detected and the differences between the responses of men and women in their perception of the importance of organizational leadership in Industry 4.0.

**Research limitations/implications:** In this article, the authors compile the results of their own research on leadership in Industry 4.0, being fully aware that research conducted on a purposive sample of 73 respondents does not allow generalizing conclusions to entire populations, although it does allow identifying the regularities present in a given community to guide further research. The research was conducted as part of a preliminary draft of Industry 4.0 issues and is a starting point for conducting in-depth research in this area. Due to the limitations of the small sample and its purposive selection, it is worthwhile in future research to expand the research group and use random sampling for the study.

**Originality value:** The results of the study provide important conclusions regarding perceptions of leadership, particularly between the responses of men and women on this issue. The research presented in this article is addressed to researchers dealing with the issue of organizational leadership in the context of Industry 4.0, as well as to practitioners interested in improving leadership effectiveness in the modern business world.

**Keywords:** Industry 4.0, Leadership, Organizational leadership, Management.

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

## 1. Introduction

Today's world, in the midst of the fourth industrial revolution known as Industry 4.0, is experiencing extraordinary technological changes that are having a profound impact on various aspects of business (Cresnar et al., 2023). From production methods to project management, human resources, these transformations are shaping the current business and organizational landscape (Spalek, 2017; Czupryna-Nowak, 2020; Kuzior 2020; Miśkiewicz et al., 2020; Spalek, 2020; Bijańska et al., 2020).

In the face of dynamic technological change, leadership is becoming an increasingly important and complex issue that plays a key role in the field of management and organization (Dzwigoł et al., 2020; Gębczyńska et al., 2020; Mrówka, 2021). Despite the intensive research on this issue, organizational leadership in the conditions of Industry 4.0 still remains a research area that needs further exploration (Soliński, 2023; Dębicka, 2023).

Research believes that leadership in organizations is seen as a key factor for adaptation and innovation (Ganiyu, 2022). In a dynamic environment, the ability of leaders to quickly adapt to changing conditions and effectively manage teams becomes critical (Kucharska, 2023).

The purpose of this article is to conduct an assessment of perceptions of organizational leadership in the era of Industry 4.0 among the study group, and to identify differences and similarities in perceptions of the importance of organizational leadership between genders. The article seeks a sound understanding of the role of leadership in today's organizations, taking into account today's technological and social challenges.

## 2. Importance of Leadership in Industry 4.0.

In an era of rapid technological advances and increasingly complex consumer needs, industry has undergone a series of transformations that can be put in the context of four major industrial revolutions (Thangaraj et al., 2018; Jeevitha et al., 2018; Lau et al., 2020; Raschke, 2022). The first industrial revolution, which had its origins in James Watt's invention of the steam engine, opened an era dominated by mass production (Wisniak, 2007; Vinitha et al., 2020; Zamorska, 2020). The second industrial revolution, characterized by the growing use of electricity and the introduction of innovative machinery, has revitalized the processes of production, processing and distribution of goods (Hunter, 1985; Olszewski, 2016; Schega,

2022). The third industrial revolution is described in the literature as the integration of advanced technologies such as the Internet of Things, Big Data, robotics, 3D printing and mobile technologies. These elements of a complex technological mosaic have had a significant impact on the optimization and automation of manufacturing processes (Zakoldaev et al., 2020; Ratajczak et al., 2020).

In the face of a rapidly changing business environment, accelerating technological advances and increasing global competition, organizations are obliged to constantly explore innovative strategies and models of operation. These goals are aimed at gaining and maintaining competitive advantage, which is only possible by effectively adapting to changing circumstances and taking advantage of emergent opportunities (Rogozińska-Pawelczyk, 2022). This concept is deeply rooted in the phenomenon of the fourth industrial revolution, which represents the culmination of advances in the fields of information technology and automation. The latest phase of the industrial revolution is defined by the synergistic action of elements such as digitization, the Internet of Things (IoT) and advanced production management systems. These cutting-edge approaches are not only complementary, but also mutually reinforcing, offering entirely new ways of manufacturing and managing production (Davies, 2015; Bendkowski, 2017; Gracel et al., 2017; Götz, 2018; Furmanek, 2018; Wiczorek, 2018; Cellary, 2019; Skórnóg, 2023].

Faced with the changing context of the business environment, extracted from a framework of complex dynamics resulting from technological advances and globalized competition, organizations are obliged to continue strategic innovation. They aspire to achieve and maintain competitive advantage by effectively adapting to change and exploiting newly emerging opportunities (Rogozińska-Pawelczyk, 2022). This is an understandable phenomenon in the context of the fourth industrial revolution, which is dominated by advanced information technology, automation and robotics (Gracel et al., 2017; Götz, 2018; Furmanek, 2018; Wiczorek, 2018). This revolutionary paradigm is influencing the configuration of the industry through the synergetic interaction between elements such as digitization, the Internet of Things and advanced manufacturing systems, thus catalyzing the re-engineering of manufacturing and management processes (Davies, 2015; Bendkowski, 2017; Cellary, 2019; Skórnóg, 2023).

Organizational sustainability is closely linked to the growing need for competent employees who can adequately navigate organizational activities in pursuit of strategic goals (Gajdzik, 2021; Rogozińska-Pawelczyk, 2022). This demand for skills has resulted in the formation of the concept of Leadership 4.0, which is becoming increasingly fundamental in the context of Industry 4.0 (Kasapoglu, 2018). In this modern industrial landscape, leadership is defined as the ability to dynamically adapt and mobilize integrated, networked teams to achieve designated imperatives (Rogozińska-Pawelczyk, 2022). Such leaders must possess a rich set of competencies that includes not only digital knowledge and skills, but also vision, the ability to manage risk, and the ability to collaborate effectively (Bawany, 2019).

In the era of Industry 4.0, the importance of organizational leadership is evolving, emphasizing the need for innovation and adaptation in management (Berdecia-Cruz et al., 2022). Differences in leadership styles expected by men and women can affect effectiveness and dynamics in the workplace (Sayang, 2021). Understanding generational differences in leadership perceptions is key in the context of rapidly changing technology and innovation (Naicker et al., 2018). Promoting diversity and equality in leadership, especially in traditionally male-dominated industries, is important for creating sustainable and innovative work environments (Banihammad, 2023). Additionally, there is a need to prepare future leaders to lead organizations in an equitable, diverse and inclusive manner, which underscores the importance of leadership education and strategy (Gray, 2023). Research on the impact of gender on leadership style and job satisfaction can provide insight into how different leadership approaches affect employee satisfaction (Naicker et al., 2018). Research in other authors shows that female gender can be important in building enterprise value, especially in the area of innovation (Zastempowski, Cyfert 2021).

### 3. Methods

The study was carried out by means of a survey questionnaire developed by the authors of the article and was aimed at people supporting decision-making processes in trade, production and service establishments in Poland. The survey questionnaires were distributed to 4673 purposefully selected entities. This decision allows the deliberate selection of respondents who have certain characteristics of interest to the researchers. Seventy-three correctly completed return questionnaires were obtained, which met the established sampling criteria for the study:

- respondent's length of service is at least three months,
- type of activity of the organization in which respondents work: trade, production or services,
- respondent is an adult (over 18 years of age).

The research was conducted between November 2022 and July 2023. The authors are aware that this type of research does not allow the generalization of conclusions to the entire population, although it does allow the emergence of regularities occurring in a given community, in order to guide further research directions.

The questions in the survey questionnaire made it possible to assess the phenomena under study and the relationships between them. The questionnaire consists of the following parts:

- Metrics (12 questions, 12 features).
- Specific questions (2 questions, 67 features).

The survey questionnaire contained a total of 14 questions examining 79 characteristics.



When analyzing the results obtained, the authors focused on descriptive statistics, in particular, the interpretation of the results of the percentage frequency of responses obtained, a comparison of responses among selected groups of respondents was conducted.

The objectives of this research are:

C1. Assessing perceptions of organizational leadership in the era of Industry 4.0 among the surveyed group.

C2. Identify differences and similarities in perceptions of the importance of organizational leadership among men and women.

The following research questions were posed in relation to the research objectives:

P1. How is the importance of organizational leadership in the era of Industry 4.0 perceived among the group surveyed?

P2. What are the differences and similarities in perceptions of the importance of organizational leadership among men and women in the professional group studied?

## 4. Results

73 respondents took part in the survey. Analysis of the responses of respondents to the survey included: gender, age, education, length of service, form of employment, position, form of work performed. Respondents were also asked about the province in which the organization in which they work is registered, the age of the organization, the number of employees it employs, the type of business it conducts and its scope. Table 1 shows the summary characteristics of the group of respondents and the organization in which they work.

**Table 1.**

*Summary characteristics of the group of respondents and the organization in which they work*

Variable	Variants	Volume (n = 73)	Share %
Sex	Male	46	63,01%
	Female	27	36,99%
Age	26 – 35	35	47,95%
	36 – 45	17	23,29%
	over 45	16	21,92%
Education	18 -25	5	6,85%
	Higher	56	76,71%
	Secondary	14	19,18%
	Basic vocational or primary education	3	4,11%
Seniority	3 months to 1 year	6	8,22%
	1 do 3 years	31	42,47%
	4 to 10 years	8	10,96%
	7 to 10 years	8	10,96%
	Over 10 years	20	27,40%

Cont. table 1.

Form of employment	Permanent employee, under contract	60	82,19%
	Temporary worker, contractual agreement	13	17,81%
Position	Administrative worker	33	45,21%
	Manager	20	27,40%
	Board member	13	17,81%
	Manual worker	7	9,59%
Form of work performed	Stationary work at the company's headquarters	42	57,53%
	Hybrid work	27	36,99%
	Remote work	4	5,48%
Province	Śląskie Province	52	71,23%
	Mazowieckie Province	8	10,96%
	Other: Podkarpackie Province (3), Pomorskie Province (2), Świętokrzyskie Province (2), Wielkopolskie Province (2), Lubelskie Province (1), Małopolskie Province (1), Opolskie Province (1), Warmińsko-Mazurskie Province (1)	13	17,81%
Age of the organization	Over 10	64	87,67%
	3-5	4	5,48%
	5-10	3	4,11%
	Under 3 years	2	2,74%
Size of the organization	51-250 people	27	36,99%
	More than 250 people	25	34,25%
	11-50 people	16	21,92%
	Up to 10 people	5	6,85%
Type of activity of the organization	Manufacturing	44	60,27%
	Services	19	26,03%
	Trade	10	13,70%
Organization's reach	International	48	65,75%
	National	14	19,18%
	Local/regional	11	15,07%

Source: own elaboration.

Analysis of the data showed that 63.01% of men and 36.99% of women participated in the survey. Most respondents have a university degree (76.71%), followed by high school (19.18%), and the remaining respondents have basic vocational or primary education (4.11%). Respondents represent different age groups, and therefore different generations. The 26 to 35 age bracket, which accounts for 47.95% of the sample, includes representatives of the so-called Generation Y (millennials) (Bakalova et al., 2023). Those between the ages of 36 and 45, representing 23.29% of respondents, belong to Generation X. Respondents over 45 (21.92%) represent the Baby Boomers generation (Hwang, 2022). The smallest group of respondents, i.e. 18-25 years old, is Generation Z (6.85%). Analyzing the data by generation provides a deeper understanding of the phenomenon under study, taking into account potential differences in the perception of leadership in Industry 4.0 among people in different age categories.

The seniority variable in the surveyed group of respondents also varies and is as follows: Employees with seniority of 1 to 3 years (42.47%) make up the largest group of respondents. This was followed by those with seniority of more than 10 years (27.40%), 4 to 10 years (10.96%) and 7 to 10 years (10.96%). The responses of respondents with varying length of service provide an important perspective on the surveyed phenomenon in the context of work experience.

The majority of respondents are permanent employees working on a contract of employment (82.19%), while the rest are temporary employees working on a contract (17.81%). Respondents represent the following groups of employees: administrative (45.21%), managers (27.40%), board members (17.81%) and manual workers (9.59%).

Respondents mostly work in desktop form (57.53%), followed by hybrid (36.99%). The fewest work only in remote form (5.48%).

Respondents mostly work in organizations operating in the Śląsk Province (71.23%) and Mazowieckie Province (10.96%) provinces. Other provinces, such as Podkarpackie Province, Pomorskie Province, Świętokrzyskie Province, Wielkopolskie Province, Lubelskie Province, Małopolskie Province, Opolskie Province, Warmińsko-Mazurskie Province, together account for 17.81% of the sample. The dominant sector in which respondents work is manufacturing (60.27%), followed by the service sector (26.03%) and trade (13.70%). Respondents mostly work in organizations that have been in the market for more than 10 years (87.67%), which operate in the international market (65.75%), followed by domestic (19.18%) and local/regional (15.07%). The survey included those who work in organizations that employ 51 to 250 people (36.99%), more than 250 people (34.25%), 11 to 50 people (21.92%) and up to 10 people (6.85%).

A detailed analysis of these data provides a more complete picture of the structure of the respondent group, which provides important context for further conclusions and discussions.

In order to answer the research questions posed, respondents were asked to rate the importance of organizational leadership in the era of Industry 4.0 based on a five-point Likert scale, where 1 - definitely no; 2 - no; 3 - don't know; 4 - yes; 5 - definitely yes. Table 2. presents a list of 17 questions addressed to respondents. The statements in the survey were formulated to allow respondents to express their opinions on the impact of leadership on various aspects of organizational performance, including financial performance, employee productivity, customer satisfaction, innovation, organizational culture, employee engagement and turnover. In addition, the survey touches on the importance of a leader's soft and hard competencies, providing a deeper understanding of which skills are considered key in the new business paradigm.

**Table 2.**

*List of survey questions with results of average ratings of perceptions of organizational leadership among respondents (n = 73)*

<b>Lp.</b>	<b>Statement</b>	<b>Purpose of the question</b>	<b>Average rating (n = 73)</b>
1	Organizational leadership today is far more important than ever before.	This statement explores the notion that the role of organizational leadership is now more important than ever, which may reflect the increasing complexity and speed of change in the business environment.	3,77
2	Industry 4.0 has introduced new requirements for leadership skills.	This question focuses on whether respondents believe the fourth industrial revolution has introduced new requirements for leadership skills, which may indicate the need for new competencies or adaptation of existing ones.	3,77
3	Organizations need a pro-quality model to provide effective leadership in an Industry 4.0 environment.	Here, opinion is explored on the need for a leadership model that is tailored to promote quality and efficiency in an Industry 4.0 environment.	3,79
4	Leadership is critical to an organization's success.	This statement is intended to assess the belief that leadership is a key determinant of an organization's success.	4,18
5	Industry 4.0 has influenced a shift in traditional organizational leadership models.	The question explores whether Industry 4.0 has influenced a change in traditional leadership models, which may suggest an evolution in approaches to managing and leading teams.	3,56
6	A leader is essential in an organization.	This statement assesses the belief in the indispensability of the leadership role in the organizational structure.	4,41
7	Organizational leaders should have the ability to quickly adapt to the changing conditions of Industry 4.0.	Here, respondents assess the importance of leaders' ability to adapt quickly to the changing conditions of Industry 4.0.	4,30
8	An organizational leader should have the ability to make decisions based on the values of the organization.	This question focuses on the importance of leadership skills in making decisions that are consistent with the organization's values.	4,14
9	Leadership has an impact on an organization's financial performance.	This statement explores the notion that leadership has a direct impact on an organization's financial performance.	3,96
10	Leadership has an impact on employee productivity.	Here, the belief that leadership influences employee productivity levels is assessed.	4,29
11	Leadership has an impact on customer satisfaction.	This question examines whether there is a relationship between leadership quality and customer satisfaction.	3,79
12	Leadership has an impact on an organization's innovation.	This statement assesses whether leadership is considered a factor in an organization's ability to innovate.	4,07
13	Leadership has an impact on organizational culture.	Here, respondents express their opinions on the impact of leadership in shaping organizational culture.	4,11
14	Leadership has an impact on employee engagement.	The question explores the belief that leadership affects the level of employees' commitment to their work and the organization.	4,30
15	Leadership has an impact on employee turnover.	This finding assesses whether leadership can influence the frequency of employee change within an organization.	4,07
16	A leader's soft skills are important.	The question explores the importance of a leader's soft skills, such as communication, empathy and the ability to motivate.	4,07
17	The hard competencies of a leader are important.	Here, respondents rate the importance of a leader's hard competencies, such as technical knowledge and analytical skills.	3,88

Source: own elaboration based on (Budgol, 2006; Budgol, 2010; Austen, 2010; Walczak, 2011; Hartliński, 2012; Mockało, 2013; Jucha, 2013; Mróz, 2014; Kopertyńska, 2015; Gadomska, 2015; Kazak, 2017; Dyduch, 2017; Głomb, 2020; Gundowska et al., 2020; Gostowska et al., 2021; Mrówka, 2021; Majczyk, 2022; Schwabe, 2023).

Table 3 presents the results of surveys based on calculating the average responses of respondents, taking into account their gender. Through this analysis, it is possible to better understand how different aspects of the issues under study are evaluated by respondents according to gender.

**Table 3.**

*Average scores of leadership importance for selected groups of respondents*

Lp.	Variable	Average scores for selected groups of respondents		
		The entire study group (n = 73)	Men (n = 46)	Women (n = 27)
1	A leader is essential in an organization.	4,41	4,46	4,33
2	Organizational leaders should have the ability to quickly adapt to the changing conditions of Industry 4.0.	4,30	4,26	4,37
3	Leadership has an impact on employee engagement.	4,30	4,33	4,26
4	Leadership has an impact on employee productivity.	4,29	4,30	4,26
5	Leadership is critical to an organization's success.	4,18	4,11	4,30
6	An organizational leader should have the ability to make decisions based on the values of the organization.	4,14	4,02	4,33
7	Leadership has an impact on organizational culture.	4,11	4,09	4,15
8	Leadership has an impact on an organization's innovation.	4,07	4,13	3,96
9	Leadership has an impact on employee turnover.	4,07	3,98	4,22
10	A leader's soft skills are important.	4,07	4,07	4,07
11	Leadership has an impact on an organization's financial performance.	3,96	3,96	3,96
12	The hard competencies of a leader are important.	3,88	3,87	3,89
13	Organizations need a pro-quality model to provide effective leadership in an Industry 4.0 environment.	3,79	3,74	3,89
14	Leadership has an impact on customer satisfaction.	3,79	3,85	3,70
15	Organizational leadership today is far more important than ever before.	3,77	3,61	4,04
16	Industry 4.0 has introduced new requirements for leadership skills.	3,77	3,74	3,81
17	Industry 4.0 has influenced a shift in traditional organizational leadership models.	3,56	3,46	3,74

Source: own elaboration.

For the entire group of respondents, the following variables are the most important in assessing leadership 4.0:

- A leader is essential in an organization (4,41).
- Leadership has an impact on employee engagement (4,30).
- Organizational leaders should have the ability to quickly adapt to the changing conditions of Industry 4.0 (4,30).

For men, the results are as follows:

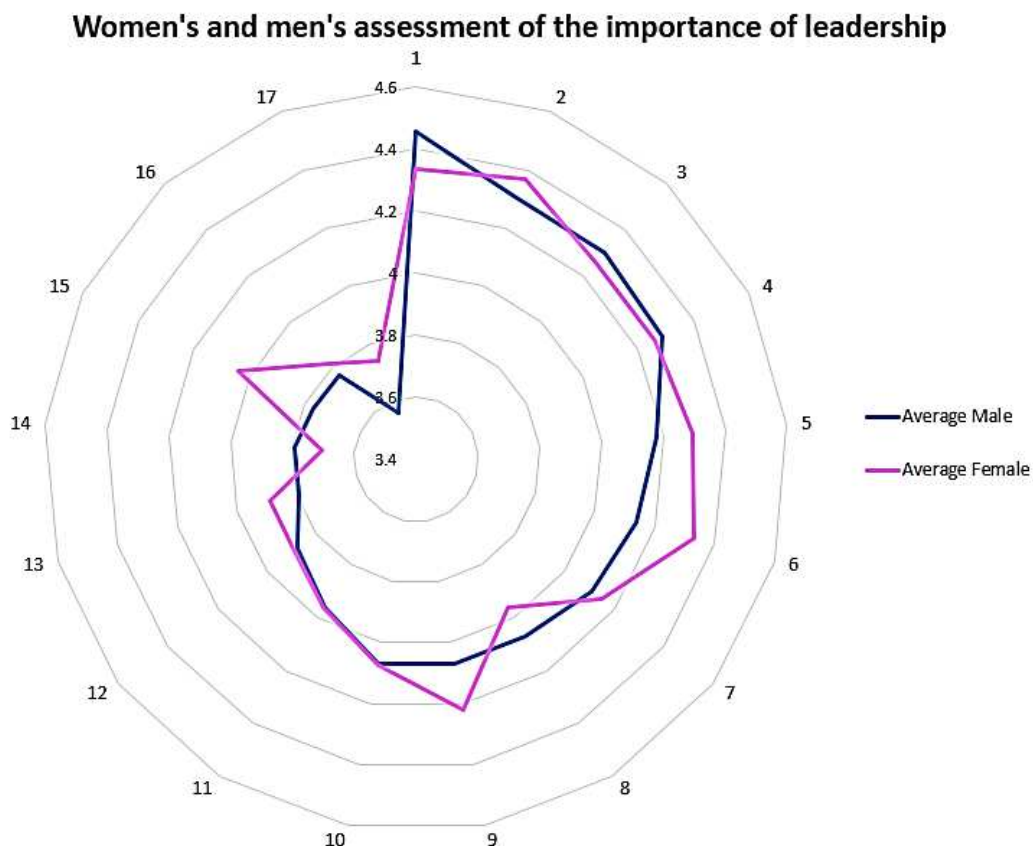
- A leader is essential in an organization (4,46).
- Organizational leaders should have the ability to quickly adapt to the changing conditions of Industry 4.0 (4,33).

- Leadership has an impact on employee productivity (4,30).

For women, the following are of greatest importance:

- Leadership has an impact on employee engagement (4,37).
- A leader is essential in an organization (4,33).
- An organizational leader should have the ability to make decisions based on the values of the organization (4,33).
- Leadership is critical to an organization's success (4,30).

Figure 1 shows in the form of a radar chart the average assessment of the importance of leadership among a group of male and female respondents.



**Figure 1.** Average rating of the importance of leadership among a group of male and female respondents.

Source: own study.

Women and men agree that a leader is essential in an organization (Schwabe, 2023). For women, however, the most important thing is that leadership has an impact on employee engagement (Walczak, 2011). Women also point out that a leader should have the ability to make decisions based on the organization's values, and note that leadership is crucial to an organization's success (Bugdol, 2006; Austen, 2010). Women also note that leadership has an impact on organizational innovation and that organizational leadership today is much more important than ever before (Hartliński, 2012; Mrówka, 2021).

For men, on the other hand, the most important thing is that organizational leaders should have the ability to adapt quickly to the changing conditions of Industry 4.0, and pay attention to the impact of leadership on employee productivity (Gostkowska et al., 2021). Men also rate higher than women on the statement that: leadership has an impact on employee turnover (Majczak, 2022).

Men also rate higher than women on the statement that: leadership has an impact on employee turnover. Differences in perceptions of leadership among men and women may be due to different experiences and expectations regarding the issue under study (Cha et al., 2023). Research in the field of leadership often points to gender differences in leadership styles and preferences, which may influence how respondents of different genders evaluate the importance and effectiveness of leadership in different contexts (Sondakh et al., 2021).

Analysis of the survey results indicates that women and men have broadly similar perceptions of the role of leadership in an organization. Women and men agree that a leader is essential in an organization, with women emphasizing the impact of leadership on employee engagement and the key role of leadership for organizational success. With respect to men, they highlight the ability of leaders to adapt quickly to the changing conditions of Industry 4.0 and the impact of leadership on employee productivity. Both genders are positive about the impact of organizational leadership on various aspects of company performance, such as organizational culture, innovation, financial performance and customer satisfaction. Respondents also agree that a leader's soft and hard competencies are important in the context of Leadership 4.0, with soft competencies rated higher on average (4.07) than hard competencies (3.88). Respondents rated lowest the statements that organizations need a pro-equality model to provide effective leadership under Industry 4.0 conditions (3.79), Industry 4.0 has introduced new requirements for leadership skills (3.77) and that Industry 4.0 has influenced a change in traditional organizational leadership models (3.54).

These results may suggest that organizational leadership is seen as an important factor in organizational success, especially in the context of the challenges and changes associated with Industry 4.0.

## **5. Conclusion**

The survey presented in this article aims to assess perceptions of organizational leadership in the context of Industry 4.0 and to identify differences and similarities in perceptions among men and women. In response to the research questions posed, the survey results point to several key findings.

First, both women and men agree that a leader is essential in an organization, highlighting the universal importance of leadership in the modern business world. The average score for this variable was 4.41 for the entire group of respondents, indicating a high degree of agreement among respondents.

Second, among women, the impact of leadership on employee engagement is of greatest importance, suggesting that women value leaders who can motivate and inspire their teams. Women also highlight the ability to make decisions based on the organization's values, and the key role of leadership for the success of the organization.

Men, on the other hand, place more emphasis on the ability of leaders to adapt quickly to the changing conditions of Industry 4.0 and on the impact of leadership on employee productivity. This indicates that men value leaders who are flexible and focused on results.

Differences in perceptions of leadership between men and women may be due to different experiences and expectations. Studies in the field of leadership often indicate differences in leadership styles and preferences between the sexes, which may affect how respondents of different genders evaluate the importance and effectiveness of leadership.

In summary, the results of the study indicate that women and men generally have similar perceptions of the role of leadership in the organization, with some differences in the emphasis of particular aspects of leadership.

Both genders express positive evaluations of the impact of organizational leadership on various aspects of company performance, such as organizational culture, innovation, financial performance and customer satisfaction. A review of these results suggests that organizational leadership is an important determinant of organizational success, especially in the context of the dynamic challenges and transformations associated with the Industry 4.0 era.

The research presented in this article may be useful for researchers working on the issue of organizational leadership in the context of Industry 4.0, as well as for practitioners interested in improving leadership effectiveness in the modern business world. The results of the survey provide important insights into perceptions of leadership, especially gender differences on this issue.

The survey can provide a basis for further research on gender differences in leadership perceptions and for developing team management strategies that take these differences into account. For business practitioners, the analysis of the results can inspire the adaptation of leadership practices to the expectations of different groups of employees, which will contribute to more effective organizational management in the era of Industry 4.0.

The findings are part of a collection of articles on perceptions of organizational leadership under Industry 4.0 conditions by different groups of respondents. In the following articles, the authors will focus on the differences in perceptions of leadership in generations BB, X, Y, Z, by position, scope of the organization, type of activity, form of work performed and number of employees in the organization.



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## REVIEW OF VIRTUAL REALITY APPLICATIONS APPLIED IN INDUSTRIAL PRACTICE

Kinga STECUŁA

Silesian University of Technology, Faculty of Organization and Management; kinga.stecula@polsl.pl,  
ORCID: 0000-0002-6271-2746

**Purpose:** The paper aims to explore the utilization of virtual reality applications in industrial practice, particularly focusing on Polish industrial enterprises. It identifies the various areas of VR application in the industry, provides new insights into VR's practical usage, and shows successful real-world examples, thus contributing to scientific knowledge by highlighting the extensive practical potential of virtual reality in Poland's industrial sector.

**Design/methodology/approach:** The objectives of the paper are achieved through a review and analysis of virtual reality applications used in Polish industrial enterprises. It focuses on specific VR solutions adopted by these companies, characterizing their practical applications and positive outcomes.

**Findings:** In the course of the study, the author conducted an in-depth review and analysis of virtual reality applications used in Polish industrial enterprises. The research identified various areas of practical VR implementation within the industry, and through the examination of specific applications, highlighted the positive outcomes and benefits of these solutions.

**Research limitations/implications:** The study's findings contribute new insights into the practical use of virtual reality in industry and can be a basis for developing directions for future research in exploring and expanding the scope of VR applications within industrial enterprises.

**Practical implications:** The practical implications of the study are significant for both the industrial sector in Poland and the broader application of virtual reality technology. By reviewing and characterizing specific VR applications used by Polish industrial enterprises, the paper offers practical insights into the diverse areas where VR can be effectively utilized in industry. These findings provide valuable information for companies seeking to improve their operations, efficiency, and safety through the implementation of virtual reality solutions.

**Originality/value:** The research addresses a knowledge gap by providing detailed descriptions and characterizations of VR applications that have been developed for specific companies and are actively used in practice. This emphasis on real-world examples and positive outcomes adds practical relevance to the study's findings, making it a valuable resource for businesses, researchers, and professionals interested in using the potential of virtual reality to enhance various aspects of industrial operations.

**Keywords:** virtual reality, VR, VR training, VR simulation, industrial practice.

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

## 1. Introduction

With the development of technology, companies are faced with new opportunities to adapt modern Information and Communications Technology (ICT). Companies improve human-machine communication because it provides good results in terms of improving work effectiveness, providing work monitoring, and minimizing errors. The use of artificial intelligence (Bahroun et al., 2023), which is one of the very important pillars of Industry 4.0, by manufacturing companies can be observed on an increasingly large scale. Industry 4.0 is an important contributor to industrial innovation (Calabrese et al., 2023). Elements such as the Internet of Things (Iot) (Nauman et al., 2020), cloud computing (Sadeeq et al., 2021), additive manufacturing (Orzeł and Stecula, 2022), autonomous robots (Aubin et al., 2022), and use and generating data (Stecula et al., 2022) are the marker of the New Era. One of the elements of Industry 4.0 is also virtual reality (VR), augmented reality (AR), and mixed reality (MR), creating great opportunities for both manufacturing and service companies. Virtual reality can be used for various purposes. One of the application areas of virtual reality is, naturally, entertainment. On many digital distribution platforms (Stecula, 2022), next to video games, virtual reality applications, designed to be played by users from all over the world, can be found. Virtual reality can also be applied to industrial practice in various areas of the company's operation and for various purposes. And it was the industrial practice that inspired the author to carry out the research described in the article.

Therefore, the author reviews the virtual reality applications used in industrial practice. The author of the study focuses on VR solutions used by Polish industrial enterprises. Therefore, the main objective of the research is to identify the areas of use of VR in practice in industry in Poland. Furthermore, the other objective of the study was to provide new knowledge on VR applications applied in industry practice in Poland. The paper reviews, describes, and characterizes VR applications that have been ordered by specific companies and are used in practice; additionally, these solutions bring positive results. Therefore, the article contributes to science and is of novelty because, by presenting practical examples, it reveals the wide practical possibilities of virtual reality used in industrial enterprises operating in Poland.

The paper is divided into 5 chapters. Chapter 2 includes the literature review, and chapter 3 includes the methods. Chapter 4 contains the results of the research that are the characteristics of the reviewed applications. Chapter 5 presents a summary and conclusions.



## 2. Literature review

Virtual reality technology is defined as the use of computer technology to create the effect of a three-dimensional interactive world in which objects give the impression of being physically present (Biocca, Lanier, 1992; Lanier, 1992). This environment allows every user to interact directly with an alternative reality. The user can immerse themselves in the virtual world. The VR environment allows one to activate the senses of sight, hearing, and touch. Despite audiovisual effects, users most often use controllers that are their virtual hands, so they can touch objects, pick them up, drop them, etc. The creator of the term "virtual reality" is Jaron Lanier (Lanier, 1992), an American computer scientist, futurologist, and founder of VPL Research. VR applications are developed in special programs operating in 3D modeling. Virtual reality design consists of multimedia that creates an image of the real or fictional world, objects, space, or events (Sherman, Craig, 2003). The process of creating a virtual reality application is very time consuming. Modern IT technologies enable the creation of any scenario for virtual reality applications using various engines, e.g., Unreal Engine 4 (Kobak, 2016), Unity (Jungherr, Schlarb, 2022; Wilk, 2017), In-house (Skop, 2018). More and more companies specialize in developing dedicated applications are founded.

Virtual reality can be applied in different industries and for different purposes. Naturally, it is the entertainment industry that has been affected by VR. Many virtual reality applications are available on free-available digital video game distribution platforms. Next to video games, their VR counterparts are available; however, original applications designed to be used with VR headsets are also obtainable. An example of such a platform is Steam, which offers over 125,000 games and applications, of which almost 6700 are VR applications (data on July 2022) (Stecula, 2022). According to the results of my previous research (Stecula, 2022), the most numerous group of VR applications on Steam is action applications – they represent more than half of all VR applications (51.22%). Subsequently, there are casual applications (40.78%), and then the third most numerous group of applications consists of simulation VR applications (37.35%). Then, there are adventure, atmospheric, strategy, exploration, arcade, puzzle applications, and so on.

Naturally, virtual reality can be used not only for entertainment. In the literature, papers showing the use of virtual reality in education. There are examples of applying VR in education for studying engineering (di Lanzo et al., 2020; Soliman et al., 2021), human anatomy (Izard et al., 2017), medicine (Baniyadi et al., 2020; Pottle, 2019), architecture and construction (Alizadehsalehi et al., 2019; Bashabsheh et al., 2019; Safikhani et al., 2022), foreign languages (Peixoto et al., 2019; Pinto et al., 2019; Symonenko et al., 2020), aviation (Brown et al., 2021; Fussell, 2020; Fussell, Truong, 2020), kinematics (Dergham, Gilányi, 2019; Nersesian et al., 2021; Xu et al., 2020) and many more. Other papers present proposals of educational VR laboratories (Zhang et al., 2018) and of application VR at technical universities (Stecula, 2019).

Virtual reality is also used in counteracting and overcoming mental problems, such as post-traumatic stress disorders (Kovar, 2019; Lyu, 2021; Park et al., 2019), anxiety (Aniki-na et al., 2021; Baghaei et al., 2021; Boeldt et al., 2019; Caponnetto et al., 2021), depression (Baghaei et al., 2021; Migoya-Borja et al., 2020) and so on. It can be also helpful with rehabilitation (Blasco et al., 2021; Maggio et al., 2019; Smits et al., 2020).

Finally, VR applications are applied in different industries. In the literature, there are papers referring to VR in, among others, the following industries: construction (Ghobadi, Sepasgozar, 2020), chemical (Fracaro et al., 2021), concrete industry (Joshi et al., 2021), hotel (Leung et al., 2020), tourism (Ozdemir, 2021), maritime (Makransky, Klingenberg, 2022), architecture (Dinis et al., 2020) and many more. Some authors show advantages of VR trainings applied in industry, such as better effectiveness (Norris et al., 2019), performance (Roldán et al., 2019), and efficiency (Naranjo et al., 2020) compared to traditional trainings. It should be noted that, especially in the case of production companies, effective preparation of employees to work at given workstations is also very important in the context of the efficiency and effectiveness of the entire production process (Loska, 2015; Loska, Paszkowski, 2022). It is also related to the effective production (Loska et al., 2016) and management of machines (Aripin et al., 2023; Balahurovska, 2023), so VR training can be an opportunity for companies.

The market of virtual reality applications is constantly evolving, and new improved goggles are being created. New controllers and other accompanying devices are introduced, and new features, such as finger recognition, are being worked on. Resolution, graphics, scenarios, and many more are improved (Xie et al., 2021).

### 3. Methodology

Due to the fact that one of the pillars of Industry 4.0 (Martin, Leurent, 2017) is the use of virtual reality in industrial practice, the author decided to review the virtual reality applications actually used in enterprises in Poland. The author reviews the application, guided by the following research questions:

- Q1: in which industries are VR applications used in practice in industry in Poland?
- Q2: in what areas of business activity are VR applications used in practice in industry in Poland?
- Q3: What are the different applications (referred to in Q1 and Q2) for?

The main objective of the research is to identify the areas of use of VR in practice in industry in Poland. The other objective of the study was to provide new knowledge about VR applications applied in industry practice in Poland. The research part of the article is presented as follows: subsequent subsections of Chapter 4 show various industries and areas of application of virtual reality applications. Each sub-chapter contains information about the

followings: which company ordered the application and which one developed it, what type of application it is, what it is for, what is its content, i.e. what application scenario is presented, and what was the goal of the project. It should be emphasized that the applications are actually used in practice by companies.

In the first stage of the investigation, the author reviewed the practical application. She then chose to research only those related to industry. Subsequently, she divided them into groups related to industries or areas of activity. The following methods are used in the study:

- Reviewing the websites of companies offering VR services in Poland.
- Reviewing websites to find practical VR applications.
- Conducting consultations with selected companies and institutes developing VR applications, companies that use VR applications in practice, and with graphic designers and computer graphics.

It is worth emphasizing that some of the VR trainings, simulations, and films presented in this article, the author of this article also had a chance to experience personally using VR headset – as part of studying the subject.

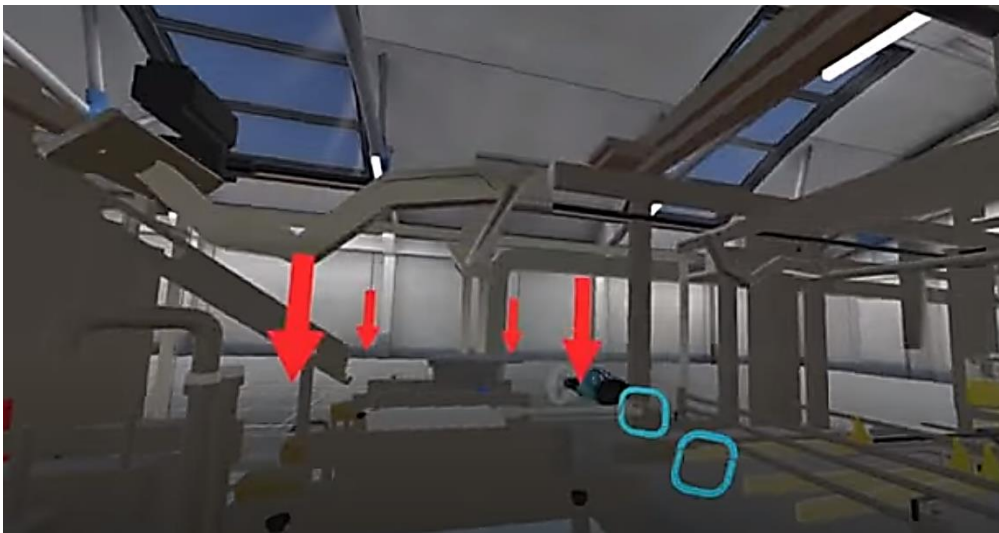
## **4. Results**

This chapter reviews virtual reality applications. The studied VR applications were provided by companies specializing in designing and developing virtual reality applications. The applications presented below have been prepared at the request of a given production or service company – this means that the VR applications are unique. They were dedicated to the given company and its special order. Each application was dedicated to a given company, which means that the application has its own original scenario, according to which it had to be prepared. The scenario of a given application had to take into account the specificity of the company that ordered the application. The applications have been applied and put into practice by companies. The applications have been used in various industries, which confirms the great potential and wide range of possibilities for using virtual reality in industrial practice.

### **4.1. Production line changeover process simulation**

The first example of a virtual reality application in the industry is a solution that provides simulations of the production line changeover process by Velvet Care – the application was developed by Epic VR. The application is intended for employees of the mentioned company who need to be prepared to operate the production line. The application allows to master the activities necessary to perform the changeover. The training participant is instructed step by step what they must do. Training with the use of virtual reality enables the participant to have audio-visual instruction. For example, the participant receives voice commands, sees subtitles,

sees arrows, and certain elements are marked or highlighted in a different color (Figure 1). Training greatly affects the sense of sight and hearing. In addition, virtual reality also activates the sense of touch, because virtual hands can touch, lift, and translate individual elements. Using the application, a person trained is under constant control, therefore he or she receives feedback on the activities and operations performed all the time. Very often, they receive feedback on what has been done well and what needs to be improved. In case of this application Epic VR transferred the entire production line consisting of 10 machines from the real world to the virtual reality. The simulation allows to teach how to change over in an effective way, unscrewing exactly the same screws with the same wrenches as in reality (EpicVR, 2021).



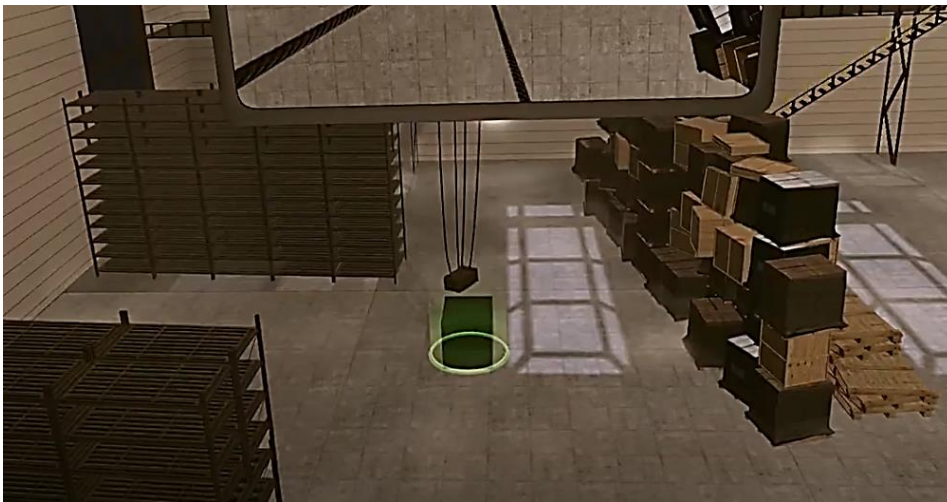
**Figure 1.** A screenshot of VR simulation of the production line changeover process for the Velvet Care company by EpicVR.

Source: (EpicVR, 2022a).

This type of training increases the safety of trainees because the conditions of virtual training are safe, unlike training on real machines, where a mistake may result in the loss of health of the trainee or other people. Furthermore, training a person in virtual conditions does not stop the production line, as would happen in the case of training on a real machine. Production can be in progress, and at the same time, employees can train themselves without contributing to any loss of production line time. Also, several people can be trained at the same time. The developed training is flexible, which means that it is possible to change the order of the tasks performed. This means that the trainee will not memorize the training but will have to think while performing subsequent tasks. Training allows training muscle memory due to repetition of movements. All the movements made in virtual reality are exactly the same as in the real world. It should be noted that the training application also verifies the correctness of the given tasks and their order of solving. The use of virtual training brings many benefits to the company that implements this training. The first benefit is shortening the changeover time and reducing the number of errors made by the employee in this regard. This, in turn, results in increased work efficiency at individual workstations and the entire production line. Training also improves employee safety (EpicVR, 2021, 2020a).

## 4.2. Gantry Crane Simulator

Another solution is a gantry crane operator simulator, developed by EpicVR. The developed VR application fully reproduces the physics and mechanics of crane operation. The simulator allows to check the skills of future and current employees. In addition, it can also be used for initial employee training. Before the employees have the opportunity to work in reality as a crane operator, they can prepare themselves for work in a non-invasive way and without the risk of damaging the transported goods. Thanks to the use of such a simulator, employees will be better prepared to work in real conditions. This application is not a typical training application, but it allows to simulate work in a very realistic way. An employee who has dealt with a machine in the virtual world will not start from scratch, when they start working in real conditions then. The simulator is so realistic that the worker can master the required actions and learn the range of movements of the manipulators. In the case of the crane, precision in moving the manipulators is extremely important. Making mistakes in virtual reality will not have any negative consequences for the employee and the crew and will make the employee aware of how difficult the job is, how it should be performed, and how sensitive the manipulators and control system are. Thanks to the application, the employer can not only reduce the probability of making a mistake by the operator, but also reduce possible losses related to it (EpicVR, 2019a). Figure 2 shows the screenshot from the simulator.



**Figure 2.** A screenshot of the VR simulation of gantry crane work.

Source: (EpicVR, 2019b).

## 4.3. Forklift simulator

Another example of a practical application of VR in the industry is the forklift simulator, also developed by Epic VR. The simulator is dedicated to future forklift operators. It allows to prepare them for work. Trainees will learn the procedures to unload various goods. Virtual reality allows to verify the user's behaviour and provide him with feedback on the correctness of the tasks performed. The application allows to select training and examination

modes. Mode 2 allows to check the acquired skills during the training mode and obtain information on the degree of mastery of individual operations, activities, and tasks. For a given application, in addition to the VR headset, additional advanced physical controllers are necessary: steering wheel, joysticks, pedals. This has also been included in the Epic VR project. The simulator is therefore an advanced configurator that allows to map different spaces. The application also allows you to add your own objects or choose from the available ones, e.g., different types of pallets, packages, as well as employees of the hall with different behaviours. The application includes several training scenarios. The applications will verify the employee's readiness to start work. The application also allows to save the results obtained by the trainee. Due to training, the employee can prepare to react appropriately to unusual and crisis situations. VR simulates certain crisis situations that an employee will find themselves in, but always in controlled and safe virtual conditions (EpicVR, 2023). Figure 3 shows a screenshot from the simulator.



**Figure 3.** A screenshot of the VR forklift simulator.

Source: (EpicVR, 2022b).

#### **4.4. Chainsaw and harvester operation training**

The CinematicVR company has created a VR training application for employees of the Oborniki Forest Inspectorate (CinematicVR, 2020a). The application consists of modules, thanks to which the user learns how to work safely with a chainsaw and a harvester. In the first module (harvester), the trainee is acquainted with the scope of activities related to the operation of the harvester. It is a machine used in the mechanized technological processes of wood harvesting, which allows, among others, the cutting of trees, moving trees, falling trees, pruning trees, and logging them. The user learns how to drive (move) this machine, how to move the organ, how to control the cabin, how to cut tree trunks, how to move tree trunks and logs, and many other activities. As part of the second module (chainsaw), the trainee learns how to operate a chainsaw. The user directly acquires skills on how to cut trees and precisely how to hold the saw (at what angle), how to turn it on and off. In addition, the user learns how to behave during this work with a device from the safety point of view.

Operators of these machines have a difficult job, because they are exposed to a lot of harmful factors such as noise and mechanical vibrations (Paszkowski, 2020, 2019) and health risks related to tree cutting. For this reason, an application that trains in such a real way is a very promising solution. The application shows written instructions to the trainee that they must follow step by step. The instructions gradually guide the trainee through the training process. Thanks to virtual reality training, the user can effectively remember sequences of movements, operations, and activities that they will then perform at work in reality. In case of failure, the trainee can repeat the activities in VR until success. The application provides feedback on the accuracy of the task. It uses two controllers that are virtual hands. Figure 4 shows a screenshot of the harvester operation training (CinematicVR, 2020a).



**Figure 4.** A screenshot of VR harvester operation training by CinematicVR.

Source: (CinematicVR, 2020b).

#### 4.5. Aviation trainings

VR can be used for aviation training. EpicVR offers training to prepare aviation personnel for procedures. The company also prepares virtual reality training and flight simulations. This type of training allows pilots to prepare for various scenarios. The application allows the user to familiarize themselves with various scenarios in which future pilots will learn how to stay calm, not panic, and save themselves and others. The application can be used by professional soldiers of the military academies and civilian aviation personnel. The use of this training should contribute to increased safety in airspace. The company also offers flight training in the field of emergency landing procedures on water and on land, as well as proper behaviors in case of a fire on board. As part of training, the participant learns how to safely land the plane considering the passengers. Additionally, the participant learns to make appropriate decisions when threats occur during flight. The application also enables the creation and analysis of training reports. The system monitors the learner's progress and shows their result at the end. The training can also be monitored remotely by the lecturer (EpicVR, 2020b, 2020c). Figure 5 shows a screenshot of aviation training – emergency landing on water scenario.



**Figure 5.** A screenshot of VR aviation training by EpicVR.

Source: (EPIC VR (EpicVR, 2020d).

Another company, named CinematicVR, also developed training for the aviation industry. The company developed a training course for Rzeszow's University of Technology Aviation Training Center. Using this application, future pilots can learn and train themselves how to operate a plane. This is an example of a simulation application which allows pilots to train themselves in landing a plane. The application in a very realistic way reproduces the pilot's deck and work conditions, and allows for virtual control of the aircraft (CinematicVR, 2020a).

#### **4.6. Mining trainings**

One of the most dangerous professions with a very high risk of loss of health and life is the profession of a miner. The work conditions underground are changeable, unpredictable, and very difficult (Stecula, Brodny, 2018). Therefore, training is a very important element in the work of a miner (Palka, Hąbek, 2017). Effective assimilation of the content provided during training reduces the risk of making a mistake while working underground, i.e., when operating mining machines, performing subsequent activities and operations, and communicating with other miners and dispatchers. In addition, training should prepare employees to react appropriately to unusual events, e.g., faults, breakdowns, or accidents.

In every enterprise, training, especially health and safety training, is very important, and in the mining industry, training an employee must result in the most effective preparation for work because working underground is associated with a high risk of loss of health and life and exposure to many harmful factors. In connection with this, mining companies can also introduce training for miners. The purpose of such training is primarily to improve overall safety at work.



The first example of using VR training in the mining industry is Jastrzębska Spółka Węglowa S.A. (JSW) (JSW Szkolenie i Górnictwo, 2020; NetTG, 2020). JSW is the largest producer of high quality hard coking coal in the European Union and one of the leading producers of coke used for smelting steel. Many research studies with great potential are conducted for JSW on coal production and coal quality (Dyczko, 2023a, 2023b, 2022; Dyczko et al., 2022; Kulpa et al., 2021; Strojny et al., 2023; Tobór-Osadnik et al., 2020), digital way of changing quality (Kopacz et al., 2020), and alternative way of using mines (Kulpa et al., 2021; Olczak et al., 2019). In the case of a new project on VR trainings, the Central Mining Institute (pl. Główny Instytut Górniczy, GIG) develops training scenarios based on real mining accidents. GIG analyzes reports of mining accidents and then extracts key situations for which training scenarios are being developed. Then, JSW Innovations (pl. JSW Innowacje – from 2022, it changed its name to JSW New Projects, pl. JSW Nowe Projekty) prepares VR applications based on prepared scenarios – it is the main contractor of the programming part. It develops a virtual environment from which up to five people can train at the same time. JSW Training and Mining (pl. JSW Szkolenie i Górnictwo), in turn, is responsible for the didactic aspects of the training environment. The application presents underground work in a very realistic way, and allows the trainees not only to obtain and supplement their theoretical knowledge, but also to develop proper procedures for dealing with dangerous situations, which are impossible to imitate in traditional training. Training scenarios cover actual accidents that took place in hard coal mines. The training plot provides users with the choice of an individual course of action and gives them the opportunity to have a real impact on how they end them (JSW Szkolenie i Górnictwo, 2020; NetTG, 2020).

Another example of VR in mining is the project also ordered by Jastrzębska Spółka Węglowa. Epic VR has pre-pared a training movie/video that can be watched in virtual reality. In order to make the film in the correct order, the company had to use a 360° camera, which allowed recording of natural conditions and the underground environment. In the virtual reality environment, it allows one to watch the movie in 360°, i.e., giving the impression that the person watching the movie is in a place shown in the movie. Thanks to the recording, the company was able to fully present the conditions of underground mining and show the longwall and corridors using virtual reality. The video has an educational character. The movie maps selected partial processes that are included in the mining production process and shows the work of miners underground. The application is used to train employees (EpicVR, 2019c). Figure 6 shows a screenshot of the 360° VR training video.



**Figure 6.** A screenshot of the 360° VR training video entitled „Wirtualno gruba” by EpicVR.

Source: (EpicVR, 2019c).

#### **4.7. Machine tool installation training**

The MojoApps.co company has prepared a virtual reality training on the machine tool installation process that must be done at the customer's place. The training is intended for new employees of Abplanalp Sp. z o.o. The VR application consists of two parts. In the first part, the user learns how to use the VR equipment and how to move in the virtual world. The other part, on the other hand, contains training, including specific tasks to be done in accordance with the rules and requirements applicable in the company. The result of training is the preparation of the employees for the correct installation and configuration of the machine tool in a given place. The undoubted advantage of using this training is that employees can learn the procedures at any time and repeat the activities until they are mastered. The trainee acquires knowledge of how to properly and in what order the machine should be installed at the company's customer. The training uses screwdrivers, screws, wrenches, ladders, and spirit levels – all in virtual form. During training, the user always sees written instructions on what they must do in a given phase of the training. The application also provides feedback to the user on whether they have followed the correct order of operations and whether they have installed the machine in accordance with all rules (MojoApps, 2020).

#### **4.8. Occupational safety training**

Another example of a practical VR solution in the industry is applications used for occupational health and safety training. Epic VR has developed an application for health and safety training consisting of four modules to educate employees. The subsequent modules contain the following areas (EpicVR, 2022c):

- Occupational health and safety engineering.
- Hazards within production plants.
- Personal protective equipment (PPE).
- Fire hazard.

The training prepares employees in a practical way on topic in particular areas. In addition, each module ends with a theory test that the employee must complete with a positive result (EpicVR, 2022c). Figure 7 shows a screenshot from the training.



**Figure 7.** A screenshot of the occupational safety training by EpicVR.

Source: (EpicVR, 2022d).

The application is an example of the modernization of the OHS training process, which in reality is not carried out at the highest level in many enterprises and is usually purely theoretical. Unfortunately, theoretical training does not provide the expected results. Virtual reality training helps prevent accidents at work, as it is interactive, immersive, and highly practical. The training participant prepares effectively to respond in crisis situations according to all health and safety procedures. During theoretical training, it is not possible to train an employee to be able to react to situations where there are various threats, for example, how to put out a fire. On the other hand, virtual reality training meets the real effective preparation of an employee who is able to face various health and safety problems directly in the virtual world, that is, under very safe and controlled conditions. For example, the trainee can try to put out a fire in VR, which first increases their imagination about fire hazards, secondly allows them to practice using a fire extinguisher in practice, thirdly allows them to mentally prepare to react during a fire (they learn how to keep cool), and additionally to all of this, the employee gains experience. In the event of failure, the employee does not suffer any damage to the health and, in addition, can repeat the given task in VR. It should also be added that no occupational health and safety equipment (e.g., protective clothing, fire extinguisher, etc.) is used during the training, so the company effectively trains the employee without bearing additional costs related to the consumption of materials and equipment.

Issues related to occupational safety are also dealt with by 4Help VR. The company provides VR software to improve the quality and attractiveness of OHS training. The company currently offers three types of trainings (training scenarios) (4HelpVR, 2020a):

- Legal basis in the field of occupational health and safety (containing, among others, legal basis for OHS, obligations of the employer and employee, as well as types of hazards at the workplace and methods of their elimination).
- Occupational risk assessment (including assessment of the sources of threats at selected workplaces, indication of possible effects of a given threat, determination and taking preventive measures, use of personal protective equipment).
- 5S method (containing, among others, what is the 5S method, what are its stages, organizing and systematizing the workplace, increasing employee awareness).

Figure 8. presents a screenshot from the VR training – it shows a fragment from module on 5S method.



**Figure 8.** A screenshot of the occupational safety training – 5S training – by 4HelpVR.

Source: (4HelpVR, 2020b).

#### 4.9. Warehouse simulator

The WSS VR Warehouse Simulator is an application developed by Epic VR for a logistics company. The WSS VR application is a simulator of warehouse activities in logistics. Training in VR combines theory with practice. Training allows one to improve the ability to collect orders and fulfil them according to the standards of the distribution center. Thanks to the application, the user can learn and how the whole way of the package shipment looks like. As part of the training, the trainee can learn how to pack and send parcels, pick orders, label parcels, scan codes, prepare warehouse documents, and many others (EpicVR, 2022e). Training is dedicated to current and future employees. On the other hand, the application is a good option for students studying logistics. Figure 9 shows a screenshot of the mentioned warehouse simulator.



**Figure 9.** A screenshot of the warehouse simulator by EpicVR.

Source: (EpicVR, 2022e).

## 5. Summary and conclusion

As a result of the research, it can be claimed that in practice virtual reality is not yet used on a large scale in Poland. The examples from practice that were cited in the article were few due to the fact that virtual reality technology is not yet very popular when it comes to application in industrial practice. VR is an innovative technology related to Industry 4.0, so it is natural that companies are yet to show resistance and fear of introducing it into practice. Nevertheless, there are companies in Poland that have decided to use this technology.

The research objectives, which included identification of the areas of use of VR in practice in industry in Poland and providing new knowledge about VR applications applied in industry practice in Poland, have been achieved. Based on the research results of the review of the practical VR applications used in practice in Poland, it can be concluded that VR training, as well as VR simulations, are most often applied in industrial practice. Referring to the first research question Q1, it has been concluded that virtual reality is used, among others, in the mining industry, aviation, logistics, transportation, machining, forestry, and many more. It is mostly used for the following (an answer to the third research question Q3):

- General training.
- On-the-job training.
- Occupational and health training.
- Machine operation training.
- Soft skills training.

- Work (of machines, of production line, at the given workstation, etc.) simulation.
- Simulation of crisis situations (for example, fire or machine failure).
- 360° videos.

When it comes to the second research question Q2, it can be claimed that the use of VR in the context of business activities of enterprises is still very limited. VR is applied on a small scale only in basic operation. It only supports basic activities through virtual trainings. On this basis, it can be concluded that the use of virtual reality in enterprises is in a very early stage.

Virtual reality has great potential to be used in industrial practice also for purposes other than those listed above. VR can be a very good working environment, for example, for architects and designers who can prepare their projects and see them in 3D. Designers often use various programs, for example (AutoCAD or Inventor), using a computer. If these programs were possible to run in VR, it would be easier for designers to imagine the designed element and work on it. In addition, the client could also get acquainted with future projects in an accessible 3D form. Thanks to this, they can get a more realistic visualization of future projects.

Machine diagnostics using virtual reality is also a very interesting direction. Thanks to the use of goggles, service technicians do not have to come to the place where the machine is located. They could work remotely, seeing a given machine in a virtual remote way and diagnosing it. Another direction is also the monitoring of a selected production line or even the entire production process using virtual reality equipment. For example, a supervisor or manager would be able to quickly control the progress of work without approaching specific positions or the production line.

Thus, in summary, virtual reality has great potential and possibilities of application in industrial practice. The possibilities and directions are huge, and VR can be used in various companies of various industries and in various areas of their activity. It should also be emphasized that, apart from VR, AR is also a very promising direction. Both technologies, as the pillar of Industry 4.0, are developing at a rapid pace and the companies that use them gain benefits.

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## DISSIMILAR WELDING OF 316L AUSTENITIC STEEL WITH DOCOL 1200 M STEEL FOR THE STRUCTURES IN AUTOMOTIVE INDUSTRY

Tomasz WEGRZYN<sup>1</sup>, Bożena SZCZUCKA-LASOTA<sup>2\*</sup>, Xianghui MENG<sup>3</sup>,  
Andrzej KUBIK<sup>4</sup>, Piotr CYBULKO<sup>5</sup>

<sup>1</sup> Politechnika Śląska, Poland; tomasz.wegrzyn@polsl.pl, ORCID 0000-0003-2296-1032

<sup>2</sup> Politechnika Śląska, Poland; bozena.szczucka-lasota@polsl.pl, ORCID 0000-0003-3312-1864

<sup>3</sup> Shanghai Jiaotong University, China; fchen@sjtu.edu.cn, ORCID 0000-0003-2387-1186

<sup>4</sup> Politechnika Śląska, Poland; andrzej.kubik@polsl.pl, ORCID 0000-0002-9765-6078

<sup>5</sup> Center for Hydrogen Technologies (CTH2), Institute of Power Engineering, National Research Institute, Warsaw, Poland; piotr.cybulko@gmail.com, ORCID 0000-0003-1146-1892

\* Correspondence author

**Purpose:** The main novelty and the goal of the paper is to develop the possibility of dissimilar welding for automotive application. The welding structure connects two various grades of steel with different structure and properties.

**Design/methodology/approach:** Two various metals have been checked in welding in order to obtain a high-quality joint of various means of transport. The properties of the joint were checked by non-destructive tests (NDT) and also the bending and the tensile strength were realized.

**Findings:** Relations between welding parameters and a quality of obtained dissimilar welds.

**Research limitations/implications:** In the future, it can be suggested to investigate the effect of nitrogen addition in gas shielding mixtures of the MAG process.

**Practical implications:** The proposed innovation will not cause problems in the production process provided that the technological regime will be respected.

**Social implications:** Modifying the welding method will not affect the environment and production management methods. Producing dissimilar welds translates into serious savings.

**Originality/value:** It is to propose a new solution with its scientific justification. The article is addressed to manufacturers of dissimilar material for automotive industry and other means of transport.

**Keywords:** dissimilar welds, 316L, DOCOL 1200 M, transport, shielding gas mixture, production savings.

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

## 1. Introduction

The paper presents the results of various MAG (metal active gas) welding tests. The obtained dissimilar welds of 316L austenitic steel with DOCOL 1200 M steel (from group AHSS - advanced. high-strength steel) were tested. These dissimilar grades of steels were taken into account as materials in the structure of transport means. An austenitic steel and AHSS (advanced high-strength steel) could be used especially in automotive industry. Many applications in other industrial sectors could be also possible. The use of dissimilar welds is mainly recommended in automotive industry because of economic savings (Jaewson et al., 2011; Darabi et al., 2016; Hadryś, 2015). The weldability of these dissimilar steels is not easy because of completely various structures: martensite and austenite (Golański et al., 2018, pp. 53-63; Skowrońska et al., 2017, pp. 104-111).

A major difficulty of 316 L and DOCOL 1200 M welding is different between the connection materials. The dominance phase in 316 L steel is austenitic and in DOCOL 1200 M is martensitic, what transfers very often into welding cracks. Therefore it is very important to determine welding parameters very precisely (Silva et al., 2019; Krupicz et al., 2020). The most important welding parameters are:

- beveling method,
- arc voltage,
- welding current,
- welding speed,
- composition of gas mixtures in MAG welding,
- type of electrode wires,
- pre-heating temperature.

Dissimilar welding of austenitic steel with martensitic steel is complicated because of the high amount of niobium and titanium, which play different role in both materials (Fydrych, Łabanowski et al., 2013; Shwachko et al., 2000). Preheating is recommended for proper dissimilar steel welds (Szymczak, 2020). In the article, it was mainly decided to examine the influence of nitrogen added to the shielding gas mixture, because in the case of 316L steel, nitrogen is an austenitic former, and in the case of DOCOL 1200 M steel, nitrogen in small amounts is even desirable because it forms nitrides that strengthen the base material and the weld. However, the nitrogen content in the mixture cannot be too high, as it will translate into too high nitrogen content in the weld metal, which usually leads to cracks (Szymczak, 2020).



## 2. Materials

For dissimilar MAG welding of austenitic S316L steel with martensitic DOCOL 1200 M steel two various electrode wires were chosen:

- Lincoln LNT 316L (austenitic structure),
- UNION X90 (martensitic structure).

There were used various gas mixtures of argon with nitrogen. Before the welding process, it was suggested to check the preheating to a temperature of 130°C. A thickness of both grades of steel was 2 mm. Table 1 shows the main properties of materials.

**Table 1.**

*Tensile strength of tested dissimilar grades of steel*

Steel	YS MPa	UTS, MPa
316L	240	610
DOCOL 1200 M	1050	1200

The data from tab. 1 indicates that both materials have completely different mechanical properties. Martensitic DOCOL 1200 M steel has much higher strength (UTS) and yield strength (YS) than austenitic 316L steel. These different mechanical properties result from the respectively very various chemical composition of both tested materials (Table 2).

**Table 2.**

*Chemical composition of tested grades of steel*

Steel	C	Si	Mn	P	S	Al	Cr	Mo	Nb	Ni	Ti
316L	0.07	0.9	1.9	0.035	0.01	0.01	18.5	2.5	0.06	13	0.05
DOCOL 1200 M	0.11	0.13	0.25	0.01	0.002	0.02	0.01	0.01	0.14	0.01	0.22

It was decided to weld both joints with two different wires, one of which had a martensitic structure and the other one had an austenitic structure (Tab. 3).

**Table 3.**

*Electrode wire UNION-X90 – composition*

Wire	C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	Ti%	P	S
UNION X90	0.11	0.8	1.8	0.010	0.35	0.6	2.3	0.005	0.015	0.01
LNT 316L	0.02	0.85	1.4		18.9	2.6	12.5		0.02	0.02

It was found that to make a 2 mm thick joint there was no need to chamfer the samples. The electrode wire diameter was selected to be 1 mm. The weld was single-pass. At the beginning, the most important voltage and current parameters were determined.

- arc voltage: 20 V.
- welding current: 117 A.

The remaining parameters were determined based on preliminary observations:

- welding speed: 300 mm/min,
- shielding gas flow: 14 dm<sup>3</sup> / min.

The typical joint is presented in Fig. 1.



**Figure 1.** View on the tested dissimilar joint.

Source: own study.

The joints were made with two variants:

- pre-heating to the temperature of 130°C,
- without pre-heating.

The shielding gas mixture was changed twice in the MAG dissimilar welding process and contained respectively:

- pure Ar,
- Ar-1.3 % N<sub>2</sub>,
- Ar-2.6 % N<sub>2</sub>.

### 3. Methods

After dissimilar MAG welding with the mention parameters variants non-destructive tests (NDT) and also (DT) destructive tests were realized.

NDT generally corresponded with:

- VT - visual test in accordance with PN-EN ISO:17638 standard with criteria of evaluation based on EN ISO 5817,
- MT- magnetic particle test in accordance with the PN-EN ISO:17638 standard.

The most important destructive tests include:

- a light microscope (LM) observation. The observation was carried out in accordance with the PN-EN ISO 9016 2021 standard;
- nitrogen content analysis in the weld metal. Measurements was realized on the LECO ONH836 analyzer;
- A bending test was performed in accordance with PN-EN ISO 7438 standard;
- Tensile strength according to PN-EN ISO 527-1 standard.

## 4. Results and discussion

The dissimilar austenitic-martensitic joints were made using two different electrode wires, three different variants of shielding gases and with two different thermodynamics variants with pre-heating, and without pre-heating. In total, 12 different joints were made, marked with samples from Q1 to Q-12 (tab. 4.).

**Table 4.**  
*Samples designations*

Sample	Electrode wire	Type of shielding gas (mixture)	Temperature, °C
Q1	UNIONX90	Ar	20
Q2	UNIONX90	Ar + 1.3 N <sub>2</sub>	20
Q3	UNIONX90	Ar + 2.6 N <sub>2</sub>	20
Q4	UNIONX90	Ar	130
Q5	UNIONX90	Ar + 1.3 N <sub>2</sub>	130
Q6	UNIONX90	Ar + 2.6 N <sub>2</sub>	130
Q7	LNT 316L	Ar	20
Q8	LNT 316L	Ar + 1.3 N <sub>2</sub>	20
Q9	LNT 316L	Ar + 2.6 N <sub>2</sub>	20
Q10	LNT 316L	Ar	130
Q11	LNT 316L	Ar + 1.3 N <sub>2</sub>	130
Q12	LNT 316L	Ar + 2.6 N <sub>2</sub>	130

The effect of NDT tests is presented in Table 5.

**Table 5.**  
*NDT results for tested dissimilar welds*

Sample	Observation
Q1	Small cracking in HAZ from the 316L steel side
Q2	Correct joint
Q3	Small cracking in HAZ from the 316L steel side
Q4	Small cracking in HAZ from the 316L steel side
Q5	Correct joint
Q6	Small cracking in HAZ from both sides
Q7	Small cracking in HAZ from the DOCOL 1200M steel side
Q8	Correct joint
Q9	Small cracking in HAZ from both sides
Q10	Correct joint
Q11	Correct joint
Q12	Correct joint

It was noticed that the most important factor influencing the good quality of the weld is the selection of the appropriate gas mixture. It was decided to test all joints that had no defects in subsequent destructive tests (marked with green colour in the Table 5). The next part of the research was to count the nitrogen content in the weld in terms of the kind of gas mixture. All measurements were carried out on the LECO ONH836 analyzer. The test results are shown in Table 6.

**Table 6.**  
*Nitrogen in weld metal deposit (WMD)*

Sample	Nitrogen in WMD, ppm
Q2	55
Q5	55
Q8	55
Q10	50
Q11	55
Q12	65

It is easy to deduce that only argon, used as a shielded gas allows to obtain with the lowest nitrogen content on the level of 50 ppm, regardless of other factors (type of wire, pre-heating).

The use of a shielding argon gas mixture containing 1.3% N<sub>2</sub> ppm allows for a low increase in the nitrogen content in the weld up to the 55 ppm. The usage of a gas mixture containing 2.3% N<sub>2</sub> is not beneficial, because it translates into a higher increase in nitrogen amount in the on the level of 65 ppm.

The next part of the research was to realize tensile strength of the selected samples free from welding defects. Table 7 shows the tensile strength (UTS) of the tested welds.

**Table 7.**  
*Tensile strength of joints*

Sample	UTS [MPa]
Q2	472
Q5	488
Q8	491
Q10	505
Q11	525
Q12	497

The data from table 7 indicate that it is possible to get good tensile strength of the dissimilar joint (over the 520 MPa level). This result was achieved when simultaneously:

- amount of 1.3 N<sub>2</sub> was added to Ar gas mixture,
- pre-heating was performed,
- austenitic wire was chosen.

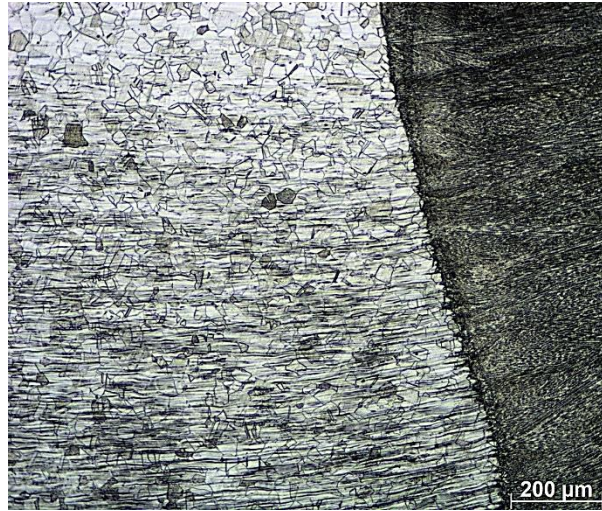
All other tested variants do not allow for obtaining such good joint properties. The last part of the research was bending tests realization, made both from the face and ridge side of the joint. The test result of bending test is shown in Table 8.

**Table 8.**  
*Bending test of dissimilar weld*

Sample	Face side	Ridge side
Q2	No cracks	Small cracks
Q5	No cracks	No cracks
Q8	No cracks	Small cracks
Q10	No cracks	No cracks
Q11	No cracks	No cracks
Q12	No cracks	No cracks

The bending tests result were mainly positive. No welding defects or nonconformities were found, when austenitic wire was used.

Finally, a microstructure was analyzed for sample Q11, which was characterized by the best tensile strength (Figure 2).



**Figure 3.** Structure of correct dissimilar weld (above 316L on the left, DOCOL 1200 M on the right). Sample Q11, electrolytic etched with 10% oxalic acid.

## 5. Summary

The article was about finding the best MAG welding parameters of two dissimilar grades steel. The welding materials characterized completely different mechanical properties, and structures. 316L steel has austenitic structure, and DOCOL 1200 M steel has a martensitic structure. Dissimilar joints are not easy to create, but they are often lead serious savings, because one of the welded materials is always cheaper. To assess the best method of dissimilar joints, it was mainly decided to check the influence of the various nitrogen content added to shielding gas mixture. Apart from that, simultaneously two different electrode wire with respectively austenitic structure and martensitic structure were tested. The influence of the preheating before welding at the level of 130°C was additionally checked. Some non-destructive tests and also destructive tests were performed. The nitrogen amount in the weld was carefully tested. Also bending tests and tensile strength were carried out. The following conclusions were made:

1. Preheat (130°C) is recommended in dissimilar 316L/DOCOL 1200 M welding.
2. It is possible to obtain the tensile strength of the dissimilar austenite steel-martensite steel joint at the level over 520 MPa.
3. On the basis of the research it can be concluded that the Ar + 1.3% N<sub>2</sub> gas mixture is more appropriate for the dissimilar welding of 316L/DOCOL 1200 M.

The obtained corrected welds can be applied in automotive industry.

## Acknowledgments

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## SMART FITNESS CLUB – COMPETITIVENESS OF SPORTS AND RECREATION ENTERPRISES IN THE ERA OF SMART SOLUTIONS

Agnieszka WIDAWSKA-STANISZ

Czestochowa University of Technology; a.widawska-stanisz@pcz.pl, ORCID: 0000-0002-0609-6758

**Purpose:** The aim of the article is to present the possibility of building competitiveness of sports and recreation enterprises by using innovations in the area of smart and modern solutions and using them for company management and marketing.

**Design, methodology and approach:** Sports and recreation enterprises are a very dynamically developing sector of the economy today. The proposed solutions were developed based on analysis of the literature on the subject and secondary sources, as well as two research methods: observation and survey. The survey was conducted among purchasers of sports and recreation services and the sample was purposefully selected. The author's own observation concerned changes taking place on the market of sports and recreation services in the context of modern technologies and other smart solutions. The time scope of the study covers the period from July to October 2023.

**Findings:** Compared to other industries, sports and recreation companies are just starting to implement smart and innovative solutions. Their surveyed customers declared in their answers interest in modern and innovative solutions and considered them very useful, expected and even "green". According to the respondents, smart solutions are currently used as tools for monitoring physical activity, time management and searching for sports and recreation facilities. The results of the study may be a contribution to further research into the use of smart solutions, for example in relation to the management of sports and recreation facilities.

**Practical implications:** The article draws attention to possible directions of developing and building competitiveness of sports and recreation enterprises using modern technologies and smart solutions. Opportunities and barriers to introducing this type of innovation were described. A set of solutions that can be used in smart fitness clubs was proposed.

**Social implications:** The proposed solutions can be used in the practice of sports and recreation enterprises, creating added value.

**Originality and value:** The subject presented in the article has not been yet widely discussed in the Polish literature. Ideas such as smart city, smart world, smart industries and smart services are very topical and market observation shows how dynamically they are developing. The article draws attention to the possibilities of using smart solutions in the sports and recreation industry.

**Keywords:** sports and recreation services, smart services, services, service buyer.

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

## 1. Introduction

The market for sports and recreation services is constantly developing. Observation of the changes taking place allowed the author to notice transformation in the way services are provided and in the services themselves. Participants in physical activity increasingly use modern technologies and smart solutions. Mobile applications, smartwatches, fitness bands, health and activity monitoring and other amenities have been with us for a long time. One of the factors that accelerated the digital transformation also in the service business of sports and recreation enterprises was the CoViD-19 pandemic. Managers were faced with choosing different business models. There were many examples of fitness clubs the owners of which decided to introduce digital and smart innovations. These solutions can be used in the activities of sports and recreation enterprises as tools to motivate people to engage in sports, improve customer relationship management and are also an important element of facility management. These innovations allow them to promote their services and make them more attractive. More and more often fitness club chains offer their own applications, which proves that modern technologies are used in this industry. It is therefore possible to use many other more advanced and smarter solutions. The aim of the article is to point out the possibility of introducing innovations in the area of intelligent and modern solutions in sports and recreation enterprises and using them in company management and in marketing. It was assumed that smart solutions can be a factor influencing competitiveness of sports and recreation enterprises, can distinguish the offer, support facility management processes, strengthen environmental awareness and motivate people to engage in physical activity.

## 2. Review of literature on intelligent services and discussion

As A. Niemczyk mentions, “innovations, while providing new values to customers, are revealed in the form of new products, technologies, ideas, approaches and systems, which must translate into benefits for customers, and these into satisfaction and loyalty, and therefore their attachment to the company based on their positive experiences, which will guarantee high profitability of the companies” (Niemczyk, 2014, p. 83). Innovation as an accelerator of economic development and a key factor in the development of every enterprise is also mentioned by P. Dziemdziała and K. Krzyżanowska (2020, p. 91). Sources of innovation may include, among others, “new knowledge” – for example rapid technological development, including “Industry 4.0”, or an unexpected event, such as the CoViD-19 pandemic (Rojek, 2021, pp. 87-88; Dalenogare, Ayala, 2019). Topics related to intelligent enterprises have been analyzed since recently. The digital economy is an inherent feature of the so-called “Industry



4.0”, a kind of emanation of the industrial revolution of the times of the information society (Rafał, Borek, 2022, p. 47). As M. Wodnicka mentions, one of the features of the latest industrial revolution, Industry 4.0<sup>1</sup>, are “advanced ICT technologies that accelerate the processes of industrial transformation, modify the ways of providing services, create new ways of doing business, bring transformations in the field of enterprise cooperation and process control, change the market structure, create intelligent products or services. The technologies that have the greatest potential to change business reality, the development of economies, the hierarchy of values and the way of life include mobile Internet, artificial intelligence (AI), virtual reality (VR), augmented reality (AR), technological cloud, the Internet of Things (IoT), advanced robotics, biometric technologies, 3D printing and blockchain. These technologies have been with us for a long time but now they are taking a more mature form, combining physical systems with the IoT, or AI, Big Data or the Cloud” (Wodnicka, 2019, p. 46; Alshehri, Muhammad, 2020, p. 3660; Ghosh, Chakraborty, Law, 2018, pp. 208-209).

In the literature, one of the concepts related to smart solutions is the Smart World. Knowledge about its existence is crucial for entrepreneurs. It will prepare organizations for changes in areas such as hyperspace, applications and integrated management, as numerous studies show (Chabiera, 2022, p. 84). The term “Smart Industry” covers all phenomena related to the digitization of the economy, and in particular technological changes in the industry. However, this topic is related to the much larger idea of digital transformation, because it also refers to strategic changes at the operational level. Outside the commodity sector there are also innovative service solutions: Smart services. Smart enterprises base their business on cyber-physical systems, the IoT and modern methods of organizing production. Their main goal is to ensure a high level of product personalization and to carry out all manufacturing processes with reduced human participation. When developing a product intended to impress the customer, Smart companies focus on preparing something extraordinary, almost unique.

Digitization has multidimensional meaning and can be understood in many ways. The factors driving the digital transformation of industry include digital data, automation, connectivity and digital consumer access. Digital transformation tools from the customer’s perspective include social media, mobile internet, applications, and e-commerce (Gajewski et al., 2016, pp. 12-13). Consumers of the 21<sup>st</sup> century show an increasing demand for products and services precisely tailored to individual needs, which in turn changes the current industrial paradigm of mass production to “mass personalization”. (Cegielko, 2021, p. 74). Also in sports and recreation services, such as fitness or gym, consumers face challenges in planning exercise, monitoring activity, sleep and stress levels, monitoring the diet and supplementation. Wearable devices have become an essential gadget for people tracking their fitness and training activities.

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<sup>1</sup> Industry 4.0 is a concept based on technologies that enable the integration of people, machines and processes. It involves the exchange of information between devices, systems and people. It provides access to information at any time, from anywhere in the world. Industry 4.0 means the integration of smart solutions including IT devices and systems, new ways of working and new roles of human resources; Wodnicka, 2021, p. 49.

(Sahu, Kumar, 2021; García-Fernández et al., 2020) P.P. Ray discusses the possibilities of combining the potential of the Internet of Things (IoT) with sports and recreational activities. Sensors, applications, the Internet, and microcontrollers can connect athletes, recreational sports participants, and medical teams (Ray, 2015). A. Farrokhi, R. Farahbakhsh, J. Rezazadeh and R. Minerva point out another important reason for using smart solutions in the fitness industry. Undoubtedly, physical activity plays an important role in the lives of many people, but most of them do not have enough knowledge about safe and effective training. Products protecting against injuries have been available on the market for years. However, they may turn out to be insufficient. Hence the need to look for smart solutions to predict, prevent and/or reduce the incidence of accidents and injuries (Farrokhi et al., 2021, p. 2). I. Ioannidou also discusses the use of modern solutions in sports, including monitoring, motion tracking, and coaching (Ioannidou, 2019).

The ability to innovate is considered a factor decisive for an organization's competitiveness (Lypchuk, Voytovych, 2022, p. 12). In service-oriented micro, small and medium-sized enterprises (MSMEs), including fitness clubs, barriers to innovation can be observed such as lack of funds for innovation, problems with raising capital, high technology costs, high risk associated with innovative projects, lack of qualified staff and lack of free time to undertake innovative activities. However, MSMEs have the advantage of having less bureaucracy (limited number of procedures), flatter structure and more flexible organizational culture (Łobacz, Tylżanowski, 2021, p. 110).

### **3. Market of sports and recreation services**

The commercial mass fitness market is relatively young, not older than 50 years. When Poland joined the group of free market economies, foreign chains were not developed enough to immediately expand to our market. In the meantime, the gap was filled by ambitious domestic companies (Health for a billion dollars..., 2021, p. 11). The market of sports and recreation services in Poland today is complex, highly competitive and still dispersed. It is also part of the market for sectors that make up the leisure economy. B. Iwankiewicz-Rak and A. Rak (2016, p. 347) mention the dynamic development of the market of sports and recreation services as a response to the growing demand resulting from increased public awareness of the need for caring for quality of life, leading a healthy lifestyle and proper nutrition: "Globally, this industry is worth almost \$100 billion, with the United States being the largest market. The largest European markets are Germany and the UK. Poland ranks 7<sup>th</sup> with annual revenues of approximately one billion dollars. However, due to much lower market penetration and the general level of physical activity of Poles lower than in developed countries, the fitness industry

in Poland still has great potential for dynamic growth: it can even double its turnover relatively quickly (Health for a billion dollars..., 2021, p. 2).

As W. Bocheński (2022, pp. 360-361) points out, there is a noticeable division of most of Polish fitness clubs into four leading sectors: “middle market”, “low-cost”, “boutique” and “premium”. Among these fitness clubs there are large chains (including Jatomi Fitness, Calypso Fitness Club, ZdroFit and CityFit), micro-networks, often specialized (such as boutique fitness clubs, the Polish network of Harder clubs) and clubs offering their services only to women (FitCurves and MRS Sporty). New on the market are “cozy” fitness clubs for VIPs.

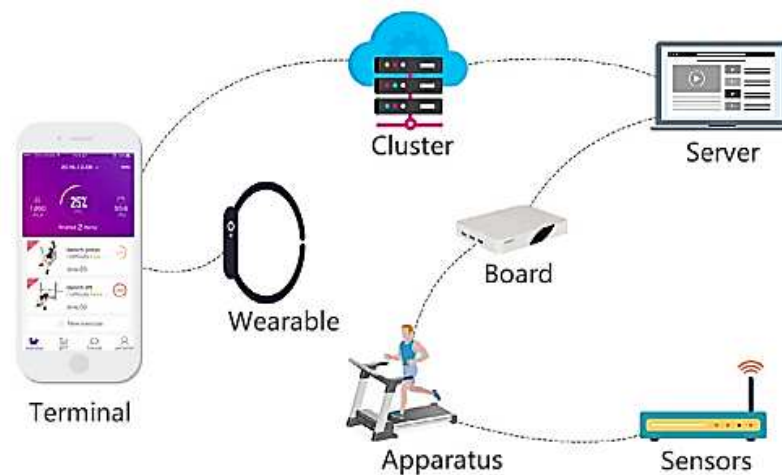
Sports and recreation enterprises, such as fitness clubs, offer comprehensive services related to physical activity (e.g. group and individual exercises conducted under the supervision of personal trainers), dietician services, beauty services, and massages. In addition, they have climbing walls, tennis courts, facilities for children, often a swimming pool, sauna, solarium, etc. The clubs’ offer also includes small shops selling sportswear, supplements, accessories and sports equipment. In addition to the wide range of services mentioned above, sports and recreation companies also offer electronic customer service systems for communication, registration or unattended use of training equipment (Iwankiewicz-Rak, Rak, 2017, p. 352).

Digitization processes are becoming fundamental to the challenges faced by the leisure market or leisure economy – and on an unprecedented scale (Rafał, Borek, 2022, p. 56). “Mobile technology also creates an opportunity to reduce enterprise costs and thus increase the price competitiveness of those who can use it best. This situation also results from consumer trends and consumer behavior on the market” (Sznajder, 2013, p. 38). Increasingly more people shop in online stores and use mobile applications and social media where groups are created around a certain activity or topic (for example, a Facebook group called Gym and Fitness dealing with diet, advice, exercise and motivation). P. Schlegel, A. Křehký and Radka Dostálová (2021, p. 246) mention challenges regarding physical activity in social media groups.

The business models of sports and recreation companies are based on the unflagging and even growing fashion for a healthy lifestyle. Moreover, each enterprise of this type must deal with the seasonality of services – for example, decreasing interest in fitness club services during the holidays and increased activity in the first months of each year (the so-called “New Year’s resolutions”). Additionally, return to physical activity can be observed after the end of the CoViD-19 pandemic. According to the last study conducted on this topic by the Central Statistical Office (2021), participation in sports or physical recreation was declared by 38.8% of people (36.7% of women and 41.0% of men). Compared to the previous study (2016), a decrease in the number of physically active people by 7.6 percentage points was observed. However, it is worth noting that it was a time when restrictions related to the current CoViD-19 pandemic were imposed on sports, entertainment and recreation. Access to sports facilities was also difficult. 20.6% of Poles who took part in sports activities regularly (21.7% in 2016). 37.6% of them exercised regularly, but only outside the periods of restrictions related to CoViD-19. More than 40% of urban residents engaged in physical activity –

mostly in large cities with 500,000 or more inhabitants (more than 50%). On the other hand, only every third rural resident declared participation in sports or physical recreation activities (Participation..., 2021, p. 1).

A new aspect of the activities of sports and recreation companies are modern technologies and smart solutions. It can be said that the pandemic accelerated changes on the market and revalued many industries. Companies from the sports and recreation industry operate in a very dynamic environment. Therefore, developing a business model requires managers to carefully analyze many factors: the environment, competition, target groups, types of services offered, offer complexity, methods of generating revenue, specificity of the facility and the type of membership. As observations show, digitization and smart solutions are slowly entering activities of sports and recreation service organizations. An example of such a solution is the SOLO Workout<sup>2</sup> smart sensor system which can be used by clients, personal trainers and fitness club managers.



**Figure 1.** The structure of a smart system for a fitness club.

Source: Yong, Xu, Wang, Cheng, Li, Wu, Zhou, 2018, p. 15.

The above illustration shows an example of a structure of a smart system for a fitness club. The system proposed by B. Yong, Z. Xu, X. Wang, L. Cheng, X. Li, X. Wu, Q. Zhou (2018, p. 15) contains fitness equipment, sensors, wearable devices (e.g. fitness bands recording users' activity outside the club), a development board, a system server, a computing cluster and a mobile terminal. Fitness clubs can use integrated solutions in their operations, offering a unified membership portal, mobile application and operating system, for example Perfect Gym which makes it easy to track clients' workouts, goals, as well as attendance and purchase history. With this information, club managers can optimize customer experiences and ensure they remain loyal (Perfect Gym, 2021).

<sup>2</sup> SOLO Workout: All training information is sent to the user's mobile application available for Android and iOS. The application provides constant access to the history of the completed training, which allows users to monitor their potential. Nearly 100 instructional videos are available, showing how to properly perform exercises. Club members can create their own training plans using over 200 available exercises and plan them using the built-in calendar (<https://fitnessbiznes.pl/cyfryzacja-silowni-z-solo-workout>, <https://soloworkout.com>, 20/09/2023).

Robots are an example of a smart solution used in catering, hotel industry, trade and leisure services such as bowling alleys or billiard clubs. Their functionality also allows them to be used in fitness clubs. Examples are RoboGym<sup>3</sup> and Pudu Robots<sup>4</sup>. “Investing in AI-powered fitness companies and startups can provide investors with exposure to this growing market, as well as a potential for significant returns. Some notable players in the AI fitness space include Tonal<sup>5</sup>, a home gym system that uses AI to personalize workouts; GYANT<sup>6</sup>, a virtual health assistant that uses artificial intelligence to provide personalized fitness and nutrition recommendations; and Myzone<sup>7</sup>, an AI-enabled wearable fitness tracker that analyzes training data and offers real-time feedback” (Frackiewicz, 2023).

#### 4. Material and Method

The literature on the subject lacks studies on smart solutions in the service activities of sports and recreation enterprises, especially in the aspect of marketing and management of this type of companies, development of the services offered, added value, motivating buyers, building company-client ties and the relationship of activity participants with sport. Smart solutions, apart from their image significance, can bring many benefits to sports and recreation enterprises and their clients. It was assumed that customers of sports and recreation enterprises are interested in the development of services towards smart solutions.

The primary aim of the partial survey was to learn the respondents' opinions on smart and technologically advanced solutions in the activities of sports and recreation enterprises. The following research questions were formulated:

1. Do the respondents prefer an active lifestyle?
2. Are the respondents clients of fitness clubs and gyms?
3. What were the reasons for choosing a specific facility? Were intelligent and technologically advanced solutions one of them?
4. Do the respondents notice modern and smart solutions in the sports and recreation facilities they use?
5. How do the respondents rate the use of this type of solutions?
6. What opportunities and barriers to introducing this type of solutions do the respondents see?

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<sup>3</sup> RoboGym: Based on sensors for recording movements and a biomechanical musculoskeletal model, the robot will advise whether training is efficient and support analysis the effectiveness of exercises (<https://www.robogym.de/>).

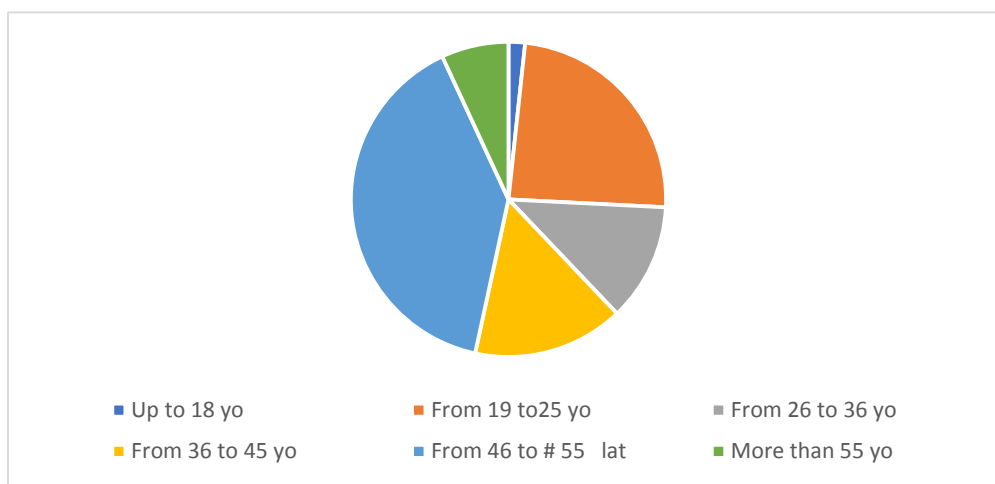
<sup>4</sup> Pudu Roboty: A solution that can be used in hotel, catering, trade and leisure services. Robots can perform various roles, for example in delivery and advertising (<https://puduroboty.pl/>).

<sup>5</sup> Smart device for a home gym (<https://www.tonal.com>).

<sup>6</sup> Gyant: Virtual health assistant (<https://gyant.com>).

<sup>7</sup> MyZone: a highly accurate and comprehensive physical activity monitor (<https://www.myzone.org>).

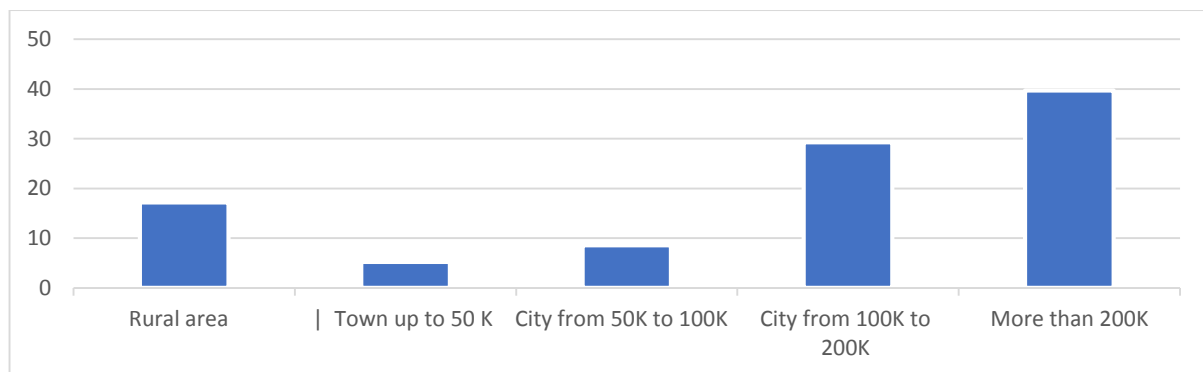
The study using the online survey method was a pilot conducted in September and October 2023 on a sample of 58 respondents. The research tool was a survey questionnaire developed using a Google form. The study used purposeful sampling using the “snowball” method. This is a method used to study communities that may be difficult to access. Thanks to this, customers of sports and recreation enterprises from various regions of Poland were reached. Respondents received a link to the survey questionnaire posted online and sent it to other people using thematic groups on social media. (for example, groups of physically active people and groups of clients of sports and recreation enterprises). Due to the small research sample, the study results should be treated as an introduction to further research on the intelligent fitness club in the era of smart solutions, both from the perspective of the client and people managing such facilities. 70% of women and 30% of men took part in the study. The chart below shows the age structure of the respondents.



**Figure 1.** Age structure of the surveyed people.

Source: own study based on completed research.

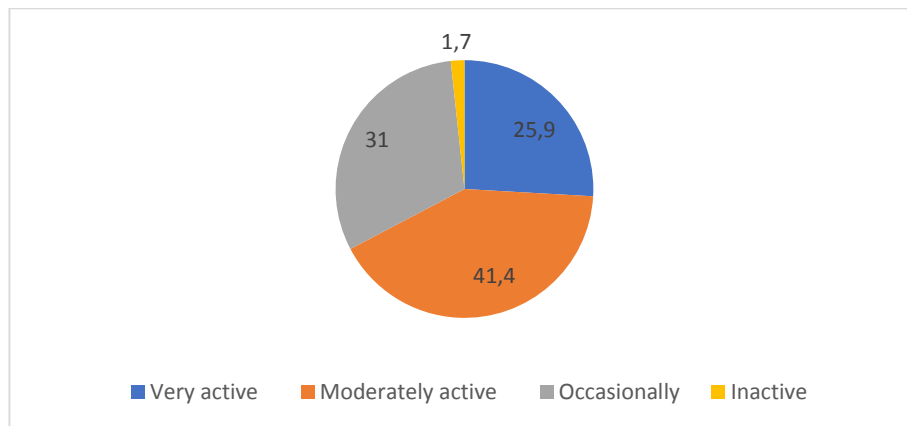
The respondents varied in age. Most respondents were 46-55 years old (40%), 19-25 years old (24%) and 36-45 years old (16%). Most respondents lived in cities with over 200,000 inhabitants (39.7%) and from 100 to 200,000 inhabitants (29.3%). Rural residents also took part in the study – 17.2%, as shown in Fig. 2.



**Figure 2.** Places of residence of the respondents.

Source: own study based on completed research.

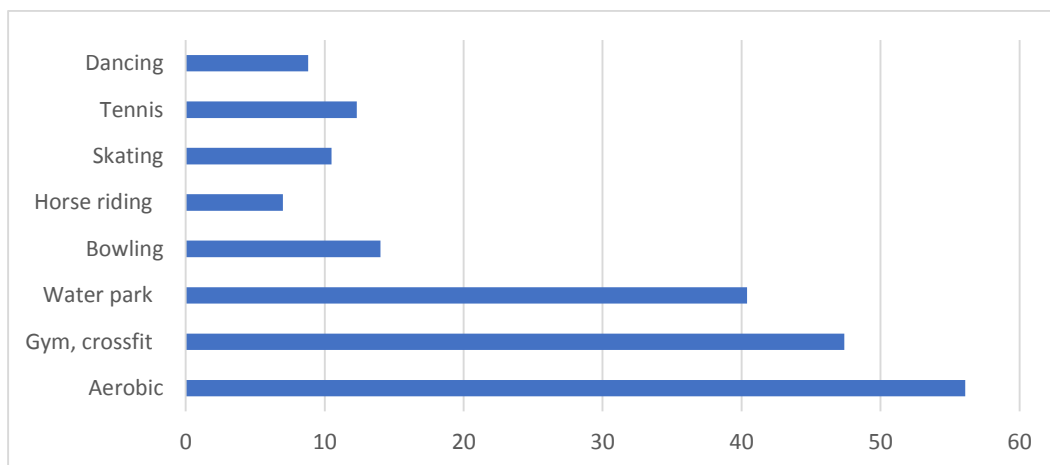
In one of the initial answers respondents declared their physical activity. Less than 26% were very physically active, and less than 42% were moderately active. Active people took part in the survey and only one person admitted to physical inactivity.



**Figure 3.** Physical activity of the respondents.

Source: own study based on completed research.

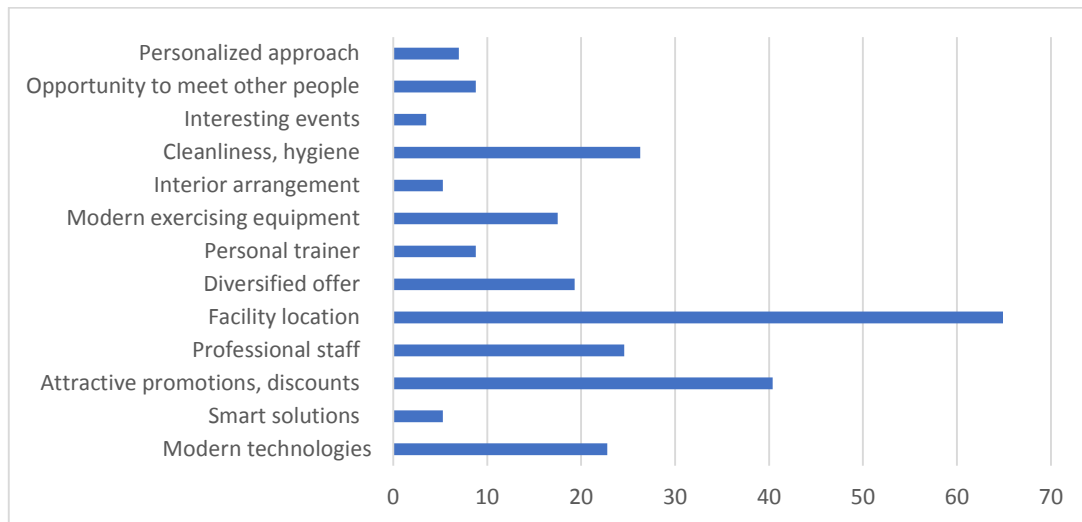
Almost 70% of the respondents had been customers of sports and recreation companies for over 5 years. Only 14% had been purchasing this type of services for less than a year.



**Figure 4.** Services used by the respondents.

Source: own study based on completed research.

The most popular forms of sports and recreation used by the respondents included aerobic classes and the gym. Water park services were also popular. The respondents could provide their own answers to this question. However, they were rare and declared activities such as karate, boxing, squash and volleyball.

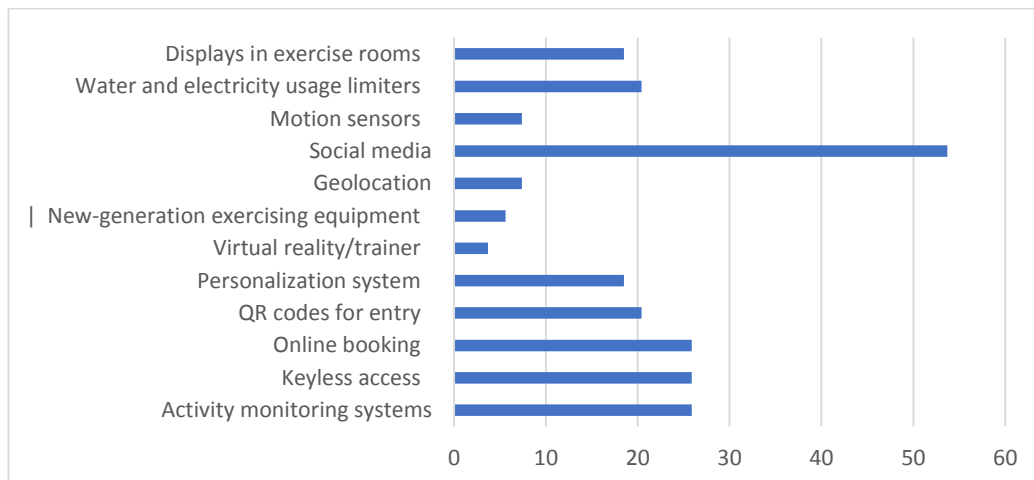


**Figure 5.** Reasons for choosing a specific sports and recreation facility.

Source: own study based on completed research.

Among the most important reasons for choosing a specific sports and recreation facility, the respondents declared the location of the facility (64.9%), attractive promotions and discounts (40.4%), cleanliness and hygiene (26.3%) and technological advancement (22.8%). Smart solutions were mentioned by only 5.3% of the respondents. Perhaps this is because sports and recreation enterprises are just starting to use smart solutions. The remaining results are presented in Fig. 5.

In the next question, the respondents listed modern solutions used by their sports and recreation service providers.



**Figure 6.** Reasons for choosing a specific sports and recreation facility.

Source: own study based on completed research.

The answers to the next question showed that sports and recreation enterprises are just starting to use advanced solutions. At the same time, we can see that customers are ready for innovations in the fitness industry. Fig. 6 shows that, according to the respondents, the solutions most frequently used by sports and recreation enterprises were social media. This result should not be surprising. This form of communication between business and consumers gained



popularity during the CoViD-19 pandemic. Other solutions included activity monitoring systems that enable customers to track their exercise progress via a mobile application, keyless access systems for entering the club using a smartphone or proximity card and online systems for booking equipment and activities in advance (almost 26% of the responses). The respondents also noticed solutions such as QR codes that facilitate entering the facility or using the service (20.4%), water and electricity usage limiters (20.4%), personalization systems that make it easier to tailor the offer to customer needs (18.5%) and displays in exercise rooms (18.5%). The displays can be a carrier of various information: opening hours, access to services, promotions, dietary recommendations, etc.

The study ended with collecting the respondents' opinions about smart fitness clubs and innovative solutions. Good ratings definitely prevailed: "it is an interesting way to expand the clubs' offer", "they make visiting such places very easy", "I like to see progress in training", "very necessary solutions" and "great facilitation". Few answers betrayed the respondents' concerns, such an increase prices with the introduction of innovations.

## 5. Conclusion

We have seen the dynamic development of the Smart City idea in recent years. M. Klepka (2019, p. 47) mentions this, among others. Opportunities and barriers of Polish enterprises on the way to smart industry and smart services are analyzed by Sz. Cegiełko who notes that these terms involve cyber-physical systems, the IoT and modern methods of organizing production. Their main goal is to ensure a high level of product personalization and to carry out all manufacturing processes with reduced human participation. When developing a product intended to impress the customer, Smart companies focus on preparing something extraordinary, almost unique (Cegiełko, 2021, p. 73). Many publications emphasize the importance of added value in relation to smart services and smart industries. Smart enterprises gain a competitive advantage through their flexibility, agility and innovation. The opportunity for sports and recreation enterprises offered by the implementation of intelligent and technological solutions is to build a relational plane between the company and its customers. As the results of the survey show, the proposed solutions were rated very well by a majority of the respondents, which may result in better matching of the offer to the needs of buyers, personalization of the offer, building customer loyalty and the image of an innovative company. Implementing innovations and smart solutions also allows companies to stand out on the market. Barriers on the way to creating a smart enterprise may be structural, systemic or resulting from society's awareness and culture or from employee competences (Cegiełko, 2021, pp. 80-81).

The technological trends discussed above will undoubtedly be of great importance for the development of the sports and recreation industry. For example, sports and recreation companies will be able to implement software based on artificial intelligence, and the acquired data can help tailor training programs adequate to the assumed goals or fitness capabilities. Moreover, sports and recreation enterprises in the SMART formula can be part of a larger system, i.e. the SMART CITY. As the research results show, service buyers are already interested in modern and smart solutions in the activities of sports and recreation enterprises. Data about physical activity, forms of activity practiced, training progress, injuries and dietary problems can be used by physicians, personal trainers, dieticians and supplement manufacturers to build even better comprehensive involvement and take care of the health and fitness of activity participants.

To sum up, the most important benefits of using digital solutions in a fitness club will be:

1. for facility managers – the ability to monitor and manage the occupancy of digitalized exercise equipment,
2. for personal trainers – the ability to observe the progress of their clients' training and plan training and nutrition,
3. for clients – the ability to stay up to date and track training progress,
4. the possibility of attracting new buyers from the Y and Z generations and, in the near future, the Alpha generation,
5. the possibility of comprehensive gamification of exercising, motivating and promoting physical activity,
6. creating a club community of physically active people.

Undoubtedly, smart solutions will help motivate purchasers of sports and recreation services to engage in physical activity, which is an important element of public health. Modern technologies allow consumers to track the effects of their exercises, which motivates them to continue their efforts. A guess may be ventured that this the direction towards which sports and recreation services will develop, and the use of smart solutions in the promotion of fitness services will be more effective than conventional activities.

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## EFFICIENCY OF POLISH HOSPITALS IN YEARS 2012-2021

Tomasz WIŚNIEWSKI

University of Szczecin, Institute of Economics and Finance; Tomasz.Wisniewski@usz.edu.pl,  
ORCID: 0000-0003-3423-5572

**Purpose:** This paper aims to explore the factors influencing the profitability of hospital operations in Poland. By dividing hospitals into homogeneous groups based on various criteria, it seeks to understand the dynamics and determinants of hospital efficiency in the context of changing healthcare policies and market conditions.

**Methodology:** The research adopts an exploratory data analysis approach, examining profitability across different hospital types and ownership models. It utilizes statistical methods to analyze changes over time, with a particular focus on profitability indicators such as Return on Sales (ROS). The study spans the period from 2012 to 2021, covering significant healthcare policy shifts and the COVID-19 pandemic's impact.

**Findings:** The study reveals that profitability is influenced by several key factors: legislative changes in NFZ financing system, hospital size, type of ownership, urban versus rural location, and regional healthcare policies. It uncovers that urban and rural hospitals' profitability did not significantly differ in each studied year, especially in the last two. The legal form of hospital operation (corporate or SPZOZ) does not conclusively affect operational efficiency. The study confirms that certain factors like size and ownership type influence hospital profitability.

**Research limitations:** Study suggests that other factors unique to each hospital, such as department structure and management quality also influence hospital profitability. The research opens pathways for further investigation into these factors, although data limitations present challenges.

**Practical implications:** The findings have implications for healthcare policymakers and hospital administrators, emphasizing the need for adaptable management strategies in response to changing funding models and market conditions. They also highlight the importance of considering local factors in policy formulation.

**Social implications:** The research underscores the importance of efficient hospital management in ensuring quality healthcare delivery, particularly in times of crisis like the COVID-19 pandemic. It also sheds light on the broader impact of healthcare policies on societal health outcomes.

**Originality:** This paper contributes to the existing body of knowledge by providing a comprehensive analysis of Polish hospitals' efficiency in a changing legislative and economic environment. It offers valuable insights for healthcare professionals, policymakers, and researchers, emphasizing the multifaceted nature of hospital efficiency.

**Keywords:** economic efficiency, profitability, hospital, health economics, NFZ (National Health Fund).

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

## 1. Introduction

The Polish healthcare system, akin to many others globally, aims to provide citizens with access to healthcare when needed. Fundamentally reliant on public financing, it ensures healthcare access for employed citizens contributing mandatory health insurance premiums. The National Health Fund (NFZ) administers funds from mandatory health insurance, reimbursing medical entities based on medical procedure pricing or lump-sum payments. A portion of healthcare funding stems from private insurance and ad hoc private payments. The scope of healthcare services encompasses outpatient care, hospitalization, medications, diagnostic tests, surgical procedures, and other simpler procedures. Healthcare is delivered through both public and private medical facilities. Poland has numerous public hospitals, medical clinics, and private entities. A significant portion of the NFZ budget is allocated to NFZ-authorized hospitals under contracts for medical services.

The Polish healthcare system faces challenges such as medical staff shortages, the need for medical infrastructure modernization, and long waiting lists for certain services. Challenges also include accessibility, especially in rural areas. A fundamental issue is the low profitability of hospitals, the main pillar of the healthcare system, leading to their poor financial health and, often, escalating debt (Bem et al., 2014). These problems have been persistent for years. A major challenge in healthcare financing is the availability of medical staff (doctors, nurses, and certain other medical professionals), leading to pressure on their wages amidst a general lack of funds. According to the Supreme Audit Office (NIK, 2015), sixteen out of twenty-two audited hospitals (73%), despite incurring losses, allocated staff salaries beyond their financial means. Hospitals' financial outcomes generally did not motivate management towards employment optimization.

High mandatory debts of Polish hospitals have led to systemic solutions, like the so-called Plan B for Polish hospitals, involving their debt relief and commercialization. Implemented from 1999-2005, this hospital reform program aimed at restructuring public hospitals by converting them into commercial law companies. Its objective was to improve hospital management, increase operational efficiency, and reduce the debt in the hospital sector in Poland. Plan B was part of a broader healthcare reform in Poland following the political transformation.

Despite debt relief and the commercialization of some hospitals in Poland, years after Plan B's implementation and significant NFZ budget increases, many hospitals still face financial difficulties and low or negative efficiency. The NFZ budget rose from PLN 37.1 billion in 2006 to PLN 62.6 billion in 2012 and PLN 135.6 billion in 2021. Adjusted for inflation, the 2021 NFZ budget was realistically 158% higher than in 2006 and 82% higher than in 2012. Despite such increases, the financial situation of most Polish hospitals did not improve commensurately. Research indicates that hospital restructuring is not always effective.

Restructuring goals are more often achieved in service quality than in economic aspects, such as debt reduction (Wielicka-Gańczarczyk, 2020). It was not only the Polish pro-efficiency reform of the health care system that was not fully successful. Attempt to reform the Greek NHS in 2007 failed to produce lasting improvements in hospital operational efficiency, while in economic terms there was only weak evidence of success (Fragkiadakis et al., 2016).

Given that financial situation and indebtedness stem from hospital profitability, investigating this parameter in practice is natural. This article aims to examine the financial efficiency of hospitals in Poland and identify factors influencing its variation. It is certainly interesting to analyze the temporal trends in profitability, as well as the variation in operational efficiency in spatial and entity-specific terms. Particularly pertinent is whether there are differences in hospital efficiency across various voivodeships (Polish provinces are called voivodeships) and other differentiating factors affecting their performance. Thus, the study of operational efficiency was conducted in temporal, spatial dimensions, and across homogeneous hospital groups, using various factors to categorize hospitals.

Multiple factors influence hospital financial results. Many internal factors have a direct impact on the hospital's operational efficiency. Collaboration between the hospital and the physician affects costs, clinical quality, and integration, which in turn impact financial results (Burns and Muller, 2008). Disseminating quality and cost information to physicians using a specialized decision support system builds lasting relationships, while insuring financial stability (Kohli et al., 2001). Furthermore, the use of electronic medical records is associated with improved financial outcomes for hospitals, as it affects revenues and overall hospital efficiency (Collum et al., 2016). Clinical decision support systems that go beyond pure electronic medical records improve not only hospital efficiency but also staff productivity, accuracy, and quality of care (Lee, et al., 2023). The necessity of applying innovative digital strategies to develop smart network connections that improve economic and medical outcomes in hospitals is increasingly recognized (Kordel, 2022). A study conducted in public hospitals in the Kingdom of Saudi Arabia shows that ineffective hospital management, lack of strategic planning and goals, weak administrative leadership, and lack of monitoring hospital performance have a profound impact on hospital efficiency (Alatawi et al., 2022). Furthermore, hospital ownership significantly influences financial outcomes, as corroborated by various empirical literature findings (Shen et al., 2007). Research among community hospitals in Tennessee indicate that community hospitals within networks of hospitals are more efficient than non-network hospitals (Roh et al., 2013). Additionally, clinical quality and process linkage to patient satisfaction also affect a hospital's financial results (Marley et al., 2004; Pai et al., 2019; Garcia-Lacalle, Bachiller, 2011). Integrating hospital and physician financing is recognized as a means of improving clinical processes, care quality, and care outcomes, thereby influencing financial results (Upadhyay et al., 2021). Contracts with NHS for healthcare service provision were examined to determine their impact on the financial outcomes of profit-oriented private hospitals in Spain, with specific models estimated for hospital subgroups based on size

and specialization (Ruiz-Mallorquí et al., 2021). It was also found that hospital service quality is related to patient satisfaction and financial outcomes, highlighting the importance of quality in shaping financial results (Alexander et al., 2006; Lim et al., 2018; Wiśniewska et al., 2022). Research on hospital performance includes both cross-sectional studies in a population and sample of hospitals and focuses on detailed analyses of individual cases (Paździor, Maj, 2017; Orliński, Nistrata-Ortiz, 2016; Grespan Bonacim, Procopio de Araujo, 2011).

Significant financial differences remain depending on respective hospital characteristics. Those differences are influenced by location, size, teaching status, system affiliation, and critical access designation among others (Turner et al., 2015). An important aspect differentiating hospitals, explored in academic literature, is their location (Kaufman et al., 2016; Zhang et al., 2018). In Poland, studies have compared the financial outcomes of public hospitals by location, as well as ownership and size (Miszczyńska, Miszczyński, 2021). Based on an analysis of 257 hospitals in Poland and their financial outcomes, the authors report no differences in debt levels between large and medium-sized hospitals. However, medium-sized hospitals run by voivodeships are less indebted than medium-sized county hospitals. Conversely, among large hospitals, those run by voivodeships are more indebted than large county hospitals. Similar studies concern the efficiency of rural and urban hospitals. Siedlecki et al. (2016), based on a study of 201 hospitals (103 rural and 88 urban), indicate that Polish rural hospitals have better financial indicators, are less indebted, and less prone to insolvency than urban hospitals. These are somewhat unusual findings compared to results in other countries, especially in the USA, where rural hospitals typically have worse financial outcomes and lower financial liquidity than urban hospitals. In the USA, this is such a significant issue that over 100 rural hospitals were closed from 2010 to 2019 (O'Hanlon et al., 2019). The poorer financial situation of rural hospitals is attributed to factors including lower health insurance uptake among rural residents, medical staff shortages (Bernd et al., 2016), smaller hospital sizes, and a decline in admissions in these hospitals (Pai, Dissanayake, 2022). Methods to increase their efficiency, such as expanding insurance programs, are also analyzed (Lindrooth et al., 2018). However, in European hospitals, the situation is different. For instance, Garcia-Lacalle and Martin (2010) point out that in the hospitals they studied in Spain, rural and urban hospitals perform similarly in terms of efficiency, but rural hospitals significantly outperform urban ones in patient satisfaction. The impact of agglomeration economies on hospital financial outcomes was examined by Krzeczewski, suggesting significant differences in financial outcomes depending on hospital location (Krzeczewski et al., 2019). Additionally, a cross-sectional study among Polish healthcare providers compared the financial outcomes of public hospitals, emphasizing differences depending on the size of the cities where hospitals are located (Dubas-Jakóbczyk et al., 2020). Financial outcomes of hospitals in the German hospital sector were also analyzed, providing insight into the relationship between ownership and financial outcomes (Augarzký et al., 2009). Moreover, a financial analysis of ten national



university hospitals in Korea from 2008-2011 revealed negative trends in their financial condition and business outcomes (Lee, 2015).

In summary, the literature review indicates that many factors influence the financial outcomes of hospitals, including hospital-physician collaboration, ownership and size of the hospital, clinical and process quality, use of electronic medical records, service quality, hospital location, and integration of financial activities at the hospital-physician interface. These factors play a significant role in shaping the financial outcomes of hospitals, highlighting the complex interaction of various elements determining a hospital's financial results. This study focuses on available data, excluding medical data related to internal and organizational processes not available in financial databases. It hypothesizes that the level of operational efficiency varies over time, mainly due to changes in healthcare funding levels. It also hypothesizes that the efficiency level of hospitals in different voivodeships is similar due to a uniform medical procedure pricing system nationwide. In relation to other differentiating factors, the study examines hospital performance in relation to the legal form of the entity and the dominant owner, aiming to determine the impact of these factors on operational efficiency.

## 2. Data and methods

In the article, secondary data derived from financial statements were utilized. These data were acquired from the ORBIS database on October 5, 2022, originating from the database update of September 30, 2022. The gathered data pertain to 2,455 entities operating in Poland with the primary activity code according to NACE Rev. 2 being 8610, indicating hospital activities. However, this code is often applied incorrectly to entities providing medical services other than hospital activities, such as primary care units, outpatient clinics, health resorts, and entities specialized in certain procedures like dialysis, dentistry, or plastic surgery. This misclassification occurs in practice as entities self-declare their sector and industry affiliation without significant verification by registering institutions.

Entities not strictly defined as hospitals were excluded in several steps. Initially, 1133 entities lacking essential financial data for the study were removed, leaving 1322 entities. From the remainder, 89 entities with financial data ending before 2012 were excluded, leaving 1233 entities. Subsequently, entities with revenues from sales in the last year of operation below 2.5 million euros were removed, excluding 500 entities and leaving 733. It was assumed that the smallest hospital under study should have revenues exceeding 2.5 million euros, approximately 11.5 million PLN, based on practical observations of hospitals with the smallest contracts with NFZ in Poland. In the next step, entities with specific words and their inflected forms in their names, qualifying them for the study, were retained. These terms included: hospital, clinical, clinic, center, mother and child, group, medical, American heart, SPZOZ,

NZOZ, independent, public, facility, care, healthcare. This process excluded 103 entities, leaving 630 for further analysis. Excluded entities were manually reviewed based on their websites, and if they conducted typical hospital activities (general or specialized hospitals), they were re-included in the research set. In total, 33 entities were added back, resulting in a final count of 663 entities. This set was then subjected to further manual analysis, and 23 entities with non-hospital and homogeneous activities (e.g., health resorts, clinics, diagnostic laboratories, dialysis stations) were removed. Following these adjustments, data pertaining to 640 entities were retained. Further verification steps for data consistency revealed that one entity appeared twice in the database, identified by different "BVD id numbers" (ORBIS database's internal index). This situation concerned the University Center for Women's and Newborn's Health of the Medical University of Warsaw Sp. z o.o. Data from the two records for this entity were merged, resulting in a final database of 639 entities subject to study.

The article employed procedures for analyzing descriptive statistics of the examined indicators and data characterizing the studied entities. Positional measures and quartile analysis were used, and the significance of distribution differences and medians were examined using the Kruskal-Wallis test. For examining differences in median indicators across different years, the Mann-Whitney U test was utilized. Data processing and calculations were performed in R language (2023), using the tidyverse, ggplot2, readxl, janitor, and openxlsx packages.

The presented data selection and cleaning procedure indicates that the ORBIS database may contain certain inaccuracies or errors. This somewhat limits confidence in the obtained results. It was assumed that the impact of data errors on the outcomes is low, as they do not occur for the largest entities. This does not affect the overall picture of the situation obtained in the descriptive statistical analysis of individual data and indicators. Outlier information in the research set was not subjected to correction or exclusion procedures. However, due to distribution inconsistencies with the normal distribution, as examined by the Shapiro-Wilk test, the focus was on median and quartile analysis.

### **3. Financial Aspects of Hospital Efficiency**

It should be noted that hospitals fulfill significant social functions as a primary component of the healthcare system. Their activity is not solely business-oriented but also carries high social significance. Therefore, in broadly examining their efficiency, it is necessary to consider not only financial but also economic, medical, health, and social outcomes. Such a multidimensional assessment of hospital efficiency goes beyond the scope of this article, which focuses exclusively on the financial measurement of hospital efficiency. However, the specificity of hospital operation and evaluation should be taken into account when interpreting financial indicators. In particular, profitability indicators based on net profit may

show lower levels, including negative ones over an extended period, especially when the owners are local governments or the State Treasury. This is an atypical situation for private businesses. Any losses reducing the net capital in companies running hospitals must be supplemented by public entities owning the hospital only to the level ensuring non-negative net capital. The second limitation in this case is the financial condition of the company running the hospital, i.e., according to bankruptcy law, it is necessary to ensure that the company is solvent. To prevent hospital insolvency, it is essential to ensure that the profitability calculated from EBITDA is positive, meaning that the hospital generates operational cash surpluses at a level sufficient to maintain financial liquidity. A negative value of such indicators quickly leads to financial difficulties for the hospital. Long-term maintenance of operational efficiency also requires asset replacement and growth investments, but these do not necessarily have to be self-financed, as the source of capital in such cases can be the public authority governing the hospital, which is interested in the development of local medical services. Of course, it would be advisable for self-financing of replacement and development to occur, but this is not a categorical condition for hospitals run by local governments or the State Treasury. Maintaining financial liquidity is in fact the only economic criterion for hospitals operating in the form of independent public healthcare facilities (a special legal form, discussed further in the article), as, due to regulations, their capital situation is irrelevant for the continuity of their operation. As practice shows, even this sole significant factor is often improperly controlled, resulting in some cases in the aforementioned phenomenon of excessive indebtedness of these entities.

In line with the above-mentioned details of measuring the financial efficiency of hospital operations, the article focuses on two types of profitability indicators: one calculated from net profits and the other from EBITDA. For both types of profitability indicators, three detailed indicators were calculated: profitability of sales, assets, and equity ( $ROS = \text{Profit (Loss) before tax} / \text{Operating revenue}$ ;  $ROA = \text{Profit (Loss) for period} / \text{Total Assets}$ ;  $ROE = (\text{Profit (Loss) for period} + \text{Interest Paid}) / (\text{Shareholders Funds} + \text{Non-Current Liabilities})$ ;  $ROS\_EBITDA$ ,  $ROA\_EBITDA$ ,  $ROE\_EBITDA$  are calculated similarly with  $EBITDA = EBIT + \text{Depreciation replacing profits in numerators of indices}$ ). However, it is essential to remember the specifics of the formation and operation of Polish hospitals. This includes, among others, that many hospitals run post-commercialization in the form of commercial law companies lease the most expensive equipment from hospital governing bodies. At the time of commercialization, governing bodies sometimes decided on a low level of own capital and assets in entities running hospitals, which theoretically was to protect the most valuable hospital assets from purchase associated with liquidation in case of continued liquidity problems of commercialized hospitals. Such a structure of operation of assets and capital in companies running hospitals affects the increase in the level of asset and equity efficiency indicators, so they should be analyzed taking into account the above-mentioned distorting factor. In particular, this may affect the efficiency indicators ROA and ROE as well as ROA\_EBITDA and ROE\_EBITDA.

Another important factor that must be considered in interpreting the results of profitability analysis is the still-present special legal form of hospital operation, namely the independent public healthcare facility (SPZOZ). According to the provisions of the Act on Medical Activity, this is a non-continued form, which means that currently, it is not possible to create new SPZOZs. The activity of SPZOZs has been regulated since 2011 by the provisions of the Act on Medical Activity. Characteristic of SPZOZs is that they are 100% publicly owned, without the legal possibility of private entities' participation, including, among other things, the absence of bankruptcy and the financial director's non-liability for debts exceeding the company's assets. This is one of the reasons for the lack of current motivation among managers to effectively control the costs of operations and the operating profile of SPZOZs. SPZOZs are not independent entrepreneurs but organizational units of the minister or selected government administration bodies, voivodes, local government units, or state medical universities or state universities conducting educational and research activities in the field of medical sciences. Consequently, any unpaid liabilities are de facto obligations of the entity creating the SPZOZ.

#### 4. Results

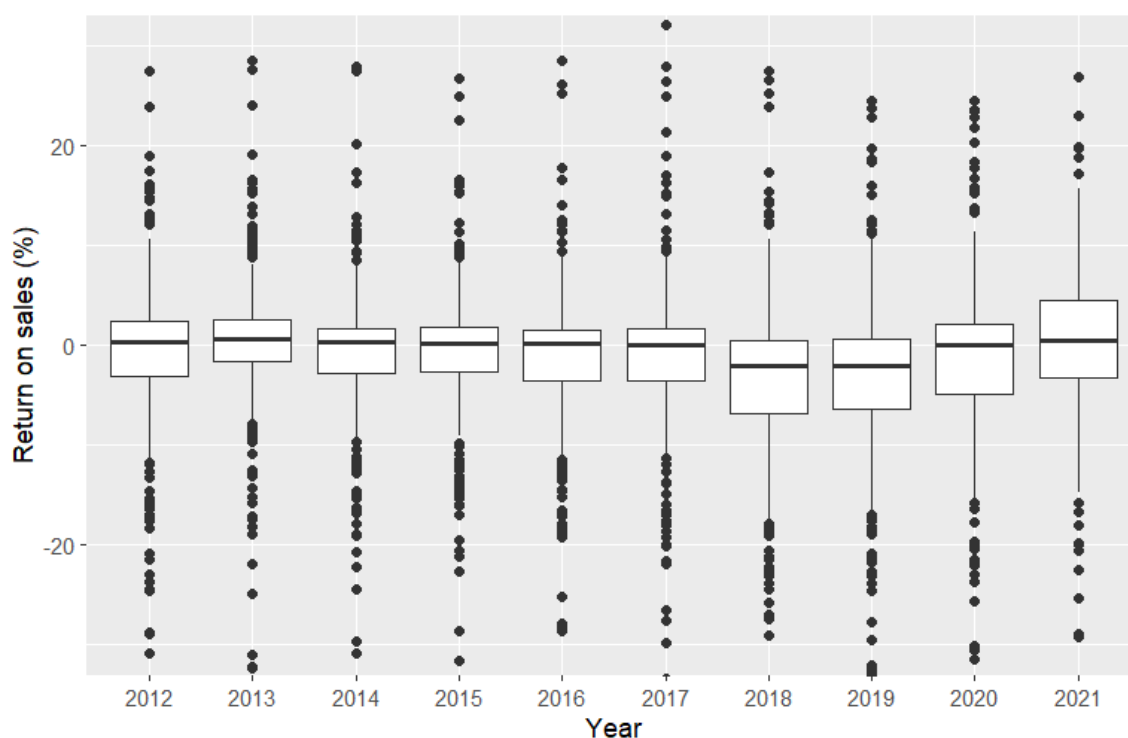
The exploratory data analysis commenced with examining changes in selected **profitability indicators in Polish hospitals for the period 2012-2021**. Descriptive statistics for the Return on Sales ratio (ROS) are presented in Table 1, while profitability according to other indicators can be found in Appendix Table 4. Based on annual data, box plots of the Return on Sales ratio for successive years were presented (see figure 1). In 2018, an interesting event was observed involving a sudden drop in efficiency. The median of the ROS indicator decreased by 2 percentage points compared to 2017, and other indicators behaved very similarly to the ROS, decreasing by approximately 2 percentage points (ranging from 1.7 to 2.8 percentage points). In the fourth quarter of 2017, the National Health Fund (Polish name Narodowy Fundusz Zdrowia, NFZ) implemented the Act on the so-called hospital network, the effects of which were fully visible for the first time in 2018. This was the most likely cause of the decline in hospital operational efficiency in 2018. An increase in the variability of efficiency indicators is also noticeable from that year onwards. This is likely due to the fact that in 2017, 594 facilities out of a total of 949 hospitals qualified for the hospital network, leaving the remaining 37% of hospitals outside it. The diversification of funding following the enactment of this law applied to both hospitals within the network, depending on hospital classification (six types of hospitals were distinguished), and hospitals outside the network (Dubas-Jakóbczyk et al., 2019). After the initial shock in 2018, adaptation to the changes is visible, leading to an increase in efficiency from 2020, reaching levels similar to those before the changes. This phenomenon is worthy of more detailed investigation, but it goes beyond the scope of this study.

**Table 1.***Descriptive statistics of Return on Sales in Polish hospitals in years 2012-2021*

year (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N	428	455	458	470	458	478	510	558	502	151
Min	-45,7	-98,9	-37,8	-71,6	-81,8	-67,7	-77,6	-67,1	-68,7	-33,6
Q1	-3,2	-1,5	-2,8	-2,7	-3,6	-3,5	-6,9	-6,3	-5,0	-3,3
Median	<b>0,3</b>	<b>0,6</b>	<b>0,3</b>	<b>0,2</b>	<b>0,1</b>	<b>0,0</b>	<b>-2,0</b>	<b>-2,1</b>	<b>0,0</b>	<b>0,5</b>
p(t-1,t)		0,0010 ***	0,0000 ***	0,4513	0,0037 ***	0,0913 *	0,0000 ***	0,4441	0,0000 ***	0,0061 ***
Q3	2,4	2,6	1,7	1,9	1,5	1,6	0,4	0,6	2,1	4,5
Max	38,2	28,4	27,9	26,6	28,4	32,0	27,4	99,7	99,6	26,8
Mean	<b>-0,6</b>	<b>0,0</b>	<b>-0,9</b>	<b>-0,8</b>	<b>-1,7</b>	<b>-1,3</b>	<b>-3,6</b>	<b>-3,2</b>	<b>-1,9</b>	<b>-0,2</b>
Std.dev.	8,1	8,6	6,5	7,2	8,6	7,8	9,0	9,4	10,7	9,4
Mean_95	<b>-0,5</b>	<b>0,4</b>	<b>-0,7</b>	<b>-0,6</b>	<b>-1,2</b>	<b>-1,0</b>	<b>-3,3</b>	<b>-3,0</b>	<b>-1,7</b>	<b>-0,1</b>

Note. ROS values in %; N – number of observations in a given year; Q1, Q3 – quartiles 1 and 3; p(t-1, t) – p-value of the U Mann-Whitney test among observations in year t-1 and t; \*\*\* p <= 0.01; \*\* p <= 0.05; \* p <= 0.1; Mean\_95 – ROS mean on observations truncated by 2,5% each side.

Source: own elaboration.

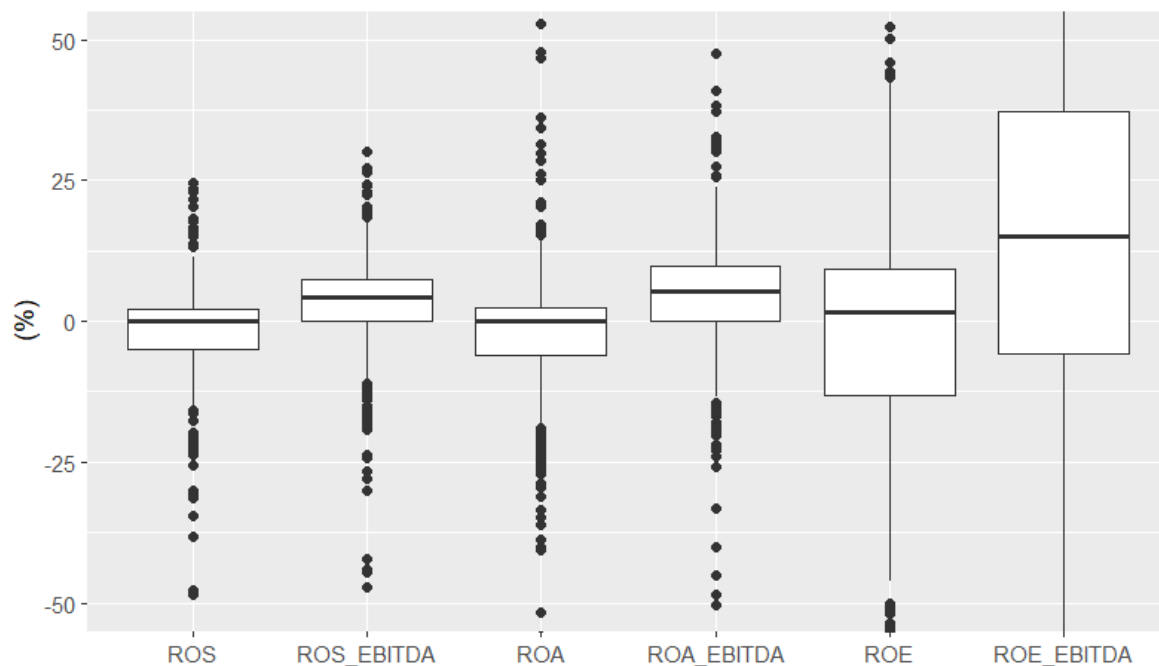
**Figure 1.** Hospitals' Return on sales by year.

Source: own elaboration.

The difference between the median in 2017 and 2018 is significant at the  $p < 0.01$  level (see Table 1). The median difference between 2018 and 2019 was not statistically significant, indicating that hospitals adapted over two years to changes in healthcare financing rules. As evidenced by the significances of differences measured by the Mann-Whitney U test (refer to Table 1), statistically significant differences in ROS median values also occurred in other years; however, these differences were not as dramatic as between 2017 and 2018 and during the return to the previous efficiency level in 2020. It is also important to note that 2020 was the

first year of the pandemic and additional funds allocated to support medical entities due to it. Certainly, these additional funds and the reduction in regular patient admissions, effectively reducing some costs while maintaining lump-sum compensation in the hospital network, contributed to their improved financial situation that year.

The sample sizes for each year vary depending on the completeness of data, ranging from 428 to 558 for the ROS indicator in the years 2012-2020, with the year 2021 being significantly lower at only 151. This is due to the lack of data inflow at the time of their acquisition from the Orbis database (September 2020). A similar situation applies to other efficiency indicators, with a data gap in 2015 for indicators calculated from EBITDA. Further analyzes in this article, if they concern specific years, will focus on 2020, with particular emphasis on changes occurring between 2017 and 2020.

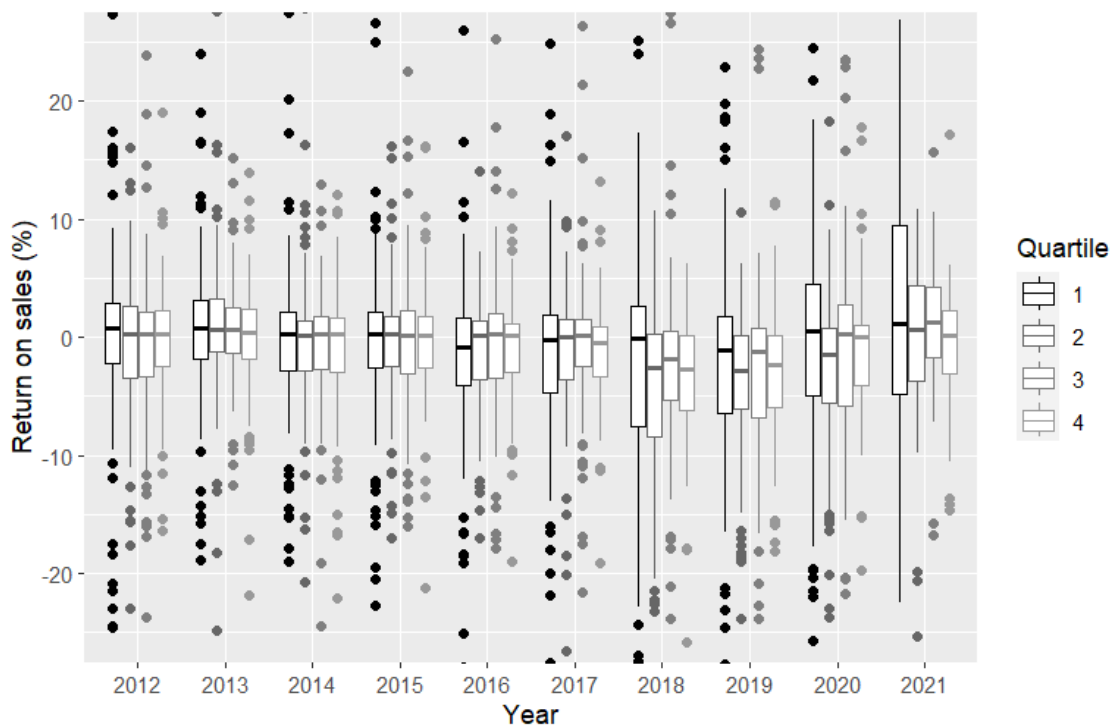


**Figure 2.** Hospitals' efficiency in 2020.

Source: own elaboration.

It should be noted that there is greater variability in the ROA and ROE indicators, especially those calculated from EBITDA (see Figure 2). This is due to the conservative approach of public hospital owners who, post-commercialization, equipped hospitals with relatively small assets. Often, high-value assets are not directly owned by the hospital but are merely leased from the public owner. The same applied to capital, which post-commercialization could be minimal and was supplemented only in subsequent years as needed, either for investment expenditures or to cover the previous year's losses.

The analysis, **segmented by company size**, was based on sales revenue. The study sample was divided each year into four quartiles. Comparisons were conducted between individual quartiles in selected years. The situation in years 2012-2021 is presented in Figure 3.



**Figure 3.** Return on sales by hospital size in 2017-2020.

Source: own elaboration.

The comparison of Return on Sales across groups of companies of varying sizes indicates a practically unchanged situation in these groups from 2012 to 2017. There is no statistical significance in the differences of medians measured by the Kruskal-Wallis test among all hospital size quartiles until 2018, when significant differentiation in profitability outcomes begins to appear across companies of different sizes (see Table 2). In the years 2018-2020, significant differences occur between quartiles 1 and 2, as well as 1 and 4, and in 2018 and 2020 between quartiles 2 and 3. From 2018, a decrease in the ROS median can be observed in companies of quartiles 2, 3, and 4 (refer to Table 2). The profitability of the smallest hospitals in 2018 did not decrease, although among these hospitals (from quartile 1), a decline in efficiency is noticeable in hospitals with ROS profitability lower than the median. Since 2018, there has also been an increase in the variability of profitability indicators in groups of companies of different sizes, affecting all quartiles. From 2020, there is an improvement in the situation of companies in all quartiles, and this trend continues into 2021. However, differences between quartiles remain and are statistically significant in the case of half of the pairs of indicators in the quartiles (see Appendix Table 5). It should be remembered that the sample size in the last year of the study is significantly smaller than in previous years, which may affect the significance of the results obtained in 2021.

Unusually, the smallest companies, where the ROS efficiency indicator slightly decreased only in 2019, behave differently. The change in the NFZ's financing system caused a greater dispersion of results obtained by companies of all quartiles by company size in 2018, although this is most visible in quartiles 1 and 2. It seems that in the case of hospitals in the first two

quartiles, the mechanism of qualifying hospitals to the hospital network had a sharp effect, causing both an increase in efficiency for some hospitals and a decrease in efficiency for other hospitals in these quartiles.

**Table 2.**

*Descriptive statistics of Return on sales (2018-2020) categorized by hospital size quartiles based on revenues*

Year	2017				2018			
Turnover quartile	1	2	3	4	1	2	3	4
N	119	119	120	120	125	128	129	128
Min	-67,7	-26,5	-29,8	-29,8	-77,6	-23,1	-35,2	-25,8
Q1	-4,7	-3,6	-2,5	-3,4	-7,6	-8,4	-5,4	-6,2
<b>Median</b>	<b>-0,2</b>	<b>0,0</b>	<b>0,1</b>	<b>-0,4</b>	<b>-0,1</b>	<b>-2,6</b>	<b>-1,8</b>	<b>-2,7</b>
Q3	1,9	1,5	1,5	0,9	2,6	0,2	0,5	0,1
Max	32,0	27,9	26,4	13,1	25,1	10,7	27,4	6,3
<b>Mean</b>	<b>-2,4</b>	<b>-0,8</b>	<b>-0,7</b>	<b>-1,2</b>	<b>-3,6</b>	<b>-4,5</b>	<b>-2,7</b>	<b>-3,4</b>
Std.dev.	11,8	6,2	6,5	5,0	14,2	6,5	7,9	4,8
<b>Mean_95</b>	<b>-2,1</b>	<b>-0,8</b>	<b>-0,7</b>	<b>-1,1</b>	<b>-2,6</b>	<b>-4,3</b>	<b>-2,7</b>	<b>-3,2</b>
Year	2019				2020			
Turnover quartile	1	2	3	4	1	2	3	4
N	139	139	140	140	125	126	126	125
Min	-67,1	-51,3	-34,3	-43,5	-68,7	-38,3	-21,7	-48,4
Q1	-6,5	-6,1	-6,8	-5,9	-5,0	-5,5	-5,8	-4,0
<b>Median</b>	<b>-1,1</b>	<b>-2,9</b>	<b>-1,2</b>	<b>-2,3</b>	<b>0,6</b>	<b>-1,5</b>	<b>0,2</b>	<b>0,0</b>
Q3	1,7	0,2	0,8	0,2	4,5	0,7	2,8	1,0
Max	22,8	10,5	99,7	11,5	24,5	18,3	99,6	17,7
<b>Mean</b>	<b>-3,1</b>	<b>-3,8</b>	<b>-2,3</b>	<b>-3,4</b>	<b>-2,4</b>	<b>-3,4</b>	<b>-0,2</b>	<b>-1,7</b>
Std.dev.	11,5	6,7	11,5	6,5	14,2	8,0	11,9	6,8
<b>Mean_95</b>	<b>-2,7</b>	<b>-3,4</b>	<b>-2,9</b>	<b>-3,1</b>	<b>-1,4</b>	<b>-3,1</b>	<b>-1,0</b>	<b>-1,4</b>

Note. ROS values in %; N – number of observations in a given year; Q1, Q3 – ROS quartiles 1 and 3; Mean\_95 – ROS mean on observations truncated by 2,5% each side.

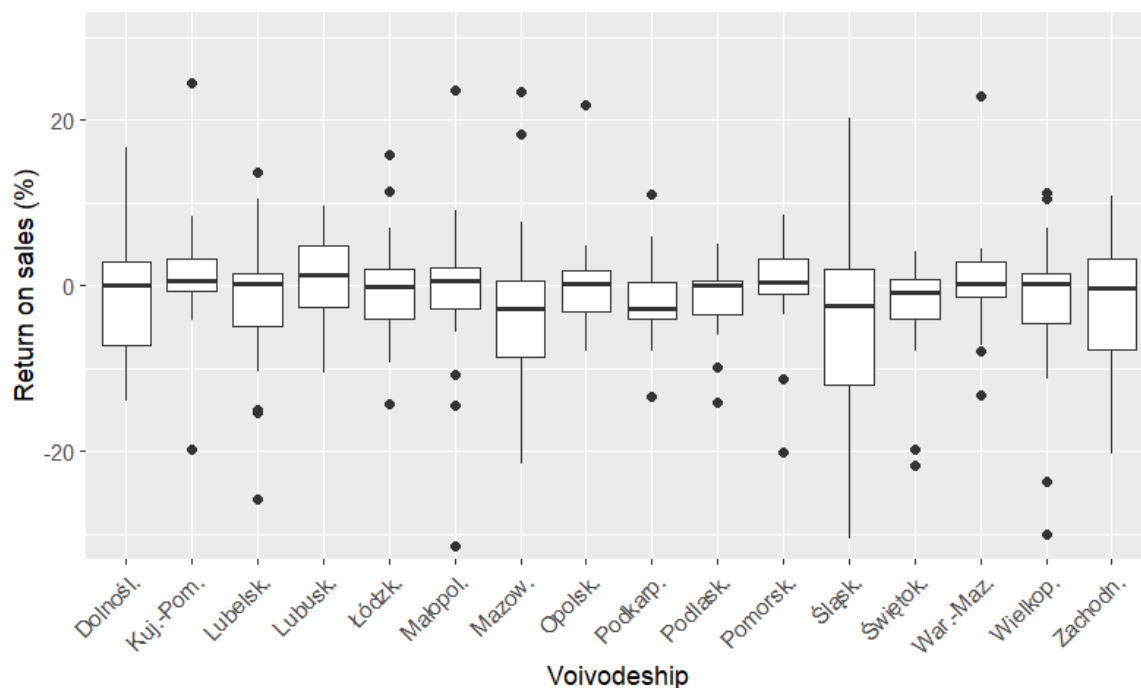
Source: own elaboration.

The division of companies **operating in different voivodeship** should not, in theory, indicate differences in efficiency, as most of the analyzed hospitals derive their revenue primarily from contracts with the National Health Fund (NFZ), usually covering over 95% of revenues. However, an analysis of efficiency indicators reveals significant differences in some voivodeships. In the case of the Return on Sales ratio, lower efficiency indicators occur in the Mazowieckie, Śląskie, and Podkarpackie voivodeships (refer to Figure 4, detailed data in Appendix Table 6). Similar results apply to other profitability indicators. Considering all efficiency indicators, the Świętokrzyskie voivodeship should be added to the three voivodeships with the least efficient hospitals (see Table 3). The median ROS in Mazowieckie is statistically significantly different from the median ROS in other voivodeships in 60% of cases (9/15), in Śląskie in 27%, in Podkarpackie in 20%, and in Świętokrzyskie in 27% of cases. The best efficiency results are found in hospitals in the Lubuskie, Kujawsko-Pomorskie, Małopolskie, and Pomorskie voivodeships. The medians of the ROS indicator in these voivodeships are significantly different from medians in other voivodeships in 27% of cases comparing other voivodeships to Lubuskie, 33% to Kujawsko-Pomorskie, 20% to Małopolskie, and 27% to Pomorskie.



Such varied profitability results of hospitals in individual voivodeships are surprising due to theoretically identical financing principles. However, differences in profitability may result from the specificity of voivodeships, both in terms of the health situation in individual voivodeships and the structure of hospital types in their area. As indicated by the report of the Supreme Audit Office, there are also differences in the prices of the same services purchased by the National Health Fund from medical entities (NIK, 2019). This phenomenon is justified in the NIK report (2019) by regional differences, the reference level of entities, as well as the financial capabilities of individual provincial branches of the Fund, i.e. the offer by medical entities of a price lower than expected in the competition procedures announced by the provincial branches of the National Health Fund or the results of negotiations. There are also differences in access to services, which ultimately affect the efficiency of hospitals. According to the Supreme Audit Office (2019), the factors influencing differences in access to services include: uneven distribution of the material base of the system, including the structure of the services provided, differences in the development and distribution of medical potential throughout the country and voivodeships, especially medical staff, historical events, provision of similar services in various scopes, behavior of healthcare providers, but also the financial status of patients, level of education, place of residence and age.

The observed decrease in efficiency in 2018 across the entire sample affected hospitals in individual voivodeships differently. The changes in efficiency in 2018 are practically cosmetic and positive in the Lubuskie voivodeship, where an increase in hospital efficiency measured by the median ROS of 0.3 percentage points was noted, while the largest decrease in operational efficiency was recorded in the Podlaskie voivodeship – a decrease in the median ROS of 4.2 percentage points.



**Figure 4.** Return on sales in hospitals by voivodship in 2020.

Source: own elaboration.

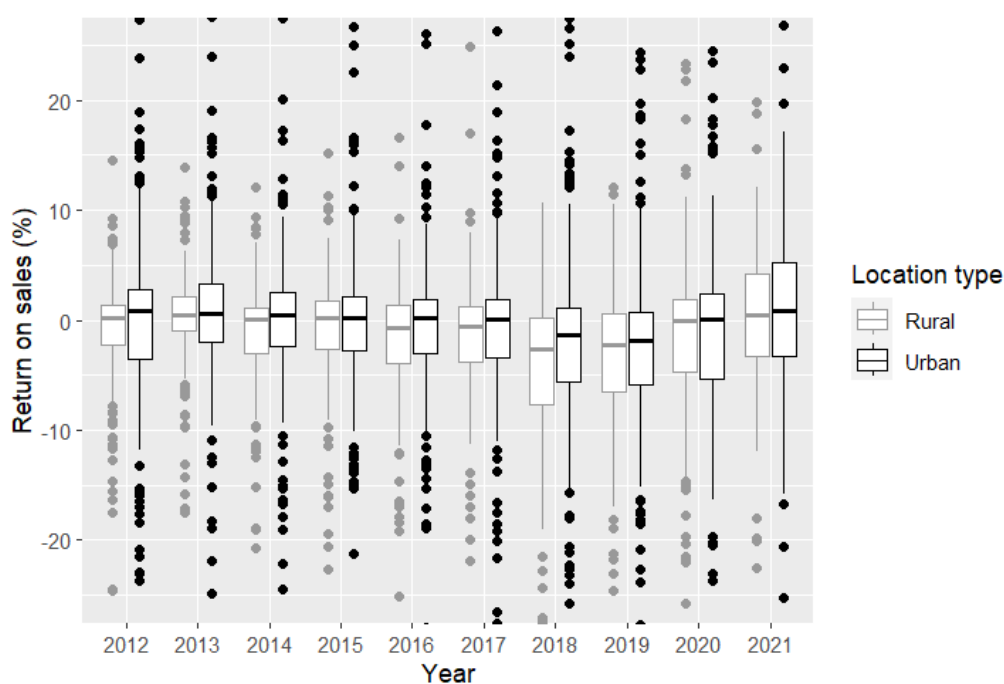
**Table 3.**  
*Profitability of hospitals by voivodeships in 2020*

Voivodeship	ROS	ROA	ROE	ROS EBITDA	ROA EBITDA	ROE EBITDA
Dolnośląskie	0,0	0,0	3,0	4,2	6,0	17,5
Kujawsko-Pomorskie	0,6	0,6	4,8	4,1	8,2	15,8
Lubelskie	0,2	0,2	3,5	4,3	5,1	2,0
Lubuskie	1,3	0,8	10,1	6,6	7,1	33,3
Mazowieckie	-2,8	-3,0	-3,6	3,6	3,2	6,6
Małopolskie	0,5	0,5	2,9	5,8	5,6	24,3
Opolskie	0,2	0,1	1,6	4,7	6,7	19,1
Podkarpackie	-2,8	-3,0	0,6	3,1	2,8	13,9
Podlaskie	0,1	0,1	2,6	6,0	7,1	18,8
Pomorskie	0,4	0,6	1,7	6,6	6,1	17,7
Warmińsko-Mazurskie	0,2	0,3	2,7	5,0	6,0	7,1
Wielkopolskie	0,2	0,2	1,5	3,9	5,9	18,7
Zachodniopomorskie	-0,3	-0,8	-5,2	4,2	7,6	-11,3
Łódzkie	-0,1	0,0	5,2	3,2	6,4	19,0
Śląskie	-2,4	-2,7	1,3	1,9	2,5	11,1
Świętokrzyskie	-0,9	-1,1	1,1	2,9	4,2	8,3

Note. values in %.

Source: own elaboration.

The comparison of efficiency by voivodeships shows differences in health policy and the structure of hospitals and medical procedures in various regions of the country. The literature also highlights differences in the efficiency of **urban (regional) and rural (local) hospitals**. For the purposes of this study, urban (regional) hospitals are those located in larger cities where they are not the only hospitals. Conversely, rural (local) hospitals are those situated in smaller towns, where they are the sole hospitals. The efficiency of hospitals in both groups is illustrated in Figure 5.

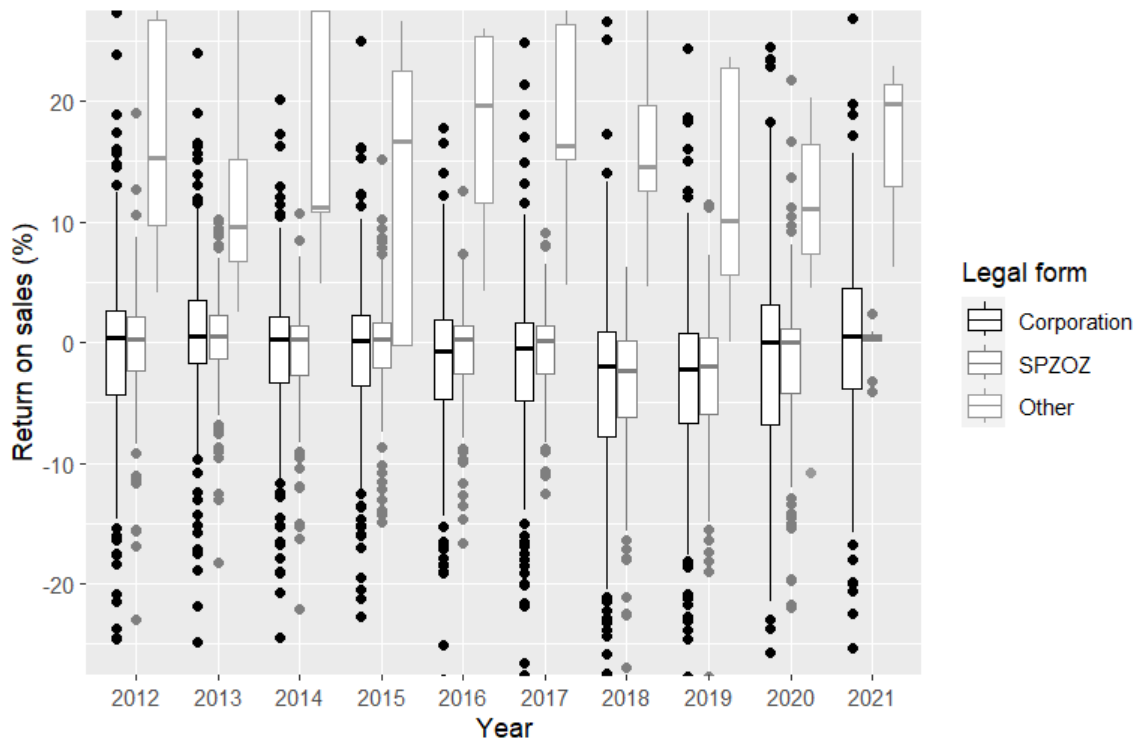


**Figure 5.** Return on sales in hospitals by location type in 2012-2021.

Source: own elaboration.

In almost all the studied years, rural hospitals exhibit a lower level of efficiency, yet the significance of the difference in the Return on Sales (ROS) medians only appears in the years 2012, 2014, 2016, 2017, and 2018 (refer to Appendix Table 7). In the years 2020 and 2021, the difference between the efficiency of urban and rural hospitals was practically eliminated, largely due to the funds supporting hospital operations in response to the COVID-19 pandemic. It can be said that these additional funds saved the efficiency of rural hospitals in 2020 and 2021. A very similar situation occurs with respect to other efficiency indicators, with almost all indicators in 2018 showing a statistically significant difference in median efficiency between the two types of hospitals (urban and rural) at a high significance level of  $p < 0.01$  (except for the ROE\_EBITDA indicator, for which the significance of the median difference does not occur). This indicates that the changes to the financing system introduced by the NFZ in 2017 affected rural hospitals more, as evidenced by the increase in the ROS median difference in 2018 and the shape of the statistical distribution of this indicator in 2018 compared to 2017.

Polish hospitals are essentially **operated in two legal forms**. The first is the historically dominant form of an independent public health care facility (abbreviated as SPZOZ), an entity providing health care that is not an entrepreneur. Such an entity does not have a separate legal personality and constitutes a separate part of the entity creating the hospital. The founding entity is most often a local government, a university or a ministry. The entire responsibility for the activities of SPZOZ rests with the founding body. They are responsible for entrusting the day-to-day management of the hospital to competent persons and for supervising their activities and results. The second legal form is commercial law companies, most often a limited liability company, less often a joint-stock company. In this case, the company operating the hospital as a legal entity bears all the consequences of its actions, therefore operational efficiency directly affects its functioning and survival. Additionally, there are completely private hospitals, of which there are exactly nine in the sample. They operate in the form of a limited partnership or a general partnership, and in some cases, a partner in a civil partnership is also a limited liability company. These entities are various forms of civil partnerships in which the owners (or selected owners in the case of limited partnerships) are responsible for the company's activities with their entire assets. The hospitals run by these entities are not multi-specialty and operate on the basis of several departments, only a small part of which is financed under contracts with the National Health Fund. Figure 6 shows that these entities are much more effective than other hospitals, which are mainly multi-specialty and almost entirely financed by the National Health Fund.

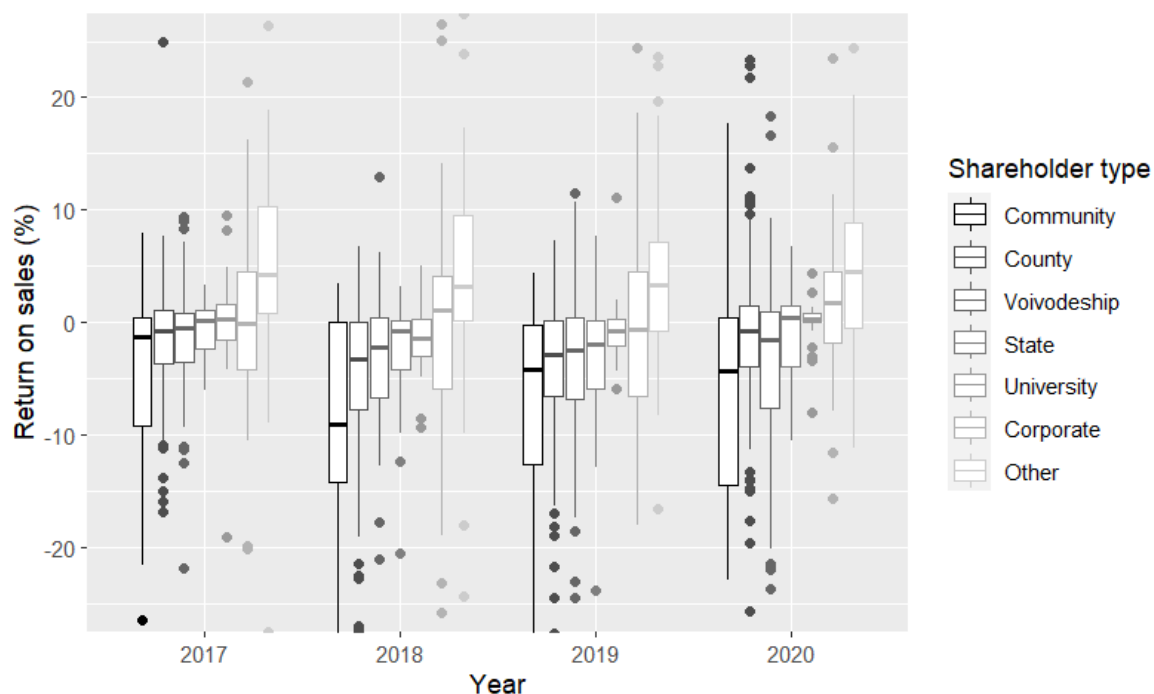


**Figure 6.** Return on sales in hospitals by legal form in 2012-2021.

Source: own elaboration.

Entities operating in the two dominant legal forms demonstrate very similar profitability across all years. Only in the years 2016, 2017, and 2018 are minor differences in median levels noticeable (refer to Appendix Table 8), with only in 2016 these differences being statistically significant (except for the ROE and ROE\_EBITDA indicators). This suggests that legal form is not a significant characteristic affecting the achievement of markedly better economic outcomes. This is a consequence of almost complete funding of these entities from the NFZ, impacting both types of entities similarly. It also implies that these entities are managed very similarly, with even a slightly greater diligence observed in hospitals operated as SPZOZs in achieving better results. In 2016 and 2017, worse results can even be observed in hospitals operating as commercial law companies compared to the somewhat archaic form of SPZOZs, which, as it turns out, even manages better than corporate entities. Of course, these statements do not apply to hospitals operating as civil partnerships, most often single-profile or with a small number of departments and significantly lower NFZ funding than other hospitals. These entities achieve much higher profitability (median ROS and other indicators above 10%). It seems, therefore, that the problem lies in NFZ funding. However, it should be remembered that hospitals have low bargaining power relative to main workers (doctors) due to a shortage of doctors in most specialties in Poland. The ratio of doctors per 100,000 inhabitants is significantly lower in Poland compared to other European Union countries (344 in 2021 compared to an EU average of 406 doctors per 100,000 inhabitants, Eurostat data).

The last criterion examined is the **ownership of the hospital** or the entity operating the hospital. The main owners of hospitals or entities operating hospitals are local government units (communities, counties, and voivodeships), universities, ministries, and commercial law companies. It is very rare for hospitals to be owned by private individuals, foundations, associations, or churches. These last cases were grouped into one category labeled 'Other'. Owners marked as community, county, and voivodeship refer to hospitals operated by local authorities at various levels. Community hospitals are usually hospitals operated by medium and large cities. County hospitals are typically rural-type hospitals located some distance from larger cities. Voivodeship-supervised hospitals are multispecialty hospitals, usually larger, and sometimes very large or specialized hospitals located in various locations (both in large cities and away from major centers). Hospitals classified as 'State' are hospitals operated by various ministries, usually located in larger cities. These include, for example, multispecialty hospitals operated by the Ministry of National Defense. However, most hospitals in this group are directly under governance of the Ministry of Finance. University hospitals are clinical hospitals that handle the most severe medical cases. They also conduct scientific research and implement innovations. Hospitals operated by corporations are usually two types of hospitals. These are privatized multispecialty hospitals in various locations and specialist hospitals focusing on well-paid medical procedures.



**Figure 7.** Return on Sales in hospitals by shareholder type in 2017-2020.

Source: own elaboration.

The results of the profitability analysis indicate that the type of owner has a significant impact on profitability outcomes. The impact of the changes to the NFZ financing system in 2017 most significantly reduced the efficiency of community hospitals (see Appendix Table 9). It can be surmised that some of these hospitals simply did not make it into the hospital network

and consequently received poorer funding for their operations. Since 2018, the ROS profitability level for these hospitals has been significantly lower than for other hospital groups in this division. County and voivodeship hospitals do not differ significantly in terms of operational profitability measured by the ROS indicator. Also, the profitability of hospitals overseen by the State Treasury maintains similar levels, although hospitals with very low profitability are less common in this group. University clinics achieve very similar results to hospitals managed by the State. Hospitals operated by corporate entities achieve better results than local government hospitals. Finally, the last of the examined groups – other owners, have decidedly better profitability outcomes compared to the previously mentioned owner groups. However, it should be remembered that hospitals in the Other category often generate revenues outside of the NFZ, which naturally allows them to achieve higher levels of profitability.

## 5. Discussion

The study presents results from an exploratory data analysis concerning the profitability of hospitals in various segments. The identified differences in profitability shaping can often be attributed to objective factors influencing the observed differences in profitability indicators. However, in many instances, the results are surprising and different from those in previous studies.

The differences in the profitability results of Polish hospitals are influenced by the following objective factors and processes identified in this study:

1. Changes in the law and financing rules implemented by the NFZ during the observed period, evident in the decrease in hospital profitability in 2018.
2. Hospitals' adaptation to the aforementioned changes, visible in maintaining lower profitability in 2018-2019 and an increase in hospital profitability in 2020 and 2021.
3. Additional funding for hospitals during COVID-19 prevention measures in 2020 and 2021, resulting in increased profitability in those years. Similar effects of COVID-19 prevention measures were present in the USA (Li et al., 2023).
4. Hospital size, which started to significantly differentiate hospital profitability from 2018 onwards following changes in the law and NFZ financing rules. Interestingly, the worst profitability results were achieved by the biggest hospitals (fourth quartile measured by revenues), but from 2018, hospitals in the third size quartile began catching up, and from 2019, hospitals of this quartile recorded the worst results. Conversely, since 2018, the smallest hospitals have better results than the others. This contradicts the theoretical expectations that scale effect would result in higher efficiency in the largest hospitals what is generally observed in other countries (Rosko et al., 2020). It turns out this is not the case in Poland.

5. The country's region (voivodeship). These results were quite unexpected, as it was assumed that there would be no differences in hospital operating efficiency between voivodeships due to theoretically the same financing rules and levels of medical procedure valuation. As indicated by the report of the Supreme Audit Office in reality, there are differences in the prices of the same services purchased by the National Health Fund from medical entities (NIK, 2019) and regional differences in access to services, which ultimately affect the efficiency of hospitals.
6. Division into rural and urban hospitals – since the COVID-19 pandemic, there has been virtually no differences in the profitability of rural and urban hospitals. In previous years, a slight yet sometimes statistically significant advantage in efficiency was observed for urban hospitals, thus findings were consistent with international literature (O’Hanlon et al., 2019; Pai, Dissanayake, 2022) but contradicting with findings from Polish hospitals (Siedlecki et al., 2016). However, this has changed since 2020. It is important to remember that comparable studies' findings were also pre-COVID, and it is unknown whether the situation changed there during the COVID-19 pandemic as it did in Poland.
7. The legal form of hospital operation (SPZOZ or a company) does not affect their operating efficiency except for 2016, when statistically significant difference in efficiency was observed in favor of entities operated as SPZOZs, which is also quite unexpected. The lack of differences in efficiency among entities does not apply only to private hospitals other than multispecialty operating as civil partnerships. The literature notes the assertion, backed by research (Tiemann, Schreyögg, 2012), that commercial law entities (corporate companies) take better care of profitability (Augarzky et al., 2009; Herr et al., 2011), as they operate under the pressure to maintain financial liquidity and capital financial stability. However, the situation reported in international literature is not entirely comparable to the situation in Poland, as both types of entities in Poland are operated by public authorities at various levels and public institutions. The lack of differentiation in profitability of hospitals operated in different legal forms can be attributed to equal funding of both types of entities by the NFZ. A greater diligence in operating efficiency by SPZOZ entities can even be observed, evidenced by the clearly lower range of interquartile deviation (IQR) in the profitability of these entities in each year.
8. Hospital owner – there is a differentiation between the profitability of local government hospitals and hospitals of other owners. This particularly applies to community hospitals, which in practically all years have significantly lower median efficiency indicators compared to other types of owners. A similar situation applies to county hospitals, which usually had significantly lower profitability indicators than other local government hospitals, although in 2020, county hospitals achieved significantly higher profitability than voivodeship hospitals.

Beyond the presented results, the quite large deviations in observed profitability across all segments are puzzling, both towards lower and higher values. This means that apart from the studied factors influencing hospital operating efficiency, there are other factors differentiating the profitability of these entities. These are likely specific factors for individual hospitals such as the structure and size of hospital departments, hospital cooperation with doctors, clinical quality and process quality, patient satisfaction, use of electronic medical records and electronic document flow, cooperation with the payer, and solutions used in contracts with the NFZ, which are studied in the literature cited earlier. This opens the possibility for further research on the dependency of profitability on other shaping factors. A desirable direction for research would be to link hospital operating profitability with their medical activity structure and detailed organization methods. Identifying which hospital departments are part of the organizational structure and how they influence achieving high or low levels of financial efficiency would be extremely valuable in this aspect. Of course, the results would generally depend on the valuation of medical procedures, and specifically on the structure of medical procedures in each department, as well as on their actual costs. Unfortunately, such a study, albeit extremely valuable and interesting, is very demanding in terms of input data, which is not available in typical databases describing the operation of economic entities, including hospitals.

Another direction for extending hospital profitability research is to link it with economic and medical parameters describing the operation of each hospital, such as the number of beds, number of procedures and operations, number of medical staff, patient readmission rate, and other detailed medical and economic data. In this analysis expansion, there are also very significant difficulties in data acquisition. The mentioned characteristics are indeed reported by hospitals to the NFZ and the Ministry of Health, but access to these data, even for research purposes, is limited.

Further research should also cover identifying the impact of additional funds related to COVID-19 pandemic prevention. As the data analysis shows, the COVID-19 pandemic generally helped hospitals achieve a higher level of efficiency thanks to the additional funds pumped into hospitals during this period. The smallest effect of this assistance occurred in hospitals run by communities.

Another important topic for further exploration arising from this study is the reaction of hospital profitability to changes in the NFZ financing system in 2017. Overall, this reaction is negative and reduced hospital operating efficiency in 2018 and 2019. What this analysis failed to investigate is the impact of qualifying or not qualifying hospitals for the so-called hospital network on their operating efficiency. The study did not have data on qualification for the hospital network, and it is unknown whether the decrease in efficiency in 2017 affected only entities outside the hospital network, entities within the network, or both groups of hospitals simultaneously. Therefore, this presents an assumption for further research.



Of course, the techniques used to divide the population into homogeneous groups and the applied data cleaning procedure were not entirely unambiguous, as in some points they relied on qualification for individual subgroups of the studied hospitals according to characteristic formulations in the hospital's name itself or in the name of the entity establishing the hospital (or dominant entity – in the case of commercial law companies). This means that in individual groups, there may have been individual cases of hospitals that were misclassified, especially misclassified generally among hospitals subject to the study. This is due to some voluntariness in the entity's decision regarding the main type of activity shown in the NACE code, which additionally is not strictly verified by register courts and other public institutions. Often, there is a factor of ennoblement to a respected group of entities (hospitals) based on the mere declaration of the primary activity as hospital activity despite the fact that the actual activity includes fragmentary medical activity in addition to non-hospital character. This could have caused minor distortions in the results obtained, but the study's advantage was the manual verification of approximately 20% of entities qualified for the study and the relatively small extent to which non-hospital activities were included in this group.

## 6. Summary

The search for factors influencing the profitability of hospital operations through division into homogeneous groups does not always yield entirely unambiguous results, and in some aspects, further research is required. It was determined that factors such as time and changes in financing methods with the payer (NFZ) occurring during the study period, location in a selected region of the country, hospital size, urban or rural location, and type of owner influence efficiency. However, no differences in the efficiency of hospitals operated in different legal forms (corporate or SPZOZ) were confirmed. Also, differences between the efficiency of urban and rural hospitals are not significant in every studied year, especially in the last two years of the study.

The findings of this study add valuable insights to the ongoing discourse on operational efficiency within healthcare institutions, opening avenues for additional investigative queries that extend beyond the context of Polish hospitals. These insights hold relevance for a diverse audience encompassing academic researchers, policy makers at both local and central levels, healthcare sector practitioners, as well as academic institutions overseeing clinical hospitals. Moreover, they bear significance for governmental bodies such as the Ministry of National Defense, which administers hospitals for uniformed services, and the Ministry of Health alongside the National Health Fund, which collectively steward the healthcare system in Poland.

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## Appendix

**Table 4.**  
*Profitability of Polish hospitals in years 2012-2021*

	ROA									
year (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N	426	455	461	470	458	477	510	558	502	151
Min	-85,7	-68,3	-87,3	-93,7	-88,4	-77,5	-93,9	-97,4	-82,9	-90,2
Q1	-3,7	-2,2	-4,0	-3,4	-5,1	-4,4	-8,8	-8,6	-6,1	-4,1
Median	0,5	0,8	0,2	0,2	0,1	0,0	-2,8	-2,8	0,0	0,7
p(t-1,t)		0,0074	0,0000	0,3594	0,0041	0,4542	0,0000	0,7997	0,0000	0,0834
		***	***		***		***		***	*
Q3	3,0	3,3	1,9	2,1	1,7	1,7	0,5	0,5	2,4	6,0
Max	42,3	41,0	47,9	48,4	57,1	79,3	68,8	69,6	70,0	62,7
Mean	-0,9	0,3	-1,9	-1,1	-1,9	-1,3	-5,2	-5,2	-2,4	-0,9
Std.dev.	12,3	9,9	11,5	9,1	9,9	10,8	14,9	14,9	13,3	18,1
Mean_95	-0,3	0,8	-1,2	-0,8	-1,5	-1,3	-4,7	-4,7	-2,2	-0,4
	ROE									
year (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N	335	370	372	381	360	368	372	394	350	128
Min	-951,7	-519,4	-527,3	-544,7	-752,5	-627,9	-844,6	-903,3	-874,7	-285,6
Q1	-4,7	-1,7	-5,0	-5,6	-10,2	-8,3	-20,1	-20,8	-13,2	-4,1
Median	2,1	2,3	0,9	1,2	0,5	0,4	-2,1	-2,8	1,5	3,8
p(t-1,t)		0,0903	0,0000	0,0222	0,0000	0,1323	0,0000	0,0041	0,0087	0,1578
		*	***	**	***		***	***	***	
Q3	10,1	9,6	5,8	6,5	4,8	5,3	2,6	2,8	9,3	12,6
Max	387,1	758,7	680,1	187,0	570,2	826,1	718,1	199,3	243,6	117,8
Mean	-4,6	4,4	-3,2	-6,4	-11,9	-6,7	-18,1	-33,2	-23,9	-2,7
Std.dev.	93,6	80,5	58,4	48,5	83,3	75,9	95,3	112,4	118,2	52,5
Mean_95	0,5	3,0	-1,5	-3,4	-5,0	-4,0	-12,5	-22,4	-13,0	0,7
	ROS_EBITDA									
year (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N	387	411	416	0	459	479	514	560	503	151
Min	-1862,5	-97,2	-2644,8	NA	-80,8	-134,9	-145,2	-171,6	-47,1	-23,9
Q1	2,6	3,4	2,4	NA	0,9	1,0	-2,2	-1,4	0,1	-0,1
Median	5,4	5,9	5,1	NA	4,3	3,9	2,1	2,4	4,2	4,9
p(t-1,t)		0,0003	0,0000		0,0443	0,5252	0,0000	0,3315	0,0000	0,1106
		***	***		**		***		***	
Q3	8,4	8,9	8,2	NA	7,7	7,2	6,0	5,8	7,3	9,1
Max	44,6	38,7	39,0	NA	33,9	43,3	4385,7	99,8	99,7	27,0
Mean	0,7	5,8	-3,3	NA	3,8	3,7	9,3	1,3	3,0	4,0
Std.dev.	95,3	8,8	134,2	NA	9,2	10,0	193,9	13,0	9,9	9,0
Mean_95	5,5	6,2	5,0	NA	4,2	4,1	1,7	1,9	3,2	4,1
	ROA_EBITDA									
year (t)	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N	387	411	416	0	460	480	514	561	503	151
Min	-265,7	-162,6	-95,1	NA	-122,7	-1621,4	-180,5	-188,8	-157,0	-90,2
Q1	3,4	4,2	2,8	NA	1,2	1,4	-3,3	-2,0	0,1	-0,2
Median	7,4	7,6	6,4	NA	5,4	5,1	3,1	3,2	5,4	6,3
p(t-1,t)		0,0364	0,0000		0,1071	0,7852	0,0000	0,0436	0,0000	0,0488
		**	***				***	**	***	**
Q3	11,6	11,9	10,7	NA	9,7	8,9	7,0	7,2	9,7	12,5
Max	180,5	57,4	67,0	NA	76,8	110,4	79,2	85,2	93,2	100,8
Mean	6,9	7,8	5,9	NA	4,6	1,3	0,7	1,6	4,2	6,3
Std.dev.	21,1	13,2	12,8	NA	13,3	76,5	19,5	17,3	15,6	19,3
Mean_95	7,7	8,3	6,5	NA	5,2	5,3	1,6	2,1	4,3	6,3

year (t)	ROE_EBITDA									
	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
N	387	411	416	0	460	480	515	561	503	151
Min	-3038,1	-4100,0	-96766,7	NA	-4206,6	-6148,7	-1871,9	-2350,2	-11700,0	-223,8
Q1	1,4	5,1	2,7	NA	-0,4	-3,1	-9,0	-5,1	-5,9	2,5
Median	14,4	17,3	14,3	NA	11,2	10,5	8,1	9,5	15,1	18,2
p(t-1,t)		0,4261	0,0000		0,0119	0,0139	0,0002	0,4836	0,2089	0,2824
			***		**	**	***			
Q3	32,7	37,2	31,6	NA	25,8	24,6	24,3	26,8	37,1	43,2
Max	14895,3	12003,7	1479,8	NA	1281,4	6320,0	9446,2	42815,0	23890,2	2619,8
Mean	51,8	46,3	-243,2	NA	-9,2	16,5	34,7	140,9	25,9	40,5
Std.dev.	802,0	635,4	4762,8	NA	297,6	435,9	451,3	2026,2	1265,3	229,6
Mean_95	15,5	22,4	16,8	NA	11,0	12,3	11,5	10,0	15,2	20,3

Note. values in %; N – number of observations in a given year; Q1, Q3 – quartiles 1 and 3; p(t-1, t) – p-value of the U Mann-Whitney test among observations in year t-1 and t; \*\*\* p <= 0.01; \*\* p <= 0.05; \* p <= 0.1; Mean\_95 – mean on observations truncated by 2,5% each side, NA – not available.

Source: own elaboration.

**Table 5.**

*Statistical significance of median Return on Sales variations by revenue-based hospital size quartiles in Polish hospitals in 2018-2020*

Year	2017			
Quartile	1	2	3	4
1		0,5980	0,4823	0,8825
2	0,0178**		0,8714	0,3791
3	0,4330	0,0627*		0,2536
4	0,0660*	0,5339	0,1680	
Year	2018			
Year	2019			
Quartile	1	2	3	4
1		0,0607*	0,3947	0,0966*
2	0,0014***		0,2692	0,7407
3	0,3178	0,0198**		0,3806
4	0,0317**	0,1693	0,2980	
Year	2020			

Note. p-values of the Kruskal-Wallis test among observations in respective quartiles of a given year; \*\*\* p <= 0.01; \*\* p <= 0.05; \* p <= 0.1.

Source: own elaboration.

**Table 6.**

*Return on sales in Polish hospitals by voivodeships in 2012-2021*

Voivodeship	Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
Dolnośląskie	N	43	46	45	42	44	46	44	42	36	19
	Median	<b>0,2</b>	<b>0,6</b>	<b>0,4</b>	<b>0,2</b>	<b>-0,9</b>	<b>0,1</b>	<b>0,1</b>	<b>-1,1</b>	<b>0,0</b>	<b>1,7</b>
	Mean	-2,9	-0,4	-2,0	-3,2	-2,8	-0,3	-2,8	-3,5	-2,1	0,1
	Std.dev.	10,2	8,0	8,5	8,7	7,0	5,7	10,6	11,5	11,9	10,5
Kujawsko-Pomorskie	N	23	23	20	19	17	16	22	30	28	9
	Median	<b>0,3</b>	<b>0,6</b>	<b>0,3</b>	<b>0,0</b>	<b>0,3</b>	<b>0,1</b>	<b>-0,3</b>	<b>-0,6</b>	<b>0,6</b>	<b>1,3</b>
	Mean	-0,1	0,0	-0,4	-1,3	1,2	1,5	-1,5	-0,9	1,4	4,9
	Std.dev.	4,4	5,1	3,9	8,8	4,1	5,7	6,1	5,9	6,7	10,2
Lubelskie	N	30	30	28	30	31	30	33	33	29	4
	Median	<b>0,6</b>	<b>0,3</b>	<b>-0,2</b>	<b>0,6</b>	<b>0,4</b>	<b>0,6</b>	<b>-2,4</b>	<b>-2,7</b>	<b>0,2</b>	<b>0,0</b>
	Mean	-1,0	-0,3	-1,8	0,0	-1,4	0,4	-2,3	-3,3	-1,8	1,2
	Std.dev.	5,8	4,9	4,0	4,3	10,7	3,9	7,3	7,6	8,2	8,7



Lubuskie	N	15	16	17	19	19	20	19	19	17	12
	<b>Median</b>	<b>0,9</b>	<b>1,5</b>	<b>0,4</b>	<b>3,0</b>	<b>0,9</b>	<b>-0,5</b>	<b>-0,2</b>	<b>-1,1</b>	<b>1,3</b>	<b>1,0</b>
	Mean	1,1	2,1	2,6	3,0	1,0	-3,5	-2,6	-0,7	1,0	3,0
	Std.dev.	2,4	3,9	5,4	3,6	3,3	15,8	8,2	5,2	5,3	3,6
Mazowieckie	N	61	68	65	63	59	59	62	71	65	24
	<b>Median</b>	<b>-4,4</b>	<b>-1,3</b>	<b>-1,8</b>	<b>-1,4</b>	<b>-2,7</b>	<b>-2,5</b>	<b>-4,7</b>	<b>-3,5</b>	<b>-2,8</b>	<b>-2,5</b>
	Mean	-5,5	-6,0	-4,3	-4,1	-5,4	-4,6	-7,0	-5,1	-3,5	-4,7
	Std.dev.	11,0	15,9	8,1	11,4	11,8	8,8	11,5	15,3	18,2	11,5
Małopolskie	N	32	34	37	36	33	37	30	40	36	4
	<b>Median</b>	<b>1,3</b>	<b>1,2</b>	<b>0,5</b>	<b>1,2</b>	<b>0,6</b>	<b>0,7</b>	<b>0,1</b>	<b>0,2</b>	<b>0,5</b>	<b>10,4</b>
	Mean	2,5	2,9	1,0	2,3	1,2	1,3	0,1	0,2	-0,4	8,3
	Std.dev.	6,6	6,7	5,8	5,7	4,5	4,7	8,0	8,1	7,9	5,4
Opolskie	N	14	14	14	21	18	21	19	19	17	6
	<b>Median</b>	<b>0,9</b>	<b>0,9</b>	<b>0,6</b>	<b>0,6</b>	<b>0,0</b>	<b>0,3</b>	<b>-0,6</b>	<b>-1,3</b>	<b>0,2</b>	<b>-5,6</b>
	Mean	1,6	1,4	1,1	0,1	-0,7	-0,9	-1,9	-1,3	0,4	-5,0
	Std.dev.	2,0	1,6	1,4	3,6	3,0	3,1	4,6	3,9	6,3	12,3
Podkarpackie	N	23	22	24	19	12	15	24	26	21	3
	<b>Median</b>	<b>-1,1</b>	<b>0,2</b>	<b>-2,4</b>	<b>-2,7</b>	<b>-3,7</b>	<b>-2,3</b>	<b>-2,9</b>	<b>-6,0</b>	<b>-2,8</b>	<b>-2,8</b>
	Mean	-1,3	-0,5	-1,6	-1,5	-2,0	-1,3	-4,4	-6,8	-1,8	0,4
	Std.dev.	2,9	3,2	5,0	6,3	5,5	5,2	7,3	9,2	5,2	6,0
Podlaskie	N	15	15	16	18	18	20	22	22	15	2
	<b>Median</b>	<b>1,8</b>	<b>2,5</b>	<b>1,3</b>	<b>0,9</b>	<b>1,3</b>	<b>0,3</b>	<b>-3,9</b>	<b>-2,9</b>	<b>0,1</b>	<b>10,5</b>
	Mean	2,0	3,4	3,1	2,3	2,8	1,4	-2,8	-2,5	-1,8	10,5
	Std.dev.	1,8	3,7	6,8	6,6	6,4	8,3	7,6	8,3	5,1	13,0
Pomorskie	N	17	21	24	22	23	25	26	25	26	15
	<b>Median</b>	<b>0,3</b>	<b>0,9</b>	<b>0,3</b>	<b>-0,9</b>	<b>0,2</b>	<b>0,0</b>	<b>-1,9</b>	<b>-1,1</b>	<b>0,4</b>	<b>2,2</b>
	Mean	1,1	1,3	0,2	-0,6	-0,7	-0,9	-2,2	-1,9	0,1	1,9
	Std.dev.	7,8	4,3	3,8	3,6	3,6	3,5	3,8	3,0	5,7	4,4
Warmińsko-Mazurskie	N	14	14	16	23	12	14	25	26	23	6
	<b>Median</b>	<b>0,1</b>	<b>0,6</b>	<b>0,1</b>	<b>0,0</b>	<b>-0,3</b>	<b>-0,2</b>	<b>-0,7</b>	<b>-1,2</b>	<b>0,2</b>	<b>0,1</b>
	Mean	-0,2	0,0	-2,4	-0,2	-1,2	-0,1	-2,0	-2,9	-1,6	2,3
	Std.dev.	4,3	2,6	5,9	2,1	4,7	3,3	5,7	8,9	12,1	6,6
Wielkopolskie	N	42	46	42	49	51	54	51	54	50	8
	<b>Median</b>	<b>0,4</b>	<b>0,5</b>	<b>0,6</b>	<b>0,3</b>	<b>0,2</b>	<b>0,3</b>	<b>-2,7</b>	<b>-2,2</b>	<b>0,2</b>	<b>2,5</b>
	Mean	0,4	1,0	0,1	0,7	-1,6	-0,5	-3,2	-2,6	-1,7	0,8
	Std.dev.	7,0	5,1	5,0	5,4	12,4	5,6	5,3	3,8	6,9	6,2
Zachodniopomorskie	N	12	14	16	22	21	21	23	25	18	6
	<b>Median</b>	<b>1,0</b>	<b>1,1</b>	<b>0,3</b>	<b>-1,6</b>	<b>-2,5</b>	<b>-3,4</b>	<b>-3,5</b>	<b>-2,4</b>	<b>-0,3</b>	<b>0,2</b>
	Mean	-0,9	-0,2	-2,6	-3,4	-3,1	-6,0	-6,0	-4,0	-1,8	-3,0
	Std.dev.	8,5	5,6	7,5	7,3	7,9	9,0	8,0	7,9	8,3	9,1
Łódzkie	N	27	28	27	28	30	29	32	34	32	8
	<b>Median</b>	<b>1,0</b>	<b>1,0</b>	<b>0,1</b>	<b>0,3</b>	<b>0,5</b>	<b>0,2</b>	<b>-2,2</b>	<b>-1,7</b>	<b>-0,1</b>	<b>2,2</b>
	Mean	0,8	2,1	0,2	0,5	0,3	0,9	-2,1	-2,9	-1,9	2,6
	Std.dev.	7,7	4,4	4,4	4,3	4,0	5,5	8,1	8,3	10,4	2,2
Śląskie	N	57	63	64	54	68	66	65	72	69	25
	<b>Median</b>	<b>0,8</b>	<b>1,2</b>	<b>0,4</b>	<b>0,3</b>	<b>0,1</b>	<b>-0,9</b>	<b>-4,4</b>	<b>-3,1</b>	<b>-2,4</b>	<b>-0,9</b>
	Mean	1,1	1,5	-0,1	-1,4	-2,9	-3,1	-5,7	-4,6	-4,6	-3,3
	Std.dev.	9,1	8,1	7,0	7,4	9,2	10,8	13,3	11,0	12,5	10,8
Świętokrzyskie	N	3	1	3	5	2	5	13	20	20	0
	<b>Median</b>	<b>-2,0</b>	<b>7,6</b>	<b>4,9</b>	<b>1,1</b>	<b>-9,6</b>	<b>1,1</b>	<b>0,0</b>	<b>-0,2</b>	<b>-0,9</b>	<b>NA</b>
	Mean	0,5	7,6	-0,3	1,7	-9,6	4,4	-4,0	-3,3	-3,2	NA
	Std.dev.	8,4	NA	10,5	2,8	22,0	11,6	7,2	6,1	6,7	NA

Note. ROS values in %, NA – not available.

Source: own elaboration.

**Table 7.**  
*Profitability of Urban and Rural Hospitals in the Years 2012-2021*

Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ROS (urban)	0,8	0,6	0,4	0,2	0,2	0,1	-1,4	-1,8	0,1	0,9
ROS (rural)	0,2	0,5	0,1	0,2	-0,7	-0,6	-2,7	-2,3	-0,1	0,5
p	0,0585 *	0,5896	0,0087 ***	0,4125	0,0677 *	0,0752 *	0,0042 ***	0,3091	0,8501	0,7716
ROA (urban)	0,8	0,8	0,4	0,2	0,1	0,1	-1,4	-2,4	0,0	0,9
ROA (rural)	0,3	0,6	0,1	0,2	-0,8	-0,9	-3,9	-3,4	-0,1	0,5
p	0,2324	0,7727	0,0263 **	0,5111	0,0689 *	0,0174 **	0,0002 ***	0,0787 *	0,6366	0,8509
ROE (urban)	2,7	2,6	1,2	1,2	1,0	0,7	0,1	-3,2	1,6	3,8
ROE (rural)	1,4	2,0	0,4	1,2	0,1	-0,1	-5,5	-2,2	1,2	3,8
p	0,0416	0,3948	0,0195 **	0,6898	0,0118 *	0,0669 **	0,0001 ***	0,4378 *	0,3928	0,9033
ROS EBITDA (urban)	5,7	6,1	5,8	NA	5,1	4,8	3,2	2,5	4,3	5,6
ROS EBITDA (rural)	5,2	5,7	4,5	NA	3,5	3,5	1,6	2,2	4,0	4,2
p	0,2509	0,5493	0,0247 **		0,0071 ***	0,0188 **	0,0008 ***	0,0906 *	0,4975	0,4600
ROA EBITDA (urban)	7,6	7,3	6,8	NA	5,8	5,5	3,8	3,4	5,1	6,3
ROA EBITDA (rural)	7,4	8,0	6,0	NA	4,7	4,7	2,0	3,1	5,6	6,3
p	0,5248	0,5067	0,1500		0,1192	0,1173	0,0007 ***	0,1920	0,9011	0,9985
ROE EBITDA (urban)	14,0	17,2	14,7	NA	12,2	12,2	9,8	10,0	17,5	17,3
ROE EBITDA (rural)	15,4	17,6	12,6	NA	9,5	8,8	6,7	9,5	12,6	19,5
p	0,3639	0,6682	0,9771		0,2891	0,1852	0,1716	0,3676	0,0120 **	0,6166

Note. values in %, p-values of the Kruskal-Wallis test between urban and rural hospitals in respective years; \*\*\* p <= 0.01; \*\* p <= 0.05; \* p <= 0.1, NA – not available.

Source: own elaboration.

**Table 8.**  
*Profitability in Polish Hospitals by Legal Form in the Years 2012-2021*

	Legal form	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ROS	Corporation	0,4	0,5	0,2	0,1	-0,8	-0,5	-1,9	-2,2	0,0	0,5
	SPZOZ	0,3	0,5	0,2	0,3	0,2	0,1	-2,4	-2,0	0,0	0,4
	p	0,7834	0,7415	0,9430	0,4798	0,0491 **	0,1215	0,5288	0,7981	0,3400	0,6302
	Other	15,3	9,6	11,2	16,6	19,6	16,3	14,5	10,1	11,1	19,7
ROA	Corporation	0,6	0,9	0,2	0,1	-0,9	-0,7	-2,5	-3,0	-0,1	0,7
	SPZOZ	0,3	0,6	0,2	0,3	0,1	0,1	-3,1	-2,9	0,0	0,5
	p	0,4521	0,6902	0,8325	0,3975	0,0345 **	0,1539	0,5843	0,4563	0,3642	0,6020
	Other	21,6	23,7	24,9	6,8	42,9	49,9	43,7	39,7	39,2	60,3
ROE	Corporation	1,7	2,1	0,6	0,6	0,1	0,0	-2,0	-3,6	1,4	3,8
	SPZOZ	2,2	2,5	1,0	1,6	1,0	0,7	-3,2	-2,2	1,3	2,0
	p	0,9410	0,2396	0,3058	0,2124	0,1071	0,1774	0,2321	0,5804	0,4600	0,6649
	Other	44,2	204,0	63,5	22,5	61,1	94,2	88,1	87,2	74,3	82,1

ROS EBITDA	Corporation	5,1	5,7	4,4	NA	3,5	3,5	2,1	1,9	4,2	4,9
	SPZUZ	5,4	5,9	5,3	NA	5,1	4,0	2,0	2,4	4,0	3,7
	p	0,4551	0,1570	0,0763		0,0268	0,1549	0,5096	0,5562	0,7043	0,6765
				*		**					
ROA EBITDA	Other	22,4	14,1	17,7	NA	25,8	24,8	18,8	14,0	14,5	24,7
	Corporation	8,1	7,8	6,3	NA	4,5	4,6	3,1	2,7	5,5	6,3
	SPZUZ	6,9	7,4	6,2	NA	5,8	5,4	3,0	3,7	5,1	4,1
	p	0,1648	0,9916	0,5730		0,0699	0,3369	0,6136	0,4425	0,6806	0,6648
ROE EBITDA						*					
	Other	48,0	34,9	38,6	NA	56,8	71,6	60,6	51,5	48,3	71,8
	Corporation	15,9	17,3	13,5	NA	10,2	10,2	6,8	9,3	15,9	19,5
	SPZUZ	13,6	17,2	14,3	NA	11,8	10,5	8,8	9,4	13,9	6,3
ROE EBITDA	p	0,2535	0,7468	0,8196	0,6071	0,6071	0,2241	0,8321	0,8822	0,6010	0,1377
	Other	59,8	296,2	88,9	NA	94,2	131,2	104,1	97,1	99,7	94,0

Note. values in %, p-values of the Kruskal-Wallis test between hospitals run in the form of corporation and SPZUZ in respective years; \*\*\* p <= 0.01; \*\* p <= 0.05; \* p <= 0.1.

Source: own elaboration.

**Table 9.**

*Profitability of Polish Hospitals by Owner Type in the Years 2012-2021*

	Year	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021
ROS	Community	-1,9	0,2	-1,9	-2,2	-1,7	-1,3	-9,0	-4,2	-4,4	-3,3
	County	0,2	0,4	0,0	0,2	-0,7	-0,7	-3,3	-2,9	-0,7	-0,1
	Voivodeship	0,4	0,4	0,3	0,2	0,0	-0,5	-2,2	-2,5	-1,6	0,3
	State	0,3	1,0	0,2	0,3	0,5	0,1	-0,8	-2,0	0,4	1,3
	University	0,3	1,3	1,5	0,8	0,8	0,2	-1,4	-0,8	0,2	0,2
	Corporate	1,1	1,3	0,3	1,8	-0,3	-0,1	1,1	-0,7	1,8	4,1
	Other	4,1	5,6	3,2	3,0	2,7	4,2	3,2	3,3	4,5	6,4
ROA	Community	-1,2	0,1	-1,5	-2,8	-1,2	-1,2	-7,8	-5,7	-5,6	-5,6
	County	0,3	0,5	-0,3	0,2	-1,4	-1,1	-4,7	-4,6	-1,1	0,0
	Voivodeship	0,5	0,5	0,3	0,2	0,0	-0,7	-2,7	-2,5	-1,7	0,1
	State	0,5	0,7	0,2	0,2	0,4	0,1	-0,7	-2,0	0,3	1,5
	University	1,2	2,2	3,2	0,7	0,9	0,4	-2,6	-2,2	0,2	0,2
	Corporate	1,1	2,0	0,2	1,8	-0,9	-0,4	0,3	-0,5	1,0	6,5
	Other	7,7	7,6	5,4	4,4	3,4	6,1	3,4	1,9	4,5	8,8
ROE	Community	-0,5	0,6	-2,7	-1,8	-1,4	-1,0	-26,4	-11,4	-11,8	-7,8
	County	1,4	1,6	0,2	0,6	0,2	-0,3	-8,9	-5,7	1,1	0,8
	Voivodeship	2,1	1,7	1,1	1,0	0,1	0,0	-1,3	-1,5	0,5	0,4
	State	2,4	2,0	0,8	1,3	1,1	0,3	-1,0	-7,8	1,0	6,0
	University	8,4	8,1	7,7	3,8	2,5	2,1	-1,3	-0,9	2,0	1,5
	Corporate	7,0	4,7	1,1	7,8	2,4	6,6	5,8	3,7	5,8	14,0
	Other	17,0	14,5	9,2	9,0	10,7	11,2	6,7	6,5	7,8	16,0
ROS EBITDA	Community	3,5	4,1	3,6	NA	2,8	1,9	-2,9	0,4	1,1	0,4
	County	5,0	5,4	4,3	NA	3,2	3,0	0,7	1,5	3,4	2,5
	Voivodeship	5,3	6,0	6,0	NA	4,3	3,7	1,9	1,8	2,8	4,9
	State	5,6	6,8	5,6	NA	7,3	6,0	4,3	2,6	5,9	7,5
	University	5,3	5,2	5,4	NA	5,3	4,5	3,1	4,4	4,4	3,2
	Corporate	7,5	6,1	5,2	NA	6,8	7,3	7,3	5,8	6,8	9,1
	Other	10,0	11,1	9,1	NA	7,8	8,0	8,3	7,6	9,0	10,8
ROA EBITDA	Community	4,0	4,5	3,3	NA	2,2	2,6	-2,3	0,7	1,3	0,7
	County	7,7	8,2	6,1	NA	4,7	5,3	1,4	2,6	5,7	5,1
	Voivodeship	5,9	5,8	5,5	NA	4,3	4,0	2,0	2,1	2,8	3,9
	State	6,3	7,4	5,3	NA	5,7	4,9	4,1	2,6	5,4	7,6
	University	10,6	9,0	9,9	NA	9,0	7,4	5,4	6,8	8,0	5,4
	Corporate	11,5	11,8	11,3	NA	8,8	8,1	9,2	7,7	9,4	12,7
	Other	15,5	16,7	12,8	NA	11,0	12,2	11,8	11,8	12,6	15,5

ROE EBITDA	Community	8,2	14,3	9,2	NA	9,3	7,6	-0,1	11,4	16,5	8,5
	County	13,5	17,6	12,9	NA	9,9	9,3	6,0	9,2	13,6	17,5
	Voivodeship	12,6	14,1	11,5	NA	9,1	6,6	5,1	6,3	9,7	8,4
	State	13,8	13,2	10,5	NA	10,5	9,6	3,7	3,8	13,7	25,6
	University	16,6	16,7	15,3	NA	17,8	19,3	10,6	20,6	23,1	14,6
	Corporate	26,6	23,9	27,0	NA	20,2	18,2	18,7	20,4	22,4	33,8
	Other	27,6	30,7	30,1	NA	22,8	25,0	25,1	21,0	22,7	38,1

Note. values in %, NA – not available.

Source: own elaboration.

**Table 10.**  
*Statistical Significance of Differences in Median Return on Sales Between Hospitals by Owner Type in the Years 2017-2020*

2017							
	Community	County	Voivodeship	State	University	Corporate	Other
Community		0,0451**	0,0593*	0,0206**	0,0039***	0,0248**	0,0000***
County	0,0120**		0,7806	0,2600	0,0337**	0,1619	0,0000***
Voivodeship	0,0004***	0,0442**		0,1994	0,0243**	0,1928	0,0000***
State	0,0015***	0,0234**	0,4332		0,3642	0,6416	0,0001***
University	0,0008***	0,0082***	0,1401	0,5719		0,9186	0,0011***
Corporate	0,0002***	0,0010***	0,0109**	0,0655*	0,2650		0,0069***
Other	0,0000***	0,0000***	0,0000***	0,0000***	0,0009***	0,0344**	
2018							
2019							
	Community	County	Voivodeship	State	University	Corporate	Other
Community		0,0373**	0,0150**	0,0810*	0,0005***	0,0039***	0,0000***
County	0,0010***		0,4992	0,8282	0,0048***	0,0189**	0,0000***
Voivodeship	0,1025	0,0253**		0,8103	0,0274**	0,0536*	0,0000***
State	0,0039***	0,3494	0,0289**		0,0277**	0,0944*	0,0000***
University	0,0022***	0,1377	0,0372**	0,9711		0,9434	0,0046***
Corporate	0,0008***	0,0182**	0,0009***	0,1482	0,1843		0,0371**
Other	0,0000***	0,0000***	0,0000***	0,0008***	0,0062***	0,0432**	
2020							

Note. p-values of the Kruskal-Wallis test between hospitals run by different owners in respective years; \*\*\* p <= 0.01; \*\* p <= 0.05; \* p <= 0.1.

Source: own elaboration.

## PROBLEMS IN SUSTAINABLE ENERGY TRANSITION – THE FIRST POLISH NUCLEAR POWER PLANT IN THE POMERANIAN REGION

Anna WOJEWNIK-FILIPKOWSKA<sup>1\*</sup>, Aleksandra KOSZAREK-CYRA<sup>2</sup>,  
Ewelina NAWROCKA<sup>3</sup>

<sup>1</sup> University of Gdansk, Faculty of Management; anna.wojewnik-filipkowska@ug.edu.pl,  
ORCID 0000-0003-4715-6101

<sup>2</sup> University of Gdansk, Faculty of Management; aleksandra.koszarek-cyra@ug.edu.pl,  
ORCID: 0000-0003-4796-8396

<sup>3</sup> University of Gdansk, Faculty of Management; ewelina.nawrocka@ug.edu.pl, ORCID: 0000-0003-0739-1705

\* Correspondence author

**Purpose:** The identification of gaps in the Environmental Impact Assessment (EIA) Report in the investment planning process in the managerial and social dimensions.

**Design/methodology/approach:** The research is based on the method of the analysis of the subject literature and a critical analysis of the source documentation, i.e., the Environmental Impact Assessment Report on the project to build and operate the first Nuclear Power Plant (NPP) in Poland.

**Findings:** Gaps identified refer to the issue of coordination of the accompanying investments with the NPP Investment; an identification of the real impact area of the NPP in the scope of the analysis of its impact on residents; the impact of the investment on the functioning of the local government units; the impact of the investment on the local labour market, tourism and the property market.

**Research limitations/implications:** Although the research implements a cost-benefit analysis, which is a recognised method of analysis, the study is conducted in the reality of local (national) regulations. The issue of environmental impact assessment is not the subject of the analysis. The analysis is limited to the impact on society, i.e., on residents, the functioning of local government units, and selected local markets.

**Practical and social implications:** The article draws attention to the problem of nuclear plants and sustainability standards including environmental, social and economic dimensions (impact). It shows the necessity of improving the content of the evaluation report, draws attention to the issues neglected in the report and aims to increase the knowledge available to the public.

**Originality/value:** A nuclear power plant is a strategic, capital-intensive investment, demanding in terms of technology but also of organisation, with a significant impact on society. The first nuclear power plant in Poland is analysed. The article provides knowledge that has not been previously presented.

**Keywords:** nuclear energy, nuclear power plant, cost-benefit analysis, impact on society.

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

## 1. Introduction

Global climate change, low air quality and the problems related to energy security encourage a search for energy sources alternative to coal, oil and gas. Renewable energy sources (solar, wind and geothermal energy) are considered to be more environmentally friendly than traditional sources. Investments in renewable energy sources are perceived as opportunities for a reduction in the quantities of greenhouse gases and air pollution, which is important for human health and nature conservation. At the same time, energy security based on energy supply irrespective of the weather conditions is important, as renewable energy sources cannot ensure it. The building of an energy system based on many sources, such as coal, natural gas, nuclear energy and renewable energy makes it possible to reduce the risks posed by breakdowns and limitations at one source. However, energy security is an issue which is determined not only by the diversification of energy sources but also by energy policy, political and geopolitical stability and sustainable development.

A consistent and long-term energy policy, including planning, regulations, investments and international cooperation, is of key importance for safeguarding energy security. Over the recent decades, energy has gained in political importance and has been often treated as a key issue of foreign policy. It seems, however, that the vision based on the economy-energy security-sustainable development triangle recently lost some of its importance. Indeed, first it was dominated by its economic domination as a result of an economic crisis, while after the Russian attack on Ukraine the issue of energy security became crucial (Wagner, Grobelski, Harembski, 2015). Two key dimensions of energy security have been indicated: availability (the possession of a sufficient quantity of energy) and the reliability (its possession at any time and place) (Szulecki, Westphal, 2014). In this context, the advantages of nuclear power plants have been noted, as they need smaller quantities of raw materials and can operate for many years. This means that they are more energy efficient than the other sources of conventional and renewable energy.

The question arises, however, about the extent to which nuclear power plants are consistent with the concept of sustainable energy development. Do they really make it possible to take into account the environmental, social and economic aspects and to maintain the balance between energy security and the protection of the environment and society, not only in the several dozen years long process of production and consumption, but also at the investment implementation stage? According to Verbruggen (2008), nuclear energy does not meet sustainability standards and has low public acceptance. Therefore, the discussion on investments in installations of renewable energy sources vs. investments in nuclear power plants does not result only from the commitment to substantially reducing greenhouse gas emissions under the climate treaty signed in 2015 in Paris, the efforts to reach energy independence or the objective advantages and disadvantages of the use of such an energy

source. It also results from different interests and social values, leading to different and often contradictory preferences regarding environmental protection and energy security.

Energy transition can be defined as a change of the character or model of energy use in the system, which can be a change related to the type of fuel, access, supply, delivery, reliability or end-use, as well as the general orientation of the system. This change can take place at any level – from local systems to the global one (Araújo, 2014). The basic directions of changes in Poland's energy policy (Ministerstwo Gospodarki, 2009) are as follows:

- improvement of energy efficiency,
- higher security of fuel and energy supply,
- diversification of the electricity generation structure by introducing nuclear energy,
- development of the use of renewable energy sources, including biofuels,
- development of competitive fuel and energy markets,
- limitation of the environmental impact of the energy sector.

In an overall approach, experts contrast the cost of energy transition (and, in the long term, the savings generated) vs. higher operating costs based on the current model. The latter was mercilessly exposed by the geopolitical situation last year and the related energy price increases. Consideration is seldom given to the addition of the costs of unmeasurable external effects in the form of climate change, its impact on human health and increasingly frequent extreme weather events (Wojewnik-Filipkowska, Filipkowski, Frąckowiak, 2023).

On 14 July 2021, the European Union published a package of new climate regulations, called 'Fit for 55' and providing for an emission reduction by at least 55% in the EU by 2030. The EU as a whole intends to become climate neutral by 2050. Is this realistic, in the context of the recent geopolitical events and the particular interests of the non-EU states? There are many indications that it is not. Is it needed? Everything indicates that it is. In practice, these actions will include a reform of the present Emissions Trading System, new carbon taxes and more stringent emission standards, as well as new investments in both renewable energy sources and nuclear power plants. The investment in a nuclear power plant is strategic. It is a capital-intensive investment, demanding in economic terms and in terms of technology and organisation, with a significant impact on the natural environment and society. But while some countries are investing heavily in expanding their nuclear energy supplies, others are taking their systems offline. The role of nuclear power in the energy system is therefore very country-specific. There are 440 commercial nuclear power reactors operable in about 30 countries. About 60 more reactors are under construction, notably in China, India and Russia. The nuclear plans are present all over the world – there are 168 nuclear plants in Europe (Statista, 2023). Currently, Poland remains one of the few European countries that does not yet use energy generated by nuclear power plants, and the decision to build a nuclear power plant arouses a lot of controversy and is the basis for a broad discussion about the benefits and risks associated with the implementation of these investments (Kowalski, Cwyl, Piotrowski, 2013).

The purpose of this study is to identify gaps in the Environmental Impact Assessment Report on Poland's first Nuclear Power Plant in Pomerania (hereinafter referred to as the Report and the Investment or NPP Project). The authors focus on gaps in the Report in two ranges. From the managerial point of view, the analysis will address the issues related to the timetable of the investment and its objective range (accompanying investments), while in the scope of the social impact, the analysis covers the impacts on the functioning of local government units, residents and local markets. The issue of the assessment of the impact on the natural environment is not analysed. The formulated research question addresses not only the extent of gaps in the Report, but also their causes.

The research methods include critical analysis of the selected subject literature and the source documentation, i.e., the Environmental Impact Assessment Report on the project to build and operate the first Nuclear Power Plant in Poland with an electrical capacity of up to 3,750 MWe, in the areas of the Municipalities of: Choczewo or Gniewino and Krokowa, Vols. II, IV and VI, including attachments. The method of cost-benefit analysis was used to analyse the Report.

The study consists of 4 Sections. Section 2 presents materials and methods which include information about the first Polish Nuclear Power Plant in the Pomeranian Region, and its administrative determinants relevant for the Environmental Impact Assessment Report. This Section includes a brief explanation of the methods applied. Section 3 presents results and discussion relating to managerial and social gaps identified in the Report. The Conclusions in Section 4 close the study.

## **2. Materials and methods**

On 22 August 2023, the company Polskie Elektrownie Jądrowe (PEJ) submitted to the Pomeranian Voivode an application for the issue of a location decision for the first nuclear power plant in Poland, to be built in Pomerania, in the Municipality of Choczewo (Polskie Elektrownie Jądrowe, 2023). This was not the first attempt to incorporate nuclear energy into Poland's energy system. In the 1970s, taking into account the favourable geological, meteorological and demographic conditions and the large energy demand in the northern regions of the country, a decision was taken to locate the power plant at the village of Kartoszyno on Lake Żarnowieckie. On 12 August 1971, the Polish Government adopted a decision to build a nuclear power plant, while on 10 April 1986 the Parliament adopted the Act on Nuclear Law in Poland, the first act of this rank in Polish law to regulate the activities using nuclear energy (Komunikat IPN, 2023). After the first construction works began on the Żarnowiec Nuclear Power Plant in 1982, fears associating a nuclear power plant with a nuclear bomb intensified. Opposition and environmental organisations strongly joined the protests.



In 1987, when the economy of the People's Republic of Poland plunged into crisis, the construction works were halted, while at the end of 1988 only the existing structures were secured and no new ones were erected. Under the impact of growing public protests, in December 1989 the Government of Tadeusz Mazowiecki took a decision to suspend the construction for a year and on 17 December the new Government adopted a resolution to put the investment 'The Żarnowiec Nuclear Power Plant under Construction' into liquidation. Works began to dismantle and scrap the already purchased equipment of the power plant (Serwis Rzeczpospolitej Polskiej, 2023).

The Polish Nuclear Power Programme – a strategic government document constituting a roadmap for the construction of the first Polish nuclear power plant – was adopted by the Council of Ministers on 28 January 2014 and on 2 October 2020 so was its updated version (Serwis Rzeczpospolitej Polskiej, 2023; Ministerstwo Klimatu, 2021). The construction of the nuclear power plant in Poland is presented as a strategic investment for the sustainable development of the whole country, indicating that nuclear power generation is a stable source of electricity and that, moreover, that the capability to store nuclear fuel for a long time improves the energy independence of the country.

However, the process of implementing an investment with such a wide impact range as a nuclear power plant is long-lasting and multi-stage; it can also cause numerous problems which are not always fully identified by the investor. In formal terms, the administrative procedure consists of specific stages:

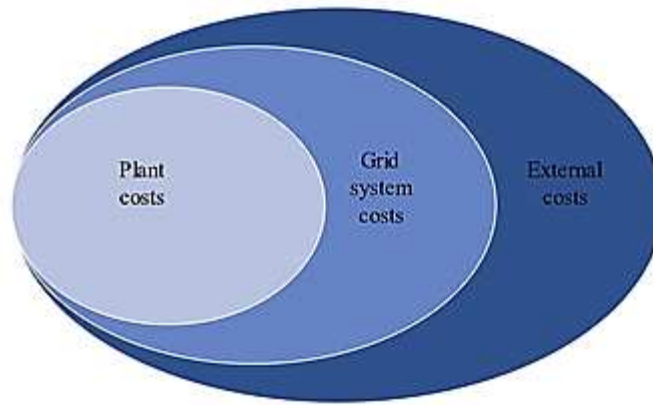
1. decision-in-principle,
2. decision on environmental conditions (environmental decision),
3. decision determining the location of an investment to build a nuclear power unit (location decision), a construction consent,
4. construction permit,
5. commissioning permit (after the completion of the construction),
6. operating permit.

This article focuses at the stage of a decision on environmental conditions (the so-called environmental decision) – the Environmental Impact Assessment (EIA), with particular consideration given to the analysis of one of the key elements of this procedure – the Environmental Impact Assessment Report. This decision is an instrument to ensure comprehensive environmental protection (Ustawa o udostępnianiu informacji..., 2008). The performance of the environmental impact assessment of a project is required for the implementation of projects likely to always have a significant effect on the environment, i.e., in accordance with the Act, a proposed project likely to always have a significant effect on the environment or a proposed project likely to potentially have a significant effect on the environment (if the obligation to perform the environmental impact assessment of a project has been determined).

In accordance with the cited Act, the environment includes all the natural and social elements, as well as the one understood to be cultural. The environment affects the condition, quality of life and welfare of humans and other forms of life on Earth. The purpose of the EIA is to identify, describe and assess the effect of a proposed project or action on the environment so as to enable the protection and preservation of the environment and to ensure sustainable development. The EIA analyses not only the effects on air, water, soil, ecosystem, landscape and human health, but also the economic, social and cultural aspects. Thus, the assessment also addresses technical, organisational and economic aspects related to the implementation of a specific project. Ultimately, the purpose of the assessment is to work out solutions to minimise the adverse environmental impacts, to adopt protective measures, to compensate for potential damage and to promote actions to protect the broadly understood environment – not only the natural environment, but also the social and cultural environment. Its purpose is also to ensure transparency of the decision-making process and to take into account the views of the public and stakeholders in the process of taking decisions on projects and actions likely to have an effect on the specific environment (surroundings). The final scope of the report is determined by the Regional Directorate for Environmental Protection (RDOŚ) or the Chief Inspectorate of Environmental Protection (GIOŚ).

On 29 March 2023, the company Polskie Elekrownie submitted the Environmental Impact Assessment Report mentioned above to the General Directorate for Environmental Protection (Polskie Elekrownie Jądrowe, 2023). The Report is one of the elements of the procedure, intended to facilitate the determination of all the potential threats related to the implementation of the proposed project.

The completeness of the Report was analysed using the method of a cost-benefit analysis (CBA). The essence of the CBA is the comparison of all the costs related to an action or project with their possible benefits and the selection of the best option of action on this basis. The main advantages of the CBA include the account taken of the economic value of the natural environment, which is particularly important when decisions affecting the natural environment are taken – but not only. The CBA is a tool to identify, analyse and value the long-term term outcomes of actions related to external effects of environmental, social and economic character which are not reflected the financial account of the investor (project). Thus, the CBA makes it possible to take into account the criteria of sustainable development. At the same time, the CBA has certain limitations. The analysis has a subjective character, since certain benefits and costs are difficult to estimate in monetary categories and various stakeholders can differently value individual benefits and costs. The total cost of energy supply includes three entire categories: capital expenditures at the plant level (including administrative cost, planning and documentation preparation), system costs at the grid level, and external costs (Figure 1). In fact, grid system costs which include the costs that plants impose on the system in terms of extending, reinforcing or connecting to the grid, have also external components (Nuclear Energy Agency, 2018).



**Figure 1.** Cost categories composing the full costs of electricity provision.

Source: based on the Nuclear Energy Agency (2018).

### 3. Results and discussion

The analysis of the Report focuses on gaps in the managerial and social dimensions. From the managerial point of view, the analysis addresses the issues related to the timetable of the investment and its objective range (accompanying investments). In the social scope, the analysis focuses on the impacts on society, i.e., on the functioning of local government units, residents and local markets, e.g., the labour market, tourism and the property market.

The gap analysis should, however, be preceded by the statutory definition of an accompanying investment to which the analysis of managerial and social gaps will refer. The catalogue of such investments is limited and specified (Ustawa o przygotowaniu i realizacji..., 2011). In accordance with the Act, an accompanying investment means:

1. an investment to: build, reconstruct, repair, maintain, use, change the manner of use, operate or dismantle transmission networks, distribution networks needed to connect a nuclear power facility to the power grid or for the evacuation of power from a nuclear power plant, and heating networks or cooling networks needed to evacuate heat or cold from a nuclear power plant,
2. another investment needed to: build, reconstruct, repair, maintain, use, change the manner of use, start up, operate or dismantle a nuclear power facility; particularly in the scope of power stations, temporary built structures, facilities of a gas network; power, water supply, wastewater collection, district heating, telecommunications, tele-information and cooling networks and connections; road, hydro-engineering and railway infrastructure, stacking yards, storage facilities, energy storages, installations for the production, distribution or storage of hydrogen, production buildings, assembly or manufacturing plants, as well as to perform measurements, tests or other works needed to prepare a preliminary location report, a preliminary report or an environmental impact assessment.

## **Managerial gaps**

The Report indicates that the preparation of work timetables will be of crucial importance for coordination and documents will undergo cyclical updates, taking into account progress of works and the changing conditions of their execution. At the same time, the Report fails to address the need to coordinate the NPP Investment and accompanying investments, the timetable itself is not realistic, the Report is not consistent in this respect and has a vague and wishful character. It should be pointed out here that access roads, railway lines and the accommodation base have been excluded from the Project and qualified as accompanying investments, thus failing to include these investments in the analysis of the cumulative impact. The analysis of the cumulative impact itself also assumes that the timetables of external investments will not overlap and that there will be no delays, while the criteria for including external investments in the analysis of the cumulative impacts are not clear.

Irrespective of the above, the implementation timetables of the Investment and the accompanying investments have been presented without including the time needed for design and the issuing of permits and decisions. However, the project management practice indicates that taking into account the time needed for administrative activities is an element of a correctly designed investment timetable. As regards the scope of the activities included in the timetable, the Report indicates the possibility of expanding the scope of works and a time reserve is foreseen, e.g., for the activities related to an area check for unexploded ordnance and a preliminary archaeological survey, but these time reserves are short (2 months in this case), while the risk in this scope is assessed as high. The reduction of the operating time of machinery is indicated as part of measures to minimise the external impacts, but there is no information if these measures are included in the timetable. In this scope, the Report contains phrases with the character of proposals the implementation of which is uncertain.

On the one hand, taking into account the scope of the Investment and the related investments, the indication that the Investor does not possess full information in specific areas is understandable. At the same time, the Report adopts without any problem the assumptions which result from the timetables of external investments over which the Investor has no control. It is only in the case of the Local Information Centre and partly in the case of the accommodation base that the Investor is responsible for the implementation of the investment, thus exerting an actual influence on the management of these investments. In the case of both accompanying and other investments, the Report even fails to take into account possible delays and their consequences which may follow and thus the effects of these delays on the Investment itself. There is no information, either, on the communication between the Investor and the investors/contractors of the accompanying and other investments. The accompanying investments are presented synthetically, although they are indispensable for the construction and the later operation of the NPP, while the main analyses are limited to only the site of the construction/implementation of the Investment.

For example, the transmission networks, which have not been prepared and adapted to support the Investment, pose a problem. According to Polskie Sieci Elektroenergetyczne (2022), the transmission networks are expected to be ready for the commissioning date of the investment, but the timeliness of this investment cannot be ensured. Possible delays which have not been included in the Report may result from the expropriation processes and the landowners' complaints to the courts. Moreover, in 2020 on average almost 50% of high and medium voltage networks in Poland were more than 40 years old (Tomczykowski, 2011).

In the scope of transport infrastructure, railways as well as roads, gaps include failure to take into account repairs of the existing roads which will be intensively used at the stage of preparatory works when the railway line is not in operation yet and, in consequence, the whole transport will be carried out by lorries (the Report provides for 600 lorries in a day in both directions on the road between the Port of Gdańsk/Gdynia and the Strzebielino Junction). In addition, the timetable of new investments is unrealistic, when taking into account the experiences from other investments carried out by PKP Polskie Linie Kolejowe S.A., where delays were as long as several to a dozen or so months (Madrjas, 2019).

Indeed, the effects of delays in the implementation of investments in the transport (roads and railways), transmission, water supply and wastewater infrastructures (related not only to the Investment, but also to the accommodation base) will be felt by the entities which are directly involved in the preparation and implementation of the Investment and the other stakeholders, including the NPP employees and the residents of the municipalities where the Investment and the accompanying investments are located; the same is the case with the residents of the neighbouring municipalities. In particular, the consequences of delays of the investments in the transport infrastructure mean a longer duration of the inconveniences related to the implementation of the Investment itself and the actual accompanying investments, including detours, further delays, lesser throughput capacity and the need to arrange for the cost of substitute transport. On the basis of studies carried out on transport projects, it can be indicated that a cost overrun depends to a large extent on the duration of project implementation, but does not depend on the type of a project in the scope of the transport infrastructure; with each passing year from the decision to build to the start of operation, the mean annual cost overrun is 4.64% (without financial costs); in the case of railway projects, the average cost increase is 45%; while in the case of roads, the average cost increase is 20% (Flyvbjerg et al., 2018). As indicated by the experiences from the construction of other new nuclear power plants, this technology is also prone to the risks of an overrun of the construction timetable and an increase in the investment costs. The main factors include an optimistic plan related to a new technology, administrative regulations and safety requirements (Alsharif, Karatas, 2016; Badyda, Kuźniewski, 2015).

In light of the possible difficulties caused by delays in the implementation of the abovementioned capital- and time-intensive investments in roads, transmission, water supply and wastewater collection networks, the absence of details on the investments in the

communications infrastructure seems to be insignificant. However, communications are a key element of security systems. The Report laconically indicates the need to expand the telecommunications infrastructure at the cost of an unspecified operator.

According to the Polish Nuclear Power Programme (PEJ 2020), there is already a delay of one year. In 2022, the environmental and location decisions were expected to be issued for the NPP and the agreement with the technology provider and the main contractor was expected to be signed. In turn, in 2023 the preliminary and preparatory works were expected to be started at the NPP location, including the conclusion of the connection agreement. In the meantime, a decision-in-principle was issued, formally confirming that the investment in the first nuclear power plant in Poland was consistent with the public interest and the policies pursued by the state, including energy policy (11.07.2023), and a decision was issued to indicate the location in the Municipality of Choczewo (19.09.2023) for the purposes of an in-depth geological survey to be carried out by the Investor and the issue of a construction permit by the President of the National Atomic Energy Agency. However, the issue of a decision indicating the location does not predetermine the final siting (Pomorski Urząd Wojewódzki, Aktualności, 2023). The environmental decision has been just issued (19.09.2022) and the engineering service contract has been signed (27.09.2023) (Polskie Elektrownie Jądrowe, Aktualności, 2023).

### **Social gaps – the impact on inhabitants and local administration**

The Report fails to address many aspects by referring to the arising accompanying investments. However, as indicated above, the catalogue of such investments is limited and specified by statute. Therefore, any investments which are indirectly related to the construction of the power plant, such as those intended to ensure good quality and comfort of life for the residents, healthcare or education for the construction workers and their families, may not qualify as accompanying investments.

Thus, there is an information gap here relating to the entity responsible for providing such services. On the basis of experiences related, e.g., to education, it can be assumed that this task will be imposed directly on local government units, mainly municipalities. Taking into account the social impact of the project and the necessary investments (not only the so-called accompanying investments) on the quality of life and the living conditions of the population, the labour market and the property market, in the scope of the abovementioned issues the submitted Report is hardly exact and only provides an outline of problems which arise in the context of the implementation of such a large investment.

The Report does not address many problems that the local government units will face. Predominantly, the potential problems are caused by an influx of many employees, who will become the temporary residents of the municipalities where the Investment will be implemented. These problems will also affect the neighbouring municipalities. It follows from the Report that the estimated number of hired employees exceeds 1,000 employees in the course of preparatory works, while almost 8,000 persons will work at the peak period of the

Investment. For comparison, the Municipality of Choczewo, where the investment is to be implemented, as of this writing has a population of 5,010 persons, while the neighbouring Municipalities have the following populations: Gniewino – 7,448, Łęczyce – 12, 023, Krokowa – 10,545 and Wicko – 5,561 (data as of December 2022, Bank Danych Lokalnych, 2023).

The experiences from other investments in the energy sector, including nuclear power, e.g., in the United Kingdom, raise the concern that the projected number of employees may be substantially underestimated (Thomas-Aleksander, 2022). Therefore, the increase in the number of persons inhabiting the Municipalities mentioned above could well be significant. The multi-nationality of the human resources could also be a problem; e.g., 75% of the persons working on the construction of Olkiluoto 3 in Finland represented 60 different nationalities (Muinonen, 2012). In light of this, it is justified to assume that, although the investors intend to hire local labour, many employees will be brought from outside Poland's borders. This is confirmed by the fact that State Treasury companies also bring employees from abroad to implement other investments, e.g., the workers building the Olefin III Complex near Płock include: Koreans, Indians, Malaysians, Pakistanis, Filipinos, Turks and citizens of Turkmenistan (Rowicka, 2023). A substantial number of the newcomers will significantly affect the local population and its functioning. The problems which may arise can be divided into 3 groups:

1. everyday problems of the construction workers,
2. conflicts between the residents and the construction workers,
3. burdens on the functioning of the local government units.

### **Everyday problems of the construction workers**

Basic doubts as to the manner in which the needs of the construction workers are to be met are raised by the estimates given in the Report in relation to the provision of accommodation, water supply and domestic wastewater collection.

The Report reads that 'about 1,000 employees will stay in the container accommodation base at the construction site (in the Project Implementation Area), while about 4,000 will reside in the accommodation base at Choczewo, which will be built as part of the accompanying infrastructure'. At the peak employee influx, there will be 8,000 of them; hence it is doubtful whether the accommodation base will be sufficient to house so many persons at the same time. Even when taking into account the investors' assumptions that 15% of employees will come from the local market (as a result, they will not need medium- and long-term accommodation), it should be borne in mind that the Report indicates that a part of human resources will move to the areas around the Investment with their families, who will also need an accommodation base; this has not been considered in the estimates of the necessary number of accommodations.

The quantities of water also seem to be underestimated, as during the implementation of the Investment they will have to be larger by a multiple factor than at present; especially given that the Report indicates that: 'The basic factors conditioning the occurrence of impacts on the social and economic conditions include the number of employees and the place and duration of their

stay.’ The projection of the water consumption and wastewater collection as a result of the influx of employees needed to implement the NPP does not take into account the issues related to the functioning of the accommodation base at Choczewo and the container base at the construction site. As an element of the accompanying infrastructure in accordance with the Report, the accommodation base does not fall in the scope of the Project and can be considered only as a cumulative impact, i.e., the one caused by a given type of activity in combination with other past, present and real future activities. Moreover, the section of the Report concerned with cumulative impacts fails to give numerical data on the water demand, wastewater collection or the quantities of waste generated at the newly-built accommodation bases. Therefore, it is mistaken to adopt an approach where the estimates of the water demand, the quantities of wastewater collected and the waste generated are limited to those for the site of the construction/implementation of the Project only, since all the employees who will also significantly affect these issues ‘after work’ are an element of its implementation.

In addition to the issues of basic needs, consideration should be given to such needs as trade, catering, financial services, education or primary and specialised medical care. Trade, catering and financial services do not cause such large concerns as the other two sectors, since it can be assumed that demand will shape supply, although here and there formal problems may arise, e.g., when setting up bank accounts. In turn, healthcare services are essentially expected to be provided using the existing facilities and establishments. According to the Report, the Project will additionally generate about 3,300 visits annually. The Report also indicates the need to add the members of employees’ families who decide to stay with their families (this has not been taken into account in estimating the demand for accommodation – see above). The question is whether the now-existing facilities and the personnel working in them will be able to cope with such a significant increase in the demand for their services. As an additional problem, the Report indicates the language barrier which will appear in the doctor-patient relationship. In contrast, the Report does not address other sensitive issues which may arise, e.g., the issue of financing medical care or hiring medical personnel, which even today are the problems facing many medical establishments, or the issue of incurring the costs of setting up and managing an additional health care service. The Report also fails to indicate possible formal/legal problems related to treatment, e.g., the mandatory vaccinations of the children of newcomer employees, pre-employment examinations or other requirements under Polish law.

The Report also fails to address the issue of the adaptation of both the employees themselves and their families to Polish society. It can be expected that in the case of families, especially children, the feelings of alienation and loneliness and problems with social integration may arise and they, in turn, can cause conflicts.

### **Conflicts between the residents and the construction workers**

The Report identifies the sources of potential conflicts, mainly focusing on the relationship between the Investor and the local community and engaging in reflections on nuclear energy generation seen as a threat to the residents’ security. Almost entirely, it fails to address the



conflicts which may be caused by the presence of a large group of employees in the Municipalities surrounding the Investment and resulting, e.g., from cultural differences or just the language barrier already referred to above.

As already mentioned, the implementation of the Project will cause an increase in the population in its area, characterised by substantial variations at the different stages of the implementation of the NPP. The Report indicates that 80% of employees in the sector are aged up to 55 and are mostly men. It can be assumed, therefore, that there will be a considerable gender imbalance. Employees can come from countries with different cultures and profess different religions; in the conservative Polish society, this can spark conflicts. It must also be borne in mind that the influx of several thousand young men from different cultures and nationalities will cause social fears. On the one hand, it is due to the lesser cultural differentiation in our country, the lesser familiarity with national 'otherness' and the hostility of certain communities towards any manifestations of 'otherness', and, on the other hand, due to the reports in media about immigrants' attacks on the local communities. The language barrier will additionally strengthen these conflicts. In light of this, it seems justified to deploy additional law enforcement personnel, as in the case of the Olefin investment for Orlen, where police officers are expected to be present on the site on a 24-hour basis (Serwos Policji, Aktualności, 2023).

When analysing the statements in the Report about the burdens on medical establishments, it can be concluded that the primary medical care will take over the burden related to the provision of healthcare services; this can potentially have an adverse effect not only on the everyday conditions of the Investment employees, but also on the quality of life of the present residents and can be a cause of the residents' greater frustration. The excessive stress to the system may produce such effects as: patient referrals to other establishments and reduced access to diagnostics and treatment opportunities, as a result of a greater demand for medical personnel or delays in diagnosis and treatment. Such situations can potentially increase hostility and spark a conflict.

The residents may disapprove of the NPP construction itself and the accompanying investments; especially when they affect their everyday life, e.g., traffic jams that are caused by the deliveries of raw and other materials to the construction site, the tourist traffic declines and the road infrastructure is damaged by the movement of heavy equipment on it.

### **Burdens on the functioning of the local government units**

In its biased analysis of the impacts on the socioeconomic aspects, the Report points out the opportunities for improving the socioeconomic status of the localities. In the longer term, the construction can translate into the development of the localities where the Investment is located, especially as a result of a better availability of services, which may be expected to be set up in response to a greater demand generated by the Investment employees and the development of the necessary technical and social infrastructure. In turn, it is doubtful whether, given such a large influx of non-local employees, the availability of public services and

customer service will really improve as early as at the construction stage. On the contrary, given the burden on the offices, the implementation time of the services rendered is likely to be longer. The local government units will also face the challenges of having to serve customers in a language other than Polish and to finance the current translations of document templates, guides and instructions.

These burdens can arise both due to the need to serve a larger number of residents and due to the fact that it will be necessary to improve the availability of certain services which are managed by the Municipality. In accordance with the Act on the Municipal Government, its own tasks include, among others, the matters of healthcare, water supply pipelines and water supply, wastewater collection systems, municipal wastewater collection and treatment, keeping cleanliness and order, as well as sanitary facilities, waste landfills, municipal waste disposal, electricity, heat and gas supply, local collective transport, and public education. It is more difficult to carry out the tasks related to water supply, wastewater collection or waste collection, since the estimates of their quantities are not only very general and inaccurate, but also there is no indication of the levels of demand generated by the accompanying investments. In light of this, the Municipalities will find it difficult to prepare earlier tenders, e.g., for waste collection. The Report also assumes that a wastewater treatment plant and a wastewater collection system will be built as part of the accompanying infrastructure. These activities are the own tasks of the Municipalities; therefore, the costs of these investments can be imposed on them. Moreover, the office work related to these aspects may require the creation of additional full-time jobs equivalents at the Municipal Offices for persons handling a larger number of declarations of the number of persons living at given properties or the adoption of new rules for calculating the waste collection costs or the performance of inspections; the Report fails to address it.

The source of another additional burden on the functioning of the Municipality will be the need to organise school and pre-school sections in its area for the children of employees which come together with their families. Under the Polish law, a child coming from abroad is admitted to a public pre-school, a pre-school section of a public primary school or another public form of pre-school upbringing on the conditions and in the recruitment procedure applicable to Polish citizens; the same rules apply to the admission to forms in a primary school. Moreover, pursuant Education Law Act (Prawo oświatowe, 2016) the network of public primary schools should be so organised as to enable all the children to fulfil the school obligation. This means the need to arrange for free transport of all the children to primary schools. Therefore, in the case where the number of children in the Municipalities grows, the local government units have to open new school and pre-school sections; this will not only require the employment of additional teachers, but can also cause problems with finding premises and even make it necessary to build new facilities. In addition, teachers will have to be trained in the scope of the cultures of the children's countries of origin and the development of intercultural competences (Jaworska, 2019).

All the persons who reside in Poland's territory have the right to healthcare services and examinations which are related to the control of diseases, infections and infectious diseases. These rules also apply to persons who do not have Polish citizenship and even have no rights under health insurance. Assuming that the employees at the power plant construction site will be insured and, even skipping the abovementioned problems related to the need to hire the medical personnel who will be able to communicate with non-local patients, it can be assumed that the demand for medical services will grow significantly. According to the content of the Report, in this case, too, the need to ensure health services of adequate quality and availability will be the Municipalities' problem.

The need to ensure additional law enforcement personnel will also be the Municipalities' problem. However, among the accompanying investments, there is no indication of those related to ensuring security. Thus, the local authorities are responsible for infrastructure in the form of police stations/units (mainly during the construction) or fire service bases/units (during the operation, too).

## **Social gaps – the impact on local markets**

### **Labour market**

An important aspect of the construction and operation of the first nuclear power plant in Poland is its impact on the labour market. In this scope, the analysis should address not only the number of full-time jobs by which the local labour market will change, but also the co-existing factors which will gain importance with an influx of new hires.

A basic gap identified after the analysis of the Report is its approach to the labour market at the regional scale, failing as it does to consider the direct impact of the NPP construction on the local market. Emphasis is placed on the number of new full-time jobs on the construction and operation of the NPP, while the Report does not estimate the number of jobs liquidated as a result of the exclusion from use of the extensive area where the NPP will be located and the site and sea waters around the facilities of the power plant. This includes employees in the tourism sector, broadly understood services and fisheries whose activity is strictly related to the area to be affected by the expected significant impact of the NPP and whose skills may not be sufficient for work on the construction and operation of the NPP.

In the Report, the number of full-time jobs at the level of 860 employees at the operating stage of the power plant may be an underestimation. On the basis of similar investments, it was estimated that the operation of a 1,000 MW nuclear power plant would need on average about 600 full-time jobs (Kancelaria Senatu, *Opinie i ekspertyzy OE-401*, 2022). The planned capacity of the NPP is up to 3,750 MW; therefore, the number of 860 employees in the operating period is too low.

Given the high landscape values, the area of the planned location of the NPP in the Municipality of Choczewo is now used for tourism and resting purposes. It is an area of pristine nature, right next to the Sarbska Spit Reserve. It is difficult to find a similar investment in the

studies on the siting of nuclear power plants in the world. The difficulty with estimating the impact of the construction and operation on tourism in the Municipality of Choczewo results from the long timeframe (estimated at 70 years) and the fact that NPPs are usually not sited in an attractive area in terms of tourism. For this reason, the Report does not contain an exhaustive analysis of the impact on the tourism in the region. Another gap in the Report is its failure to verify the conformity of the project to build and operate the NPP with the European Union Strategy for the Baltic Sea Region in the scope of tourism and clean waters (EU Strategy for Baltic Sea Region, 2017).

The Report presents contradictory information on fisheries. It indicates a possible decrease in the demand for fish from catches near the power plant as a result of the view that the NPP has an adverse effect on water quality. At the same time, it mentions a possible increase in the demand for fish as personal foodstuffs caused by an influx of employees into the areas on the seacoast from those where fish are less available.

In addition, the Report completely fails to consider the need to support fish processing companies by the implementation of an information campaign among consumers. The companies which operate at a short distance from the proposed location of the NPP mark their products with the fishing symbol of FAO27 (the North-eastern part of the Atlantic Ocean), which includes, among others, the Baltic Sea, the Norwegian, the North Sea, the Irish Sea, the Portuguese Waters, Azores and the Greenland Waters. The Report fails to give the information that these are the locations of several dozen nuclear power plants using seawater for cooling purposes. To date, the operation of nuclear power plants in other countries has not changed the demand for fish products in Poland and is not a contraindication against the use of fish caught in the fisheries within the FAO27 area.

The Report also fails to address the impact of the NPP on the operations of the local fishermen and the fried fish shops which they supply. The Report indicates that the seawaters extending from the shore over a distance of 1.2 to 6 km into the sea, depending on the final choice of the investment option, will be completely excluded from general use. The shoreline of the area in question is about 3 km long. To fish, the local fishermen rarely sail more than 4 km into the sea; therefore, such a substantial exclusion from the use of seawaters will significantly limit their ability to fish and supply local catering outlets.

### **Property market**

The problem which has not been sufficiently explored in the Report is the level of employment in terms of the skills required from employees. In other words, the percentage of persons with high skills among employees at each implementation stage of the investment is not known. This factor is of essential importance for the property market, particularly the property resource. Scientific research has confirmed that ‘the higher the education level is, the higher remuneration a given individual obtains and this affects his/her total income and increases his/her consumer potential’ (Wałęga, 2010). Hence, affluent persons will expect better conditions of accommodation; this is not been considered in the Report. The Report fails

to present an analysis of the existing accommodation base, but gives an approximate number of accommodations required. The Authors of the Report fail to include additional accommodations for the families of the newcomer employees. Given the long-term character of the project, it is natural that some of the newcomer employees will want to settle down near their place of work, together with the accompanying persons.

In addition to the residential properties, road properties are an important element of the resource of the property market. In order to increase the transport availability during the construction of the NPP, there is a plan to expand the network of roads, railways and sea routes. The Report indicates the location of the NPP facilities and an approximate range of the area to be excluded from use. In contrast, the road properties are cursorily mentioned. There is also a need to fill in an information gap relating to the exact location of roads and to take into account the amounts of compensations for the properties to be taken over for this purpose. The Report contains the information that the existing roads will be used at the stage of preparatory works and then a new road will be built to connect the NPP and regional road 213. In the Report, there is an information gap relating to the quality of regional road 213. It is assumed that transport will be active 250 days in a year and it is estimated that there will be 600 lorry trips to the NPP each of the 250 days. Hence, there is the concern that the factor of the quality of the access road to the NPP has not been sufficiently examined.

An important aspect of the property resource are also the historic properties and archaeological sites situated in the area of the proposed location of the NPP and the accompanying infrastructure. In the Report, there is a gap relating to the determination of the extent of the impact on historic sites generated by vibrations from transportation and industrial activity, although it has been noted that the sites which have already been identified in a given area can be damaged due to the vibrations of heavy construction machinery and other factors. The Report allows for the possibility that other, as yet unidentified sites can be found during the execution of the construction works. It has been assumed optimistically that the time needed for an archaeological excavation and a site description will be one to two months, depending on the investment variant. This assumption may turn out to be too optimistic and could cause significant shifts in the timetable of the implementation of the NPP.

Another impact on properties is a change in their value. Vibrations and noise are effects accompanying the construction of the NPP facilities. They are so-called annoyances. People try to avoid places exposed to high sound intensity levels (Senetra, Szczepańska, 2011). In turn, vibrations damage the structure of existing buildings. Landscape changes are an additional outcome of the implementation of the investment. This factor is irreversible and it is extremely important in an area with high landscape values (Senetra, 2010). The Report does not give the rate of a decrease in the value of properties. It contains the information about an adverse impact on the value of properties, presenting the following argument: 'Examples of nuclear power plants abroad indicate that the drops in prices to be seen in the markets analysed predominantly took place very close to the power plants, as presented in the 2011 study on the

U.S. market from which it follows that prices grew as the distance from a nuclear facility increased.’ The article indicates the percentage-based decreases in the property prices and rents at the level of 4-7% within a radius of 2 miles from a nuclear facility (Davis, 2011), but this fact is not included in the Report. The Davis article cited in the Report is not included in the References. Another study on a case in Finland also indicates drops in prices, especially those of residential properties situated in the direct vicinity of the nuclear power plant Olkiluoto 3, where the prices are lower by about 36% than those of properties not far away. After the construction stage is completed, there will be an outflow of persons working on the construction. A reduced demand for properties causes their prices to fall and thus affects their market value. In the Report, manifestations of the impact of the proposed construction of the NPP on the value of properties are not fully described and the information is presented in a manner designed to mitigate a possible conflict with the local community.

#### 4. Conclusions

Fit 55 is ambitious. In Poland’s case, it is difficult to achieve and absolutely too costly to be incurred at the assumed pace of changes, as it requires a change of both the model of the economy and the lifestyle. The Olefin III petrochemical complex was expected to cost PLN 13.5 billion, but will cost PLN 25 billion. It was planned to be put into operation in the 1st quarter of 2024, but this will probably take place in the 1st half of 2027 at the earliest (Furman, 2023). The Supreme Audit Office negatively assessed the implementation of the investment in the power unit with an electrical capacity of 1,000 MW in Ostrołęka, where the losses suffered from the construction of the unit were estimated at 1,348,904,500 and the auditors indicated the inability to ensure funding sources as the main cause of the failure (Najwyższa Izba Kontroli, 2021). These facts call into question not only the ability to finance this investment, but also its timeliness and its success. Indeed, the building of public trust in the long term is certainly unlikely to be developed by the documentation in which the analyses of the impacts of the Investment on the residents, the functioning of the Municipality, the labour market, tourism and the property market are incorrectly designed. It is exactly in this scope that gaps have been identified in the Environmental Impact Assessment Report on the project to build and operate the first Nuclear Power Plant in Poland with an electrical capacity of up to 3,750 MWe, in the areas of the Municipalities of: Choczewo or Gniewino and Krokowa.

Key managerial gaps include:

- the duration of the particular stages of the Project is too optimistic;
- failure to take into account probable delays, budget overruns and a change in the scope of the Project;

- failure to address the coordination of the accompanying investments with the NPP Investment;
- failure to indicate the persons/entities responsible in specific cases for the implementation and execution of measures to minimise impacts;
- the wishful qualification of an impact as low/insignificant on the condition of minimising measures, where it is not known who is responsible for them or who can/should implement them;
- investments which are necessary for the operation of the NPP (access roads, railway lines and the accommodation base) have been excluded from the scope of the Project and qualified as accompanying investments; as a result, the subject matter of the analysis of the cumulative impact is not the impact between the abovementioned accompanying investments (although they are necessary for the operation of the NPP) and the external projects.

The most important gaps in the scope of the analysis of the impact on the residents and functioning of the Municipality relate to:

- an indication of the real area of the impact of the Project;
- the application of minimising measures and their effect on the strength of impacts;
- the qualification of the construction period of a dozen years or so as a temporary impact, thus belittling its significance;
- failure to analyse the impact of the construction workers staying at the accommodation bases on the residents' everyday life;
- failure to take into account the need to create new full-time jobs in offices and public services related to transport, waste collection, education, health service and the police;
- failure to take into account the need to prepare new local land use plans or change the existing ones and the costs of this process.

The key gaps in the scope of the impacts on the labour market, tourism and the property market include:

- the absence of grounds for making the assumptions on the projected number of employees, especially at the operation stage;
- therefore, the projections based on a vaguely assumed number of employees (the required number of accommodations, the expected level of employment for the local community) can entail a significant error;
- failure to analyse the existing hotel and accommodation base;
- failure to determine the impacts of vibrations, noise and the loss of landscape values on historic sites and the value of properties or their imprecise determination;
- incomplete analyses of changes in the local labour market and projections of lost jobs.

Given the restrictions on the length of the text, the article indicates and discusses only selected problems, which the Report fails to acknowledge, or it only addresses them cursorily; however, the importance of these issues indicates how large a challenge this investment will pose for the residents and authorities of the local municipalities. At the same time, it can be inferred that the underestimation of the impact on society is a deliberate action. It diverts attention from the actual problems and risks of a social character, distorts the concept of sustainable development, incorrectly focuses on the environmental aspects only and fails to address the economic and social ones.

The Authors of the Report belittle many problems, assuming the situation to be a temporary one – including transitional burdens on the life of the local community and the burdens with which the local government units will have to cope. However, taking into account the duration of the Investment in the context of both the social relations, the work of the local government units and organisations or other environmental elements (in the context of both the natural environment and the surroundings) affected by this Investment – it is difficult to consider that the prospects of changes over almost 20 years represent a temporary or transitional situation.

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## PREDICTIVE MAINTENANCE – THE BUSINESS ANALYTICS USAGE IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK<sup>1\*</sup>, Wies GREBSKI<sup>2</sup>

<sup>1</sup> Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; [rwolniak@polsl.pl](mailto:rwolniak@polsl.pl), ORCID: 0000-0003-0317-9811

<sup>2</sup> Penn State Hazletonne, Pennsylvania State University; [wxg3@psu.edu](mailto:wxg3@psu.edu), ORCID: 0000-0002-4684-7608

\* Correspondence author

**Purpose:** The purpose of this publication is to present the applications of usage of business analytics in predictive maintenance.

**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 predictive maintenance within the context of Industry 4.0 signifies a revolutionary change in how organizations manage their industrial assets. The Industry 4.0 landscape, characterized by advanced technologies and interconnected systems, has elevated predictive maintenance as a cornerstone of operational strategies. This shift from reactive to proactive maintenance, powered by real-time data analytics, machine learning, and IoT integration, not only ensures equipment longevity but also offers a multitude of advantages. The applications of business analytics in predictive maintenance, detailed in Table 1, illustrate the comprehensive approach organizations take in collecting, integrating, and analyzing data to anticipate and prevent equipment failures. The significance of this strategic imperative is further underscored by the diverse range of business analytics software highlighted in Table 2, tailored to specific industry needs and emphasizing adaptability and scalability in Industry 4.0 conditions. The benefits outlined in Table 3 highlight the substantial positive impact of business analytics on predictive maintenance, including increased operational efficiency, cost savings, extended equipment lifespan, and improved safety. The alignment of predictive maintenance with IoT and Industry 4.0 principles ensures a smooth integration into the broader manufacturing ecosystem. However, challenges discussed in Table 4 reveal the complexities organizations face in maintaining the quality, scalability, and responsiveness of predictive maintenance systems. Addressing these challenges requires continuous investment in infrastructure, skilled resources, and resolving issues related to data quality and latency.

**Keywords:** business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; predictive maintenance.

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

## 1. Introduction

In the dynamic landscape of Industry 4.0, where advanced technologies converge to revolutionize traditional manufacturing processes, predictive maintenance stands out as a cornerstone of operational efficiency. Businesses are increasingly adopting predictive maintenance strategies empowered by cutting-edge business analytics to optimize asset management, reduce downtime, and enhance overall productivity. This paradigm shift from reactive to proactive maintenance not only ensures the longevity of equipment but also contributes significantly to cost savings and operational excellence.

The adoption of predictive maintenance, fueled by business analytics, is a strategic imperative for organizations seeking to stay competitive and agile. The ability to harness real-time data, advanced analytics, and machine learning empowers businesses to predict and prevent equipment failures, ultimately leading to increased operational efficiency, cost savings, and improved overall performance. As technology continues to evolve, the synergy between predictive maintenance and Industry 4.0 will play a pivotal role in shaping the future of industrial operations impact (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021; Wolniak et al., 2023; Wolniak, Grebski, 2023; Wolniak, Skotnicka-Zasadzień, 2023; Jonek-Kowalska, Wolniak, 2023).

The purpose of this publication is to present the applications of usage of business analytics in predictive maintenance.

## 2. The selected aspects of business analytics usage predictive maintenance

Predictive maintenance relies on a robust foundation of data. In Industry 4.0, sensors and IoT devices play a crucial role in collecting real-time data from machinery and equipment. This data is then integrated with other relevant information, such as historical performance data, maintenance logs, and external factors like weather conditions. Business analytics tools, powered by machine learning algorithms, analyze the integrated data to identify patterns and anomalies. These analytics models learn from historical data and continuously improve their predictive capabilities. As more data is fed into the system, the accuracy of predictions increases, allowing organizations to make informed decisions about maintenance activities (Zeng et al., 2022; Pech, Vrchota, 2022).

Real-time monitoring of equipment conditions is a pivotal aspect of predictive maintenance. Continuous tracking of parameters like temperature, vibration, and fluid levels provides insights into the health of machinery. Deviations from normal operating conditions trigger alerts,

enabling timely intervention and preventive actions. Predictive maintenance employs sophisticated algorithms to forecast potential failures. These models take into account a multitude of variables, including equipment usage patterns, environmental factors, and historical failure data. As a result, organizations can create accurate predictions of when maintenance is needed, minimizing downtime and optimizing resources (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, Orzeł, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021).

Table 1 contains descriptions of how business analytics is used in the case of predictive maintenance.

**Table 1.**  
*The usage of business analytics in predictive maintenance*

<b>Application</b>	<b>Description</b>
<b>Data Acquisition and Integration</b>	Predictive maintenance begins with the systematic collection of real-time data from sensors and IoT devices installed on machinery. This data encompasses a wide range of parameters, including but not limited to temperature, pressure, vibration, and operational metrics. The integration of this real-time data with historical performance data, maintenance logs, and external factors like weather conditions creates a comprehensive dataset for analysis and prediction. This process enables a holistic understanding of equipment health and facilitates more accurate predictions of potential failures.
<b>Advanced Analytics and Machine Learning</b>	Business analytics tools, powered by machine learning algorithms, are employed to dissect the integrated dataset. These tools analyze patterns, anomalies, and trends within the data, allowing for the creation of predictive models. These models continuously learn from historical data, adapting and improving their predictive capabilities over time. The use of advanced analytics in predictive maintenance empowers organizations to make informed decisions based on data-driven insights, enhancing the overall efficacy of maintenance strategies.
<b>Condition Monitoring</b>	Condition monitoring is a continuous and real-time process that involves tracking various parameters related to equipment health. This includes monitoring temperature variations, vibration levels, fluid conditions, and other relevant indicators. Deviations from established norms trigger alerts, providing an early indication of potential issues. Through robust condition monitoring, organizations gain actionable insights into the health of their assets, enabling timely intervention to prevent failures and optimize maintenance activities.
<b>Predictive Algorithms and Models</b>	The heart of predictive maintenance lies in sophisticated algorithms that leverage the integrated dataset and analytics insights. These predictive models take into account a multitude of variables, including usage patterns, environmental factors, and historical failure data. The models forecast when equipment is likely to fail, offering a proactive approach to maintenance. As these algorithms continually learn from new data, the accuracy of predictions increases, allowing organizations to optimize resources and minimize downtime.
<b>Reduced Downtime</b>	One of the primary benefits of predictive maintenance is the ability to anticipate and address potential equipment failures before they lead to unplanned downtime. By scheduling maintenance activities during planned downtimes, organizations minimize disruptions to operations and production schedules. This strategic approach to maintenance improves overall operational efficiency and ensures a more stable production environment.
<b>Cost Savings</b>	Predictive maintenance significantly reduces costs associated with reactive maintenance. Unplanned downtime, emergency repairs, overtime payments, and rush orders for replacement parts are minimized. The proactive identification and resolution of issues contribute to substantial cost savings over time, making predictive maintenance a financially prudent strategy.

Cont. table 1.

<b>Optimized Asset Performance</b>	Predictive maintenance goes beyond avoiding downtime; it actively contributes to optimizing the performance of assets. By addressing potential issues before they escalate, organizations ensure that equipment operates at peak efficiency. This not only extends the lifespan of assets but also maximizes their overall performance, leading to a higher return on investment.
<b>Enhanced Safety</b>	Proactive maintenance strategies contribute to a safer working environment. By identifying and addressing potential equipment issues before they result in accidents or malfunctions, organizations prioritize employee safety. Predictive maintenance, therefore, plays a crucial role in mitigating risks and fostering a secure workplace.
<b>Continuous Improvement</b>	Predictive maintenance is an iterative process that thrives on continuous improvement. Feedback loops, data analysis, and insights from ongoing operations contribute to the refinement of predictive models. This iterative approach enhances the accuracy and effectiveness of predictive maintenance strategies, ensuring they remain aligned with evolving operational needs.
<b>Integration with Industry 4.0</b>	Predictive maintenance aligns seamlessly with the principles of Industry 4.0. By leveraging interconnected systems, data sharing, and smart technologies, predictive maintenance becomes an integral part of the broader manufacturing ecosystem. This integration enhances the synergy between predictive maintenance and other Industry 4.0 technologies, fostering a more interconnected and efficient industrial landscape.

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 predictive maintenance in Industry 4.0 conditions

Predictive maintenance, powered by business analytics software, has emerged as a transformative approach to equipment management and operational efficiency across various industries. The integration of advanced analytics into maintenance strategies brings about a paradigm shift from traditional, reactive methods to proactive, data-driven decision-making. This evolution is particularly evident in the utilization of cutting-edge business analytics software, which plays a pivotal role in optimizing asset performance, reducing downtime, and ultimately enhancing the overall productivity of industrial processes (Bakir, Dahlan, 2022).

At the core of the usage of business analytics software in predictive maintenance is the ability to harness and analyze vast amounts of data. These software solutions facilitate the seamless integration of real-time data from sensors and IoT devices with historical performance metrics. By leveraging sophisticated algorithms, businesses can derive actionable insights from this integrated dataset, enabling them to make informed decisions about maintenance activities (Greasley, 2019). Business analytics software excels in predictive modeling and analysis, allowing organizations to forecast potential equipment failures with a high degree of accuracy (Scappini, 2016). Through machine learning algorithms, these tools can identify patterns, anomalies, and trends in the data, enabling the creation of predictive models. This predictive capability empowers maintenance teams to address issues before they escalate, minimizing downtime and maximizing the operational lifespan of assets (Ghibakholl et al., 2022).



The strategic deployment of business analytics in predictive maintenance extends beyond merely predicting failures; it includes optimizing the allocation of resources. By identifying when maintenance is truly necessary, organizations can schedule activities during planned downtimes, minimizing disruptions to operations and improving resource efficiency (Akundi et al, 2022). This proactive approach contributes to cost savings and ensures that maintenance efforts are focused where they are most needed. The strategic deployment of business analytics in predictive maintenance extends beyond merely predicting failures; it includes optimizing the allocation of resources. By identifying when maintenance is truly necessary, organizations can schedule activities during planned downtimes, minimizing disruptions to operations and improving resource efficiency. This proactive approach contributes to cost savings and ensures that maintenance efforts are focused where they are most needed (Cillo et al., 2022).

Table 2 highlighting examples of software and applications used in predictive maintenance, along with descriptions of their usage. These examples showcase the diversity of business analytics software available for predictive maintenance, catering to different industries and operational needs.

**Table 2.**  
*The usage of business analytics software in environmental sustainability*

Software/Application	Description	Key Features
<b>IBM Maximo</b>	IBM Maximo is an enterprise asset management (EAM) software that incorporates business analytics for predictive maintenance. It facilitates the integration of real-time data from sensors and IoT devices to optimize asset performance and reduce downtime.	<ul style="list-style-type: none"> <li>• <b>Condition-Based Monitoring:</b> Real-time monitoring of asset conditions through integrated IoT data.</li> <li>• <b>Advanced Analytics:</b> Utilizes machine learning for predictive modeling and trend analysis.</li> <li>• <b>Work Order Management:</b> Streamlines the execution of maintenance tasks based on predictive insights.</li> </ul>
<b>SAP Predictive Maintenance and Service</b>	SAP's solution integrates business analytics with predictive maintenance capabilities. It leverages machine learning algorithms and IoT data to forecast equipment failures and optimize maintenance processes.	<ul style="list-style-type: none"> <li>• <b>Predictive Analytics:</b> Uses historical data and machine learning to predict equipment failures.</li> <li>• <b>IoT Integration:</b> Collects and analyzes data from connected devices for real-time insights.</li> <li>• <b>Resource Optimization:</b> Enables efficient allocation of resources based on predictive insights.</li> </ul>
<b>Microsoft Azure IoT Hub</b>	Microsoft Azure IoT Hub is a cloud-based platform that provides business analytics tools for predictive maintenance. It focuses on data analytics, machine learning, and IoT integration to enhance equipment reliability.	<ul style="list-style-type: none"> <li>• <b>Data Ingestion and Storage:</b> Gathers and stores data from various sources for analysis.</li> <li>• <b>Machine Learning Workbench:</b> Enables the development and deployment of predictive models.</li> <li>• <b>Real-Time Alerts:</b> Notifies users of potential equipment failures for proactive intervention.</li> </ul>

Cont. table 2.

<b>Oracle IoT Asset Monitoring Cloud</b>	Oracle's solution is designed for monitoring and maintaining assets using business analytics. It combines IoT data with analytics to predict maintenance needs and optimize asset performance.	<ul style="list-style-type: none"> <li>• <b>Asset Health Monitoring:</b> Continuous monitoring of asset conditions through IoT sensors.</li> <li>• <b>Predictive Analytics:</b> Utilizes historical and real-time data for predictive modeling.</li> <li>• <b>Integration with Oracle EAM:</b> Seamless integration with Oracle's Enterprise Asset Management system for end-to-end asset management.</li> </ul>
<b>Siemens MindSphere</b>	Siemens MindSphere is an industrial IoT platform that integrates business analytics for predictive maintenance. It focuses on leveraging IoT data and analytics to enhance equipment performance and reliability.	<ul style="list-style-type: none"> <li>• <b>Asset Performance Management:</b> Monitors asset performance and health through real-time data.</li> <li>• <b>Advanced Analytics:</b> Utilizes machine learning algorithms for predictive maintenance.</li> <li>• <b>Collaborative Maintenance:</b> Facilitates collaboration among teams for effective maintenance decision-making.</li> </ul>
<b>Predix (by GE Digital)</b>	Predix is a comprehensive industrial IoT platform that includes analytics for predictive maintenance. It integrates with a variety of industrial equipment to provide real-time insights and predictive modeling.	<ul style="list-style-type: none"> <li>• <b>Asset Performance Management:</b> Monitors equipment health and performance.</li> <li>• <b>Data Analytics:</b> Utilizes machine learning for predictive analysis.</li> <li>• <b>Integration with Field Service:</b> Seamless connection with field service applications for streamlined maintenance workflows.</li> </ul>
<b>PTC ThingWorx</b>	PTC ThingWorx is an IoT platform that incorporates business analytics for predictive maintenance. It focuses on connecting and analyzing data from various IoT devices to optimize asset management.	<ul style="list-style-type: none"> <li>• <b>Remote Monitoring:</b> Real-time monitoring of equipment conditions remotely.</li> <li>• <b>Predictive Analytics:</b> Leverages machine learning for predicting equipment failures.</li> <li>• <b>Scalable Platform:</b> Supports scalability as the IoT ecosystem grows.</li> </ul>
<b>Infor EAM (Enterprise Asset Management)</b>	Infor EAM is an enterprise asset management solution that includes predictive maintenance capabilities. It integrates with IoT devices and business analytics for data-driven decision-making.	<ul style="list-style-type: none"> <li>• <b>IoT Integration:</b> Gathers data from sensors and IoT devices for analysis.</li> <li>• <b>Predictive Maintenance Modeling:</b> Uses analytics to predict equipment failures.</li> <li>• <b>Mobile Accessibility:</b> Allows for on-the-go monitoring and maintenance tasks through mobile devices.</li> </ul>
<b>Dynamics 365 Field Service</b>	Microsoft Dynamics 365 Field Service includes predictive maintenance features for organizations seeking to optimize field service operations. It combines IoT data with business analytics to enhance asset reliability.	<ul style="list-style-type: none"> <li>• <b>Connected Field Service:</b> Integrates with IoT devices for real-time data collection.</li> <li>• <b>Predictive Maintenance Insights:</b> Utilizes historical and real-time data for predictions.</li> <li>• <b>Work Order Optimization:</b> Streamlines work order management based on predictive insights.</li> </ul>

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 predictive maintenance**

Business analytics in predictive maintenance significantly enhances operational efficiency by leveraging real-time data analytics and machine learning algorithms. This approach allows organizations to optimize maintenance schedules, minimizing downtime and ensuring that equipment is serviced precisely when needed. The result is a streamlined industrial ecosystem that operates with heightened efficiency, aligning seamlessly with the demands of Industry 4.0 for agile and responsive processes (Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Wolniak, 2013, 2016; Hys, Wolniak, 2018). One of the primary advantages of employing business analytics in predictive maintenance is the substantial cost savings it brings. By accurately predicting maintenance needs, organizations can prevent unplanned downtime, emergency repairs, and associated costs. The ability to optimize resource allocation and prevent unnecessary expenditures on overhauls or replacements further contributes to a significant reduction in operational expenses, aligning with the cost-effective principles of Industry 4.0 (Adel., 2022).

Predictive maintenance guided by business analytics not only averts unexpected breakdowns but actively contributes to extending the lifespan of industrial equipment. By addressing potential issues before they escalate, organizations can implement preventive measures to mitigate wear and tear. This not only optimizes asset performance but also ensures that machinery operates within optimal parameters, aligning with Industry 4.0's emphasis on maximizing the return on investment (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022). Enhancing workplace safety is a paramount advantage of integrating business analytics into predictive maintenance. The proactive identification and resolution of potential equipment failures contribute to a safer working environment. By minimizing risks associated with equipment malfunctions, organizations foster a culture of safety that aligns with the principles of Industry 4.0, emphasizing the well-being of personnel and the integrity of industrial processes (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

Table 3 contains the advantages of using business analytics in predictive maintenance within Industry 4.0 conditions, along with descriptions for each advantage.

**Table 3.**  
*The advantages of using business analytics in predictive maintenance*

Advantage	Description
<b>Increased Operational Efficiency</b>	Business analytics plays a crucial role in enhancing operational efficiency in the context of predictive maintenance within Industry 4.0. By leveraging real-time data analytics and machine learning algorithms, organizations can optimize maintenance schedules. This proactive approach minimizes downtime, ensuring that equipment is serviced precisely when needed, thus maximizing production efficiency and reducing operational disruptions. The result is a streamlined and efficient industrial ecosystem that meets the demands of Industry 4.0.
<b>Cost Savings</b>	The integration of business analytics in predictive maintenance translates into substantial cost savings for organizations. Predictive maintenance, driven by data insights, helps prevent unplanned downtime and emergency repairs, reducing associated costs. Furthermore, by accurately predicting maintenance needs, organizations can optimize resource allocation, preventing unnecessary expenditures on overhauls or replacements. The financial benefits extend to improved efficiency in labor utilization and reduced overtime expenses due to better-planned maintenance activities.
<b>Extended Equipment Lifespan</b>	Predictive maintenance guided by business analytics not only prevents unexpected breakdowns but also contributes to extending the lifespan of industrial equipment. By addressing potential issues before they escalate, organizations can implement preventive measures to mitigate wear and tear. This approach optimizes asset performance and ensures that machinery operates within optimal parameters, ultimately maximizing the return on investment and deferring the need for premature replacements.
<b>Improved Safety</b>	Business analytics in predictive maintenance enhances workplace safety by enabling organizations to proactively address potential equipment failures. By identifying and rectifying issues before they lead to accidents, businesses create a safer working environment for their personnel. Predictive maintenance fosters a culture of safety by minimizing risks associated with equipment malfunctions, thus aligning with Industry 4.0's emphasis on creating technologically advanced and safe industrial workplaces.
<b>Enhanced Asset Performance</b>	Business analytics software facilitates the creation of predictive models that optimize asset performance. By continuously monitoring equipment conditions, analyzing historical data, and predicting potential failures, organizations can fine-tune their assets for peak efficiency. Enhanced asset performance not only contributes to improved productivity but also ensures that industrial processes operate seamlessly within the dynamic framework of Industry 4.0.
<b>Data-Driven Decision-Making</b>	In Industry 4.0, the use of business analytics ensures that decisions related to predictive maintenance are grounded in data-driven insights. Organizations can leverage advanced analytics tools to analyze vast datasets, identify patterns, and make informed decisions about maintenance activities. This data-driven decision-making process enhances the precision and accuracy of maintenance strategies, aligning them with real-time operational needs and historical performance data.
<b>Proactive Issue Identification</b>	Predictive maintenance, empowered by business analytics, excels in proactively identifying potential issues before they can impact operations. Through continuous monitoring and the application of predictive algorithms, organizations receive early alerts regarding deviations from normal operating conditions. This early-warning system enables maintenance teams to intervene proactively, preventing costly breakdowns and ensuring the uninterrupted flow of operations within the Industry 4.0 framework.
<b>Integration with IoT and Industry 4.0</b>	The integration of business analytics in predictive maintenance seamlessly aligns with the principles of Industry 4.0 and the Internet of Things (IoT). This integration creates a connected ecosystem where data is not only collected but shared and analyzed in real-time. The interconnectivity of systems enables a more responsive and agile industrial environment, fostering collaboration among various components and contributing to the overall efficiency and adaptability demanded by Industry 4.0.
<b>Scalability and Adaptability</b>	Business analytics solutions for predictive maintenance are designed to be scalable and adaptable to the evolving needs of Industry 4.0. These solutions can handle increasing data volumes and adapt to changes in operational landscapes. Whether scaling up to accommodate a growing industrial ecosystem or adapting to incorporate new technologies, the flexibility of business analytics software ensures that predictive maintenance strategies remain robust and aligned with the dynamic requirements of Industry 4.0.

Cont. table 3.

<b>Continuous Improvement</b>	The iterative nature of predictive maintenance, supported by business analytics, fosters a culture of continuous improvement. By incorporating feedback loops, analyzing operational data, and deriving insights from ongoing maintenance activities, organizations can refine and enhance their predictive models. This iterative approach ensures that predictive maintenance strategies remain agile, responsive, and continuously aligned with evolving operational requirements in the Industry 4.0 era.
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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).

Ensuring the quality and seamless integration of data from diverse sources, including IoT devices, sensors, and legacy systems, poses a significant challenge. Inaccuracies, inconsistencies, or incomplete data can compromise the reliability of predictive models, impacting the effectiveness of maintenance strategies. The exponential growth of data in Industry 4.0 can strain the scalability of business analytics systems. Adapting to increasing data volumes while maintaining real-time processing capabilities requires continuous investment in scalable infrastructure and technologies (Nourani, 2021).

Developing and maintaining sophisticated predictive models demands specialized skills and resources. The dynamic nature of Industry 4.0 processes, coupled with the intricacies of manufacturing, introduces complexities in designing and continually refining predictive models. Industry 4.0 emphasizes real-time decision-making, placing demands on predictive maintenance systems to process and analyze data in near real-time. Overcoming latency challenges and ensuring timely responses to emerging maintenance needs is critical for maintaining operational efficiency (Charles et al., 2023).

Table 4 contains the problems of using business analytics in predictive maintenance within Industry 4.0 conditions, along with descriptions for each problem.

**Table 4.**  
*The problems of using business analytics in predictive maintenance*

<b>Problem</b>	<b>Description</b>
<b>Data Quality and Integration Issues</b>	The effectiveness of business analytics relies heavily on the quality and integration of data from diverse sources. In Industry 4.0, where numerous IoT devices contribute data, ensuring data accuracy, consistency, and seamless integration poses a significant challenge. Incomplete or inaccurate data can compromise the accuracy of predictive models, leading to erroneous maintenance predictions.
<b>Scalability Challenges</b>	The exponential growth of data in Industry 4.0 can strain the scalability of business analytics systems. As the volume of data increases, organizations may face challenges in scaling their analytics infrastructure to handle the higher data loads. Ensuring that analytics solutions remain responsive and efficient in the face of expanding datasets is a critical consideration.
<b>Complexity of Predictive Models</b>	Developing and maintaining complex predictive models requires specialized skills and resources. In Industry 4.0, the intricacies of manufacturing processes, coupled with the dynamic nature of equipment, demand sophisticated predictive models. Organizations may encounter challenges in acquiring and retaining the necessary expertise to design, implement, and continually refine these intricate models.

Cont. table 4.

<b>Real-Time Processing Demands</b>	Industry 4.0 emphasizes real-time decision-making, requiring predictive maintenance systems to process and analyze data in near real-time. Meeting these real-time processing demands can be challenging, especially when dealing with large datasets. Delays in data processing may hinder the ability to respond swiftly to emerging maintenance needs, impacting operational efficiency.
<b>Security and Privacy Concerns</b>	The interconnected nature of Industry 4.0 raises concerns about the security and privacy of sensitive data used in predictive maintenance. Protecting data from cyber threats and ensuring compliance with privacy regulations become critical considerations. Balancing the need for data accessibility with robust security measures poses a constant challenge for organizations adopting business analytics in predictive maintenance.
<b>Cost of Implementation and Integration</b>	While predictive maintenance offers long-term cost savings, the initial costs associated with implementing and integrating business analytics solutions can be substantial. Organizations may face challenges in justifying these upfront costs, especially if they lack a clear understanding of the potential long-term benefits and return on investment.
<b>Maintenance of IoT Devices and Sensors</b>	The reliance on IoT devices and sensors for data collection in Industry 4.0 introduces challenges related to device maintenance. Ensuring the proper functioning and calibration of these devices is crucial for the accuracy of data. Device failures or inaccuracies can lead to flawed data inputs, undermining the reliability of predictive maintenance models.
<b>Overcoming Resistance to Change</b>	Industry 4.0 initiatives often require a cultural shift towards embracing new technologies and data-driven decision-making. Resistance to change from employees and stakeholders can impede the successful implementation of business analytics in predictive maintenance. Educating and fostering a culture that values the benefits of data analytics may require significant effort.
<b>Lack of Standardization</b>	The lack of standardized protocols and formats for data in Industry 4.0 can create interoperability challenges. Integrating data from different sources with varying formats and standards may lead to inconsistencies and hinder the seamless flow of information required for effective predictive maintenance.
<b>Continuous Training and Skill Development</b>	The rapid evolution of technology in Industry 4.0 demands continuous training and skill development for personnel involved in managing and utilizing business analytics for predictive maintenance. Keeping up with the latest advancements and ensuring that the workforce possesses the necessary skills can be an ongoing challenge for organizations committed to leveraging Industry 4.0 technologies.
<b>Complexity of Edge Computing</b>	The adoption of edge computing in Industry 4.0, where data processing occurs closer to the data source, introduces complexity. Implementing analytics at the edge requires addressing issues such as resource constraints, network latency, and managing distributed computing environments. Balancing the benefits of edge analytics with its inherent complexities poses a challenge for organizations.
<b>Lack of Unified Standards for Analytics Platforms</b>	The absence of universally accepted standards for analytics platforms complicates integration efforts. Organizations often use a mix of proprietary and open-source analytics tools, leading to interoperability challenges. The lack of a standardized framework can hinder seamless communication and data exchange between different analytics solutions.
<b>Unstructured Data Handling</b>	Industry 4.0 generates a vast amount of unstructured data, including images, videos, and text. Effectively handling and extracting meaningful insights from unstructured data poses a significant challenge for business analytics. Developing algorithms capable of processing and interpreting diverse data types is essential for comprehensive predictive maintenance in Industry 4.0.
<b>Limited Predictive Analytics Adoption Awareness</b>	Despite the potential benefits, there is still a lack of awareness and understanding regarding the capabilities and advantages of predictive analytics in some industrial sectors. Convincing stakeholders of the value proposition and overcoming skepticism may pose challenges, especially in industries with traditional maintenance practices.
<b>Evolving Regulatory Landscape</b>	The regulatory landscape in the context of data privacy and security is continually evolving. Navigating these regulatory changes, ensuring compliance, and adapting predictive maintenance strategies accordingly can be a challenge for organizations operating in Industry 4.0 environments.

Cont. table 4.

<b>Dependency on Connectivity Infrastructure</b>	Industry 4.0 relies heavily on interconnected systems and high-speed networks. Any disruption in connectivity, whether due to technical issues or cyber threats, can impede the seamless flow of data required for effective predictive maintenance. Organizations need robust contingency plans to address connectivity challenges and prevent disruptions.
<b>Handling Big Data Challenges</b>	The sheer volume, velocity, and variety of data generated in Industry 4.0 environments contribute to big data challenges. Efficiently managing and processing large datasets require advanced infrastructure and analytics capabilities. Organizations may face difficulties in harnessing the full potential of big data for predictive maintenance without the appropriate resources.
<b>Ethical Considerations in Data Usage</b>	As organizations collect and analyze vast amounts of data for predictive maintenance, ethical considerations become paramount. Ensuring responsible and ethical use of data, protecting privacy, and being transparent about data practices can be challenging in the rapidly evolving landscape of Industry 4.0.
<b>Legacy System Integration</b>	Many industrial facilities still operate with legacy systems that may not seamlessly integrate with modern business analytics solutions. Bridging the gap between legacy infrastructure and advanced analytics platforms requires careful planning and investment in integration solutions, posing a challenge for organizations with older technology stacks.
<b>Dynamic Nature of Industry 4.0 Technologies</b>	The rapid pace of technological advancements in Industry 4.0 introduces a challenge of staying abreast of the latest innovations. Adapting predictive maintenance strategies to leverage emerging technologies, such as artificial intelligence and augmented reality, requires continuous monitoring and strategic decision-making to remain at the forefront of Industry 4.0 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).

## 5. Conclusion

The integration of business analytics in predictive maintenance within the context of Industry 4.0 marks a transformative shift in the way organizations manage their industrial assets. The dynamic landscape of Industry 4.0, characterized by advanced technologies and interconnected systems, has propelled predictive maintenance to the forefront of operational strategies. This paradigm shift from reactive to proactive maintenance, fueled by real-time data analytics, machine learning algorithms, and IoT integration, not only ensures the longevity of equipment but also brings forth a myriad of advantages.

The applications of business analytics in predictive maintenance, as outlined in Table 1, showcase the comprehensive approach organizations adopt in collecting, integrating, and analyzing data to predict and prevent equipment failures. This strategic imperative is further emphasized by the diverse array of business analytics software highlighted in Table 2, each tailored to specific industry needs, emphasizing the adaptability and scalability required in Industry 4.0 conditions.

The advantages presented in Table 3 underscore the significant positive impact of business analytics on predictive maintenance. From increased operational efficiency and cost savings to extended equipment lifespan and improved safety, organizations stand to gain substantial benefits by adopting these data-driven strategies. Furthermore, the alignment of predictive maintenance with IoT and Industry 4.0 principles ensures a seamless integration into the broader manufacturing ecosystem. However, challenges, as discussed in Table 4, highlight the complexities organizations face in ensuring the quality, scalability, and responsiveness of predictive maintenance systems. Overcoming these challenges necessitates continuous investment in infrastructure, skilled resources, and addressing issues related to data quality and latency.

It can be stated that, the adoption of business analytics in predictive maintenance is not just a technological evolution but a strategic imperative for organizations aiming to stay competitive and agile in the rapidly evolving landscape of Industry 4.0. As technology continues to advance, the synergy between predictive maintenance and Industry 4.0 will undoubtedly shape the future of industrial operations, fostering a more interconnected, efficient, and adaptive industrial ecosystem.

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## ENVIRONMENTAL SUSTAINABILITY – THE BUSINESS ANALYTICS USAGE IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK<sup>1\*</sup>, Wies GREBSKI<sup>2</sup>

<sup>1</sup> Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; [rwolniak@polsl.pl](mailto:rwolniak@polsl.pl), ORCID: 0000-0003-0317-9811

<sup>2</sup> Penn State Hazletonne, Pennsylvania State University; [wvg3@psu.edu](mailto:wvg3@psu.edu), ORCID: 0000-0002-4684-7608

\* Correspondence author

**Purpose:** The purpose of this publication is to present the applications of usage of business analytics in environmental sustainability.

**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 environmental sustainability practices within the evolving landscape of Industry 4.0 presents both transformative opportunities and significant challenges. This convergence of digital technologies, data analytics, and environmental consciousness compels businesses to adopt sustainable practices. Business analytics acts as a pivotal tool, enabling enterprises to monitor, analyze, and optimize their environmental performance in the interconnected world of Industry 4.0. Advantages of leveraging business analytics in this context include real-time monitoring and predictive analytics, empowering proactive decision-making for resource optimization, reduced energy consumption, and minimized emissions. Smart resource allocation, improved energy management, and enhanced supply chain sustainability contribute to a comprehensive approach to environmental sustainability. The integration of environmental, social, and governance (ESG) criteria ensures transparency and a holistic approach to sustainability in the Industry 4.0 era. However, these advantages come with challenges such as data quality, integration complexities, cybersecurity concerns, and high initial implementation costs. Talent shortages, regulatory compliance complexities, and ethical considerations further complicate the landscape. Balancing short-term gains with long-term goals, addressing resistance to change, and ensuring stakeholder engagement are critical considerations.

**Keywords:** business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; environmental sustainability

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

## 1. Introduction

Environmental sustainability has become a paramount concern in the context of Industry 4.0, where technological advancements are reshaping the business landscape. The convergence of digital technologies, data analytics, and a heightened awareness of environmental issues has given rise to a new era where businesses are increasingly integrating sustainable practices into their operations. Within this framework, the application of business analytics plays a pivotal role in driving environmental sustainability initiatives.

In the Industry 4.0 paradigm, characterized by the interconnectedness of machines, real-time data exchange, and smart technologies, business analytics emerges as a powerful tool for enterprises to monitor, analyze, and optimize their environmental performance. One of the key contributions of business analytics in this context is its ability to harness big data to provide insights into resource consumption, emissions, and overall environmental impact (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021; Wolniak et al., 2023; Wolniak, Grebski, 2023; Wolniak, Skotnicka-Zasadzień, 2023; Jonek-Kowalska, Wolniak, 2023).

The utilization of business analytics in Industry 4.0 conditions has a transformative impact on environmental sustainability within the business realm. From optimizing resource utilization to promoting circular economy practices and ensuring regulatory compliance, analytics-driven insights empower businesses to make informed decisions that not only enhance their operational efficiency but also contribute to a more sustainable and environmentally responsible future. As Industry 4.0 continues to evolve, the synergy between technological innovation and environmental stewardship will play a crucial role in shaping a sustainable and resilient global economy.

The purpose of this publication is to present the applications of usage of business analytics in environmental sustainability.

## 2. The selected aspects of business analytics usage in environmental sustainability

Data analytics allows businesses to collect and process vast amounts of information from various sources, including sensors, IoT devices, and operational systems. By leveraging advanced analytics techniques such as machine learning and predictive modeling, companies can identify patterns and trends in their environmental data. This facilitates a deeper understanding of the ecological footprint of their operations, enabling informed decision-making towards sustainability goals.



Furthermore, business analytics facilitates the implementation of circular economy principles within Industry 4.0 (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). By analyzing product life cycles and supply chain processes, businesses can identify opportunities for resource optimization, waste reduction, and the promotion of recycling. Predictive analytics can help anticipate maintenance needs, minimizing downtime and extending the lifespan of equipment, thus contributing to a more sustainable use of resources (Zeng et al., 2022; Pech, Vrchota, 2022).

In the realm of energy management, business analytics empowers companies to optimize their energy consumption patterns. Real-time monitoring of energy usage, coupled with analytics-driven insights, enables organizations to identify inefficiencies and implement strategies for energy conservation (Bakir, Dahlan, 2022). This not only reduces operational costs but also aligns with environmental sustainability objectives, as energy efficiency is a critical factor in mitigating climate change (Ghibakholl et al., 2022).

Moreover, the integration of environmental, social, and governance (ESG) criteria into business strategies has gained prominence in the modern corporate landscape (Cillo et al., 2022). Business analytics provides the necessary tools to measure, track, and report on ESG performance, allowing companies to demonstrate their commitment to sustainability to stakeholders and investors (Akundi et al., 2022).

In the context of regulatory compliance, business analytics proves invaluable for monitoring and ensuring adherence to environmental standards. By continuously analyzing data related to emissions, waste management, and other environmental metrics, organizations can proactively address compliance issues, reducing the risk of regulatory penalties and fostering a culture of responsible corporate citizenship (Scappini, 2016).

Table 1 contains descriptions of how business analytics is used in the case of environmental sustainability. This table illustrates how business analytics can be applied across various facets of environmental sustainability, demonstrating its versatility in driving positive change within organizations.

**Table 1.**

*The usage of business analytics in environmental sustainability*

<b>Application</b>	<b>Description</b>
<b>Energy Management</b>	Utilizing advanced analytics to monitor energy consumption in real-time, identify peak usage periods, and optimize energy efficiency through predictive modeling.
<b>Resource Optimization</b>	Leveraging big data analytics to assess resource utilization throughout the supply chain, identifying opportunities for waste reduction, efficient production, and sustainable sourcing.
<b>Emissions Monitoring</b>	Employing analytics to collect, analyze, and interpret emissions data, enabling organizations to track greenhouse gas emissions, assess environmental impact, and ensure compliance with regulations.
<b>Predictive Maintenance</b>	Applying predictive analytics to equipment sensor data for anticipating maintenance needs, reducing downtime, and extending the lifespan of machinery, thereby promoting sustainable resource use.

Cont. table 1.

<b>Circular Economy Implementation</b>	Using analytics to evaluate product life cycles, identify opportunities for product redesign, recycling, and reusability, and implementing strategies that align with circular economy principles.
<b>ESG Performance Measurement</b>	Integrating ESG criteria into business strategies, and employing analytics to measure, track, and report on environmental, social, and governance performance, thereby enhancing transparency and stakeholder trust.
<b>Regulatory Compliance Monitoring</b>	Implementing analytics to monitor and ensure compliance with environmental regulations, enabling organizations to proactively address issues, reduce the risk of penalties, and foster a culture of legal responsibility.
<b>Real-time Environmental Monitoring</b>	Establishing real-time monitoring systems with analytics to collect and analyze environmental metrics, providing instant insights into air and water quality, waste management, and other critical factors for proactive decision-making and timely responses to environmental challenges.

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 environmental sustainability in Industry 4.0 conditions

Table 2 highlighting examples of software and applications used in environmental sustainability, along with descriptions of their usage. These software and applications offer a range of features and functionalities to cater to the diverse needs of businesses when it comes to inventory management. Depending on the size of the business, the complexity of operations, and specific requirements, organizations can select the most suitable solution to efficiently manage their inventory and streamline supply chain operations.

**Table 2.**

*The usage of business analytics software in environmental sustainability*

<b>Software/Application</b>	<b>Description</b>	<b>Key Features</b>
<b>IBM Watson Analytics</b>	IBM Watson Analytics is a cloud-based analytics platform that empowers users to explore and visualize data for better decision-making. It offers predictive analytics capabilities for process optimization.	<ul style="list-style-type: none"> <li>• Predictive analytics for forecasting and optimizing processes.</li> <li>• Data exploration and visualization tools.</li> <li>• Cognitive computing for natural language interaction.</li> </ul>
<b>Tableau</b>	Tableau is a powerful data visualization and business intelligence platform that aids in understanding and optimizing processes through interactive dashboards.	<ul style="list-style-type: none"> <li>• Drag-and-drop interface for easy data visualization.</li> <li>• Real-time data connectivity for dynamic insights.</li> <li>• Collaboration features for sharing insights across teams.</li> </ul>
<b>SAP Analytics Cloud</b>	SAP Analytics Cloud is an all-in-one cloud platform for business intelligence, planning, and predictive analytics. It helps in optimizing processes by providing unified insights across the organization.	<ul style="list-style-type: none"> <li>• Integrated BI, planning, and predictive analytics capabilities.</li> <li>• Collaboration and sharing features for team alignment.</li> <li>• Machine learning for automated insights and recommendations.</li> </ul>

Cont. table 2.

<b>Microsoft Power BI</b>	Microsoft Power BI is a business analytics tool that enables users to visualize data and share insights across an organization. It plays a crucial role in optimizing processes through data-driven decision-making.	<ul style="list-style-type: none"> <li>• Drag-and-drop interface for creating interactive reports.</li> <li>• Integration with various data sources for comprehensive analysis.</li> <li>• AI-powered insights for process optimization.</li> </ul>
<b>SAS Analytics</b>	SAS Analytics provides a comprehensive set of analytics tools for data analysis, predictive modeling, and optimization. It is used for process optimization by identifying patterns and trends in large datasets.	<ul style="list-style-type: none"> <li>• Advanced analytics and machine learning capabilities.</li> <li>• Data mining for uncovering hidden insights.</li> <li>• Optimization algorithms for process efficiency.</li> </ul>
<b>Qlik Sense</b>	Qlik Sense is a business intelligence and data visualization platform that facilitates data discovery and analysis, aiding in process optimization through interactive and user-friendly visualizations.	<ul style="list-style-type: none"> <li>• Associative data modeling for exploring relationships in data.</li> <li>• Collaborative analytics for team-based decision-making.</li> <li>• Customizable dashboards for personalized insights.</li> </ul>
<b>Oracle Analytics Cloud</b>	Oracle Analytics Cloud is a comprehensive analytics solution offering business intelligence, machine learning, and augmented analytics capabilities, contributing to data-driven process optimization.	<ul style="list-style-type: none"> <li>• Self-service analytics for business users.</li> <li>• Integrated machine learning for predictive insights.</li> <li>• Scalable cloud infrastructure for data analysis at scale.</li> </ul>
<b>Alteryx</b>	Alteryx is a data analytics platform that focuses on data blending, preparation, and advanced analytics. It empowers users to streamline processes by automating data workflows and analysis.	<ul style="list-style-type: none"> <li>• Data blending and preparation for seamless analysis.</li> <li>• Workflow automation for efficiency in data processing.</li> <li>• Predictive and spatial analytics for advanced insights.</li> </ul>
<b>Google Analytics</b>	Google Analytics is a web analytics service that provides insights into website and app performance. While traditionally used for marketing, it can also offer valuable process optimization insights.	<ul style="list-style-type: none"> <li>• Website and app performance metrics for user behavior analysis.</li> <li>• Conversion tracking for optimizing online processes.</li> <li>• Customizable reports for tailored analytics.</li> </ul>
<b>KNIME Analytics Platform</b>	KNIME is an open-source data analytics, reporting, and integration platform. It facilitates the creation of data science workflows, making it useful for optimizing processes through automation and analysis.	<ul style="list-style-type: none"> <li>• Open-source platform with a graphical interface for workflow design.</li> <li>• Extensive library of pre-built analytics and machine learning components.</li> <li>• Scalability for handling large datasets.</li> </ul>

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 environmental sustainability**

In Industry 4.0, the deployment of sensors and IoT devices enables real-time monitoring of various environmental metrics. Business analytics processes this wealth of data, providing organizations with immediate and actionable insights (Adel, 2022). This capability facilitates proactive decision-making, allowing swift responses to emerging environmental challenges and the optimization of sustainability practices in real-time. One of the significant advantages of business analytics in Industry 4.0 is its ability to utilize predictive analytics. By analyzing historical and real-time data, predictive models can forecast potential inefficiencies, resource shortages, or energy spikes. This foresight empowers organizations to proactively optimize resource usage, reduce energy consumption, and minimize emissions, contributing to continuous improvements in operational efficiency and sustainability (Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Wolniak, 2013, 2016; Hys, Wolniak, 2018).

Business analytics plays a pivotal role in smart resource allocation within Industry 4.0. With interconnected manufacturing processes and data-driven decision-making, analytics helps optimize the utilization of materials, energy, and other resources. Organizations can make informed decisions about resource allocation, minimizing waste and supporting efficient resource use, thereby aligning with sustainability goals and circular economy practices. Advanced analytics in Industry 4.0 facilitates improved energy management by monitoring energy consumption patterns and employing predictive modeling. This enables organizations to optimize energy usage across operational systems, reducing costs and aligning with environmental sustainability goals. Analytics-driven insights empower organizations to identify energy-efficient practices, implement changes, and continually enhance energy management strategies (Du et al., 2023; Fjellström, Osarenkhoe, 2023; Castro et al., 2014; Wang et al., 2023).

The comprehensive insights provided by analytics in Industry 4.0 extend to the supply chain, enabling organizations to identify opportunities for sustainability improvements. Analytics supports data-driven decisions that reduce waste, optimize transportation routes, and promote responsible sourcing practices. This enhances the overall sustainability of the supply chain within the Industry 4.0 landscape. Business analytics ensures adaptive and agile operations in Industry 4.0 by providing real-time insights into environmental performance. The dynamic nature of Industry 4.0 requires organizations to respond rapidly to changing conditions. Analytics allows for continuous monitoring, ensuring operations remain aligned with sustainability goals, and enabling organizations to address emerging challenges and capitalize on opportunities swiftly (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

In Industry 4.0, the integration of environmental, social, and governance (ESG) criteria into decision-making processes is essential. Business analytics plays a central role in measuring, tracking, and reporting on ESG performance. This integration fosters transparency and accountability in business practices, ensuring that Industry 4.0 operations are conducted with a holistic view of sustainability (Nourani, 2021).

Table 3 contains the advantages of using business analytics in environmental sustainability within Industry 4.0 conditions, along with descriptions for each advantage. This table highlights how the integration of business analytics in Industry 4.0 enhances environmental sustainability by providing comprehensive insights and facilitating data-driven decision-making across various dimensions of operations.

**Table 3.**

*The advantages of using business analytics in environmental sustainability*

Advantage	Description
<b>Real-time Monitoring and Insights</b>	In the Industry 4.0 era, the integration of sensors and Internet of Things (IoT) devices allows for real-time monitoring of environmental metrics. Business analytics processes this vast amount of data, providing organizations with instantaneous insights into various aspects of their operations. This real-time visibility empowers proactive decision-making, enabling swift responses to emerging environmental challenges and opportunities. Whether it's monitoring emissions, energy consumption, or resource usage, the timely insights derived from analytics facilitate adaptive strategies to enhance overall sustainability in Industry 4.0 environments.
<b>Predictive Analytics for Efficiency</b>	Leveraging predictive analytics within Industry 4.0, organizations can go beyond reactive approaches to address inefficiencies. By analyzing historical and real-time data, predictive models can forecast potential bottlenecks, resource shortages, or energy spikes. This foresight allows for proactive measures to optimize resource usage, reduce energy consumption, and minimize emissions. Predictive analytics contributes to the continuous improvement of operational efficiency, aligning with sustainability goals in the dynamic and data-driven landscape of Industry 4.0.
<b>Smart Resource Allocation</b>	Business analytics in Industry 4.0 plays a pivotal role in smart resource allocation. As manufacturing processes become more interconnected and data-driven, analytics helps optimize the utilization of materials, energy, and other resources. By analyzing data from various sources, including production lines, supply chains, and IoT sensors, organizations can make informed decisions about resource allocation, minimizing waste and promoting efficient use. This intelligent resource management aligns with the principles of sustainability and supports circular economy practices in Industry 4.0 environments.
<b>Improved Energy Management</b>	The integration of advanced analytics in Industry 4.0 facilitates improved energy management. Real-time monitoring of energy consumption patterns, coupled with predictive modeling, enables organizations to optimize energy usage across manufacturing processes and operational systems. This not only contributes to cost savings but also aligns with environmental sustainability goals by reducing the overall carbon footprint. Analytics-driven insights empower organizations to identify energy-efficient practices, implement changes, and continuously enhance their energy management strategies within the Industry 4.0 framework.
<b>Enhanced Supply Chain Sustainability</b>	Analytics in Industry 4.0 provides a comprehensive view of the supply chain, offering insights into various stages of production and distribution. This visibility allows organizations to identify opportunities for sustainability improvements within the supply chain. Whether it's reducing waste, optimizing transportation routes, or promoting responsible sourcing practices, business analytics empowers organizations to make data-driven decisions that enhance the overall sustainability of their supply chain operations. The result is a more resilient and eco-friendly supply chain ecosystem within the Industry 4.0 landscape.

Cont. table 3.

<b>Adaptive and Agile Operations</b>	Business analytics supports adaptive and agile operations in Industry 4.0 by providing real-time insights into environmental performance. The dynamic nature of Industry 4.0 environments, with interconnected systems and rapid data exchange, requires organizations to be agile in responding to changing conditions. Analytics allows for the continuous monitoring of environmental metrics, enabling organizations to quickly adjust strategies based on real-time data. This adaptability ensures that operations remain aligned with sustainability goals, and organizations can swiftly address emerging challenges and capitalize on new opportunities within the evolving Industry 4.0 landscape.
<b>Integration of ESG Criteria</b>	In Industry 4.0 systems, the integration of environmental, social, and governance (ESG) criteria into decision-making processes is crucial for aligning operations with broader sustainability objectives. Business analytics plays a central role in measuring, tracking, and reporting on ESG performance. By leveraging analytics tools, organizations can assess their impact on the environment, social responsibility, and overall corporate governance. This integration ensures that Industry 4.0 operations are conducted with a holistic view of sustainability, fostering transparency and accountability in business practices.
<b>Regulatory Compliance Assurance</b>	Industry 4.0 operations are subject to evolving environmental regulations, and compliance is paramount to avoid legal repercussions. Business analytics enables organizations to continuously monitor their Industry 4.0 processes to ensure adherence to environmental standards and regulations. Through data-driven insights, organizations can proactively address compliance issues, reducing the risk of penalties and legal challenges. This assurance of regulatory compliance is essential in the Industry 4.0 landscape, where staying ahead of regulatory changes is critical for maintaining sustainable and responsible business practices.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Leveraging business analytics for environmental sustainability within the complex framework of Industry 4.0 presents various challenges that organizations must navigate to derive meaningful benefits from their analytics initiatives. These challenges span technological, organizational, and ethical dimensions, influencing the effectiveness of sustainability efforts in the rapidly evolving landscape of smart manufacturing and interconnected systems (Charles et al., 2023).

Navigating these challenges requires a strategic and adaptive approach that considers both the potential benefits and the inherent risks associated with deploying business analytics for environmental sustainability in the Industry 4.0 era. Organizations must proactively address these issues to harness the transformative power of analytics for driving positive environmental impact (Greasley, 2019).

Table 4 contains the problems of using business analytics in environmental sustainability within Industry 4.0 conditions, along with descriptions for each advantage.

**Table 4.**

*The problems of using business analytics in environmental sustainability*

<b>Problem</b>	<b>Description</b>
<b>Data Quality and Integration Complexity</b>	Industry 4.0 environments often involve diverse data sources, and ensuring data quality and seamless integration can be complex. Inaccurate or disparate data may compromise the reliability of analytics insights, impacting sustainability decisions.
<b>Cybersecurity Concerns</b>	With the increased connectivity in Industry 4.0, there's a heightened risk of cybersecurity threats. Protecting sensitive environmental data from breaches and ensuring the integrity of analytics platforms becomes critical for sustainable practices.

Cont. table 4.

<b>High Initial Implementation Costs</b>	The implementation of advanced analytics in Industry 4.0 requires substantial investments in technology, infrastructure, and skilled personnel. High upfront costs can be a barrier for some organizations, particularly smaller enterprises, limiting their adoption of analytics solutions.
<b>Talent Shortages and Skill Gaps</b>	The effective use of advanced analytics demands skilled professionals proficient in data science, machine learning, and Industry 4.0 technologies. A shortage of such skilled personnel and the need for ongoing training can hinder successful analytics implementation for sustainability.
<b>Regulatory Compliance Complexity</b>	The complex regulatory landscape related to environmental sustainability and Industry 4.0 can pose challenges. Organizations must navigate and comply with various regulations, which may evolve over time, adding complexity to analytics-driven compliance efforts.
<b>Ethical Considerations and Privacy</b>	Industry 4.0 involves extensive data collection, raising ethical concerns regarding privacy and responsible data use. Ensuring compliance with privacy regulations and addressing ethical considerations is crucial for maintaining trust among stakeholders in sustainability initiatives.
<b>Lack of Interoperability Standards</b>	The absence of standardized formats and protocols across Industry 4.0 technologies may lead to interoperability issues. Ensuring seamless communication and data exchange between different systems becomes a challenge, hindering the efficiency of analytics applications.
<b>Rapid Technological Obsolescence</b>	The fast-paced evolution of technology in Industry 4.0 can lead to the obsolescence of analytics tools and platforms. Organizations must invest in scalable and adaptable solutions to avoid the risk of their technology becoming outdated over time.
<b>Balancing Short-Term Metrics with Long-Term Goals</b>	There may be a tendency to prioritize short-term gains over long-term sustainability goals in analytics-driven decision-making. Striking a balance between immediate improvements and long-term environmental objectives is crucial for a comprehensive sustainability strategy.
<b>Resistance to Change and Organizational Culture</b>	The integration of analytics into Industry 4.0 operations often requires a cultural shift within organizations. Resistance to change, both from employees and leadership, can impede the successful adoption and utilization of analytics for sustainability initiatives.
<b>Lack of Data Standardization</b>	The absence of standardized data formats and structures across Industry 4.0 systems can lead to challenges in data standardization. Diverse data formats may hinder the seamless integration and analysis of information critical for sustainability initiatives.
<b>Complexity of Analytics Models</b>	Developing and implementing complex analytics models, such as those involving machine learning algorithms, can be challenging. Ensuring the accuracy and interpretability of these models requires specialized expertise, and overly complex models may not align with organizational goals.
<b>Limited Scalability of Solutions</b>	Scalability is crucial in Industry 4.0 environments, where operations may expand rapidly. Some analytics solutions may face limitations in handling large volumes of data or supporting a growing number of interconnected devices, affecting their effectiveness over time.
<b>Difficulty in Measuring Social Impact</b>	While business analytics can effectively measure environmental impact, assessing social impact can be more challenging. Determining the social implications of sustainability efforts, such as community engagement or employee well-being, may lack clear and standardized metrics.
<b>Overreliance on Technology</b>	An overreliance on technology in decision-making processes can lead to neglecting human insights and qualitative aspects. While analytics provides quantitative data, qualitative considerations, such as local context and cultural factors, are essential for holistic sustainability strategies.
<b>Incomplete Stakeholder Engagement</b>	Successful sustainability initiatives require collaboration with various stakeholders. Incomplete engagement with stakeholders, including suppliers, customers, and local communities, may result in a lack of comprehensive data and hinder the effectiveness of sustainability efforts.
<b>Lack of Long-Term Data Availability</b>	Sustainability goals often require long-term monitoring and analysis. The lack of historical data or extended time series for certain environmental parameters may limit the ability to assess long-term trends and formulate strategies for sustained environmental improvements.

Cont. table 4.

<b>Unforeseen Consequences of Optimization</b>	Overemphasis on certain optimization goals may lead to unintended consequences. For instance, optimizing for energy efficiency in one area may inadvertently increase resource consumption in another. Organizations must carefully consider potential side effects of optimization strategies.
<b>Limited Adoption in Small Enterprises</b>	Small and medium-sized enterprises (SMEs) may face challenges in adopting sophisticated analytics solutions due to resource constraints, both in terms of finances and skilled personnel. This limitation can hinder widespread adoption of analytics for sustainability in smaller businesses.
<b>Difficulty in Demonstrating ROI</b>	Measuring the return on investment (ROI) for sustainability initiatives, especially those driven by analytics, can be challenging. Quantifying the financial benefits and demonstrating the tangible impact on sustainability goals may require careful evaluation and transparent reporting.

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 in the realm of environmental sustainability within the dynamic landscape of Industry 4.0 offers transformative opportunities and poses significant challenges. As technological advancements reshape the business landscape, the convergence of digital technologies, data analytics, and environmental consciousness is driving businesses to embrace sustainable practices. Business analytics emerges as a pivotal tool, enabling enterprises to monitor, analyze, and optimize their environmental performance in the interconnected world of Industry 4.0.

The advantages of leveraging business analytics in this context are multifaceted. Real-time monitoring and predictive analytics empower organizations to make proactive decisions, optimizing resource usage, reducing energy consumption, and minimizing emissions. Smart resource allocation, improved energy management, and enhanced supply chain sustainability contribute to a holistic approach to environmental sustainability. The integration of environmental, social, and governance (ESG) criteria into decision-making processes ensures a comprehensive and transparent approach to sustainability in the Industry 4.0 era. However, these advantages are not without their share of challenges. From data quality and integration complexities to cybersecurity concerns and high initial implementation costs, organizations must navigate a complex landscape. Talent shortages, regulatory compliance complexities, and ethical considerations add further layers of difficulty. Balancing short-term gains with long-term goals, addressing resistance to change, and ensuring stakeholder engagement are critical aspects that require careful consideration.

The publication presented an in-depth exploration of business analytics applications in environmental sustainability, covering aspects such as energy management, resource optimization, emissions monitoring, predictive maintenance, circular economy



implementation, ESG performance measurement, regulatory compliance monitoring, and real-time environmental monitoring. The examples of software and applications used in process optimization within Industry 4.0 conditions were also highlighted, emphasizing the role of technology in driving sustainability. As organizations continue to grapple with these challenges, the importance of addressing them becomes evident. A strategic and adaptive approach is essential for organizations to harness the full potential of business analytics in driving positive environmental impact. The evolving synergy between technological innovation and environmental stewardship will play a crucial role in shaping a sustainable and resilient global economy. As Industry 4.0 continues to evolve, businesses that successfully navigate these challenges will be better positioned to contribute to a more sustainable and environmentally responsible future.

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## THE USAGE OF QUALITY CIRCLES IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK<sup>1\*</sup>, Wies GREBSKI<sup>2</sup>

<sup>1</sup> Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; [rwolniak@polsl.pl](mailto:rwolniak@polsl.pl), ORCID: 0000-0003-0317-9811

<sup>2</sup> Penn State Hazleton, Pennsylvania State University; [wsg3@psu.edu](mailto:wsg3@psu.edu), ORCID: 0000-0002-4684-7608

\* Correspondence author

**Purpose:** The purpose of this publication is to present the usage of Quality Circles 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 quality circles with Industry 4.0 signifies a powerful synergy that combines modern technologies and data-driven strategies to elevate continuous improvement initiatives within organizations. Industry 4.0, representing the Fourth Industrial Revolution, introduces smart technologies and data analytics, providing an ideal environment for quality circles to flourish. Aligned with Industry 4.0 principles, quality circles leverage advanced analytics and real-time monitoring to empower members in making informed decisions and enhancing problem-solving processes. This integration establishes a holistic framework for continuous improvement, positioning organizations to excel in the era of digital transformation and smart manufacturing. Rooted in Total Quality Management (TQM) principles, quality circles originated in Japan in the 1960s and have evolved into a cornerstone of modern organizational management globally. Key principles, outlined in Table 1, emphasize voluntary participation, training, management support, continuous improvement, and adaptability. Table 3 highlights the advantages of quality circles integration, from data-driven decision-making to improved product quality. Explored in Table 2, quality circles seamlessly integrate with Industry 4.0 and Quality 4.0 through technologies like data analytics, IoT, automation, and AI, fostering operational excellence and adaptability. However, challenges, as presented in Table 4, including data overload and cybersecurity concerns, require strategic planning and collaboration to overcome. In essence, this integration represents a transformative journey towards continuous improvement, enhanced product quality, and organizational excellence in the evolving landscape of smart manufacturing, positioning organizations to thrive in the present and adapt to future challenges.

**Keywords:** Industry 4.0; Quality 4.0, quality management; quality methods, Quality Circles.

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

## 1. Introduction

The integration of quality circles with Industry 4.0 concept represents a synergistic approach that leverages modern technologies and data-driven strategies to enhance the effectiveness of continuous improvement initiatives within organizations. Industry 4.0, often referred to as the Fourth Industrial Revolution, is characterized by the integration of smart technologies, data analytics, and connectivity in manufacturing processes. Quality circles can seamlessly align with Industry 4.0 principles, creating a dynamic and responsive framework for continuous improvement. The key points of integration include:

Quality circles can leverage advanced analytics and real-time monitoring systems provided by Industry 4.0 technologies. This allows for the collection and analysis of vast amounts of data, enabling quality circle members to make informed decisions and identify patterns that may have previously gone unnoticed (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

By integrating quality circles with Industry 4.0, organizations can create a holistic and technologically advanced framework for continuous improvement. This not only enhances the efficiency of problem-solving processes but also positions the organization to thrive in the era of digital transformation and smart manufacturing. The collaboration of human intelligence, facilitated by quality circles, with cutting-edge technologies results in a powerful synergy that drives sustained improvement and competitiveness.

The purpose of this publication is to present the usage of Quality Circles approach in industry 4.0 condition.

## 2. The basics of quality circles approach

Quality circles are a fundamental component of modern organizational management and continuous improvement initiatives. Originating in Japan in the 1960s, quality circles are collaborative groups of employees who come together voluntarily to identify, analyze, and solve work-related problems. The primary goal of quality circles is to enhance product quality, streamline processes, and foster a culture of continuous improvement within an organization (Almeida, Abreu, 2023).

The concept of quality circles is deeply rooted in the principles of Total Quality Management (TQM) and the teachings of quality gurus such as W. Edwards Deming and Kaoru Ishikawa. These circles operate on the premise that those closest to the work processes are often the best equipped to identify areas for improvement. As such, quality circles empower front-line

workers to actively participate in decision-making and problem-solving, promoting a sense of ownership and responsibility for the quality of their work.

A typical quality circle consists of a small group of employees who meet regularly to discuss and address specific issues affecting their work environment. These meetings provide a forum for open communication, idea exchange, and collaborative problem-solving. Members of the quality circle share their experiences, insights, and suggestions, working together to develop practical solutions that can be implemented to enhance efficiency and quality (Maganga, Taifa, 2023).

The history of quality circles dates back to the post-World War II era, with the origins rooted in Japan's industrial landscape during the 1950s and 1960s. The concept emerged as a response to the need for economic recovery and a commitment to improving product quality and productivity in Japanese industries. One of the earliest proponents of quality circles was Kaoru Ishikawa, a Japanese organizational theorist and professor at the University of Tokyo. In the early 1960s, Ishikawa, along with other quality management experts, began to advocate for a more participatory and collaborative approach to addressing workplace issues (Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Swarnakar et al., 2023).

The term "quality circles" itself was coined by Dr. Kaoru Ishikawa in 1962. The idea was simple yet revolutionary: involve workers directly in the improvement of their own work processes. Ishikawa drew inspiration from the principles of statistical quality control introduced by W. Edwards Deming, who had a significant influence on Japanese industry. The first formal implementation of quality circles occurred at the Nippon Wireless and Telegraph Company in 1962. This early initiative focused on involving workers in problem-solving and decision-making processes, aiming to tap into the collective wisdom and experience of employees on the shop floor (Bousdekis et al., 2023).

The success of quality circles in improving product quality and enhancing workplace efficiency quickly spread across Japanese industries. The approach gained widespread recognition and adoption, particularly in companies such as Toyota, where it became an integral part of the Toyota Production System (TPS). In the 1970s, the concept of quality circles began to attract attention globally. Western countries, facing economic challenges and increased competition, started to explore and adopt Japanese management practices. The principles of quality circles became a cornerstone of the Total Quality Management (TQM) movement that gained prominence in the United States and Europe during the 1980s.

Quality circles became a popular organizational strategy, with companies around the world establishing these small, voluntary groups to address quality issues, enhance productivity, and foster a culture of continuous improvement. The success stories of Japanese companies like Toyota, renowned for their commitment to quality and efficiency, further fueled the global interest in quality circles. While the popularity of quality circles has fluctuated over the years, the underlying principles have endured. The focus on employee involvement, continuous

improvement, and a commitment to quality remains relevant in contemporary management practices. Quality circles have evolved and adapted to the changing dynamics of the business environment, but their historical roots in the Japanese commitment to excellence continue to influence organizational management strategies worldwide (Barsalou, 2023; Maganga, Taifa, 2023).

Table 1 contains description of key principles of quality circles. These principles collectively contribute to the effectiveness of quality circles in promoting a culture of continuous improvement and excellence within an organization.

**Table 1.**  
*Key principles of quality circles*

Principle	Description
Voluntary Participation	Quality circle membership is voluntary, encouraging enthusiastic and committed individuals to actively engage in problem-solving and continuous improvement.
Training and Skill Development	Members receive training in problem-solving techniques, statistical analysis, and communication skills, enhancing their ability to contribute effectively.
Management Support	Upper management provides support, ensuring that the efforts and solutions proposed by quality circles are recognized, implemented, and adequately resourced.
Focus on Continuous Improvement	Quality circles emphasize an ongoing process of improvement, addressing new challenges and adapting to changing circumstances to foster continuous organizational growth.
Employee Involvement	The active involvement of employees in decision-making processes and problem-solving fosters a sense of ownership, empowerment, and responsibility for the quality of their work.
Open Communication	Quality circles promote open and transparent communication, creating a forum for members to share experiences, insights, and suggestions freely.
Recognition and Rewards	Acknowledging the contributions of quality circle members and providing appropriate rewards for successful implementations encourages a positive and proactive culture of improvement.
Data-Driven Decision-Making	Quality circles use data and statistical analysis to identify, analyze, and solve problems, ensuring that decisions are based on objective information rather than subjective opinions.
Team Collaboration	The collaborative nature of quality circles encourages teamwork, leveraging the diverse skills and perspectives of members to develop comprehensive and effective solutions.
Adaptability	Quality circles remain adaptable to changes in the business environment, allowing organizations to respond proactively to emerging challenges and opportunities.

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 quality circles based approach can be integrated with Industry 4.0 and Quality 4.0 concept**

Industry 4.0 emphasizes the use of automation and robotics for increased efficiency. Quality circles can collaborate with automation experts to identify areas where these technologies can be applied to enhance product quality and reduce defects (Singh et al., 2023). IoT devices can be employed to collect data from various points in the production process. Quality circles can

use this data to gain insights into the performance of equipment, identify potential issues, and propose solutions to optimize processes (Sureshchandar, 2023; Saihi et al., 2023).

Quality circles can benefit from digital twin technology, which creates virtual replicas of physical systems. This allows for simulation and testing of improvement ideas before implementation, reducing the risk of negative impacts on production (Alrabadi et al., 2023).

Quality 4.0 is an extension of Industry 4.0 specifically focused on quality management and assurance. It emphasizes the integration of digital technologies to enhance the entire quality management system. Quality circles can integrate with Quality 4.0 in the following ways (Yanamandra et al., 2023):

Quality circles can collaborate with Quality 4.0 initiatives to implement smart quality management systems. These systems use digital tools and platforms to monitor and manage quality-related processes in real-time. Quality 4.0 often involves the use of blockchain technology for secure and transparent record-keeping. Quality circles can explore blockchain applications to maintain a secure and unalterable record of quality improvement initiatives and their outcomes (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

Quality circles can use AR and VR technologies to enhance training programs and simulate real-world scenarios for problem-solving. This immersive approach can accelerate the learning curve for quality circle members. Quality 4.0 encourages the use of AI for predictive quality analytics (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021). Quality circles can work with AI systems to predict potential quality issues, enabling proactive problem-solving and preventing defects quality circles based Management approach with industry 4.0. This integration enhances operational excellence, fosters a culture of continuous improvement, and positions organizations to thrive in the evolving landscape of smart manufacturing and dynamic market demands (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecula, Wolniak, 2022; Olkiewicz et al., 2021).

Table 2 present description of quality circles concept integration with industry 4.0. This integration provides a comprehensive approach to continuous improvement, combining the collective intelligence and problem-solving capabilities of quality circles with the advanced technologies offered by Industry 4.0. Together, these elements create a powerful framework for optimizing manufacturing processes, enhancing product quality, and staying competitive in the modern industrial landscape.

**Table 2.**  
*Quality circles integration with industry 4.0*

Aspect	Description
<b>Data Analytics and Monitoring</b>	Quality circles leverage advanced analytics and real-time monitoring systems from Industry 4.0 to analyze large datasets, identifying patterns and insights for informed decision-making.
<b>Internet of Things (IoT)</b>	IoT devices are utilized by quality circles to collect data from various points in the production process, enabling real-time monitoring and identification of potential issues.
<b>Automation and Robotics</b>	Quality circles collaborate with automation and robotics technologies to identify opportunities for increased efficiency, reduced defects, and enhanced quality in manufacturing processes.
<b>Digital Twin Technology</b>	Quality circles use digital twin technology to create virtual replicas of physical systems, allowing for simulation and testing of improvement ideas before actual implementation, reducing risks.
<b>Smart Quality Management Systems</b>	Quality circles integrate with smart quality management systems under Industry 4.0, utilizing digital tools and platforms for real-time monitoring and management of quality-related processes.
<b>Blockchain for Quality Assurance</b>	Quality circles explore the application of blockchain technology for secure and transparent record-keeping, ensuring a trustworthy and unalterable record of quality improvement initiatives and outcomes.
<b>Augmented Reality (AR) and Virtual Reality (VR)</b>	Quality circles employ AR and VR technologies for enhanced training programs and simulated problem-solving scenarios, accelerating the learning curve for members and improving their skills.
<b>Integration of Artificial Intelligence (AI)</b>	Quality circles collaborate with AI systems to leverage predictive quality analytics, enabling proactive identification of potential quality issues and preventing defects before they occur.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khoureshed, 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 of quality circles usage in industry 4.0. The integration of quality circles with Industry 4.0 brings a multitude of advantages, ranging from improved decision-making based on real-time data to proactive issue identification and enhanced efficiency in manufacturing processes (Liu et al., 2023). This collaborative approach positions organizations to thrive in the era of smart manufacturing, ensuring sustained improvements in product quality and operational effectiveness.

**Table 3.**  
*The advantages of Lean Management integration with industry 4.0*

Advantage	Description
<b>Data-Driven Decision-Making</b>	Integration with Industry 4.0 enables quality circles to base decisions on real-time, data-driven insights. This leads to more informed problem-solving and continuous improvement initiatives.
<b>Enhanced Efficiency</b>	Automation and robotics, integral to Industry 4.0, contribute to enhanced efficiency in manufacturing processes. Quality circles can leverage these technologies to optimize workflows and reduce operational costs.
<b>Proactive Issue Identification</b>	Real-time monitoring and IoT integration facilitate proactive identification of potential quality issues. Quality circles can address problems before they escalate, minimizing defects and production disruptions.

Cont. table 3.

<b>Improved Product Quality</b>	The combined efforts of quality circles and Industry 4.0 technologies lead to improved product quality. Automation, digital twin technology, and AI contribute to consistent and high-quality manufacturing outcomes.
<b>Risk Mitigation through Simulation</b>	Digital twin technology allows quality circles to simulate and test improvement ideas in a virtual environment. This reduces the risk associated with implementing changes in the physical production process.
<b>Streamlined Quality Management</b>	Integration with smart quality management systems streamlines quality control processes. This ensures efficient tracking of quality metrics, facilitates quick responses to issues, and enhances overall quality management.
<b>Secure and Transparent Record-Keeping</b>	Blockchain integration ensures secure and transparent record-keeping of quality improvement initiatives. This helps in maintaining an immutable record of changes, inspections, and quality outcomes, fostering trust and accountability.
<b>Accelerated Learning with AR and VR</b>	The adoption of AR and VR technologies accelerates the learning curve for quality circle members. Simulated problem-solving scenarios provide hands-on experience, improving skills and efficiency in addressing challenges.
<b>Predictive Quality Analytics</b>	Integration with AI enables quality circles to implement predictive quality analytics. By analyzing data, AI algorithms can predict potential quality issues, allowing proactive problem-solving and prevention of defects.
<b>Continuous Learning and Adaptability</b>	Quality circles, integrated with Industry 4.0, benefit from continuous learning and adaptability. The combination of human insights and technological advancements fosters a culture of continuous improvement and innovation.

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 quality circles based approach usage in Industry 4.0 and methods to overcome them. Navigating these additional challenges requires a strategic and well-coordinated effort. Organizations should approach the integration of quality circles with Industry 4.0 with careful planning, a focus on standards, and a commitment to addressing both technological and organizational aspects.

**Table 4.**

*The problems of quality circles integration with industry 4.0*

<b>Problems</b>	<b>Description of Problem</b>	<b>Overcoming Strategies</b>
<b>Data Overload and Analysis Challenges</b>	The integration of Industry 4.0 often leads to an influx of large datasets. Quality circles may struggle with processing and interpreting this vast amount of data for meaningful insights.	Implement advanced analytics tools and machine learning algorithms to automate data analysis. Provide training to quality circle members on data interpretation and utilization.
<b>Technological Resistance</b>	Employees within quality circles may face resistance to adopting new technologies associated with Industry 4.0, leading to reluctance in utilizing digital tools and platforms.	Conduct comprehensive training programs to familiarize quality circle members with new technologies. Foster a culture that encourages open communication and addresses concerns about technological changes.
<b>Integration Complexity</b>	Integrating quality circles with Industry 4.0 technologies can be complex due to the diversity of systems, hardware, and software involved. Coordination challenges may arise.	Develop a clear integration plan with defined objectives and milestones. Collaborate closely with IT and relevant departments to ensure seamless integration. Prioritize user-friendly interfaces for better adoption.

Cont. table 4.

<b>High Initial Costs</b>	The implementation of Industry 4.0 technologies often requires significant upfront investment in infrastructure, training, and technology adoption. Quality circles may face budget constraints.	Conduct a cost-benefit analysis to demonstrate long-term value. Seek funding options or phased implementation to spread costs. Prioritize technologies with a quick return on investment.
<b>Skills Gap and Training Needs</b>	Quality circle members may lack the necessary skills to operate and leverage advanced technologies. Training needs may arise to bridge the skills gap and ensure effective integration.	Invest in comprehensive training programs tailored to the specific needs of quality circle members. Collaborate with educational institutions and industry experts to address skill gaps.
<b>Cybersecurity Concerns</b>	Industry 4.0 involves increased connectivity, leading to potential cybersecurity risks. Quality circles must address concerns related to data security and protect against cyber threats.	Implement robust cybersecurity measures, including encryption and secure access controls. Regularly update and patch systems. Provide cybersecurity training to ensure awareness and vigilance.
<b>Lack of Standardization</b>	Industry 4.0 often involves diverse technologies and standards, leading to interoperability challenges. Quality circles may face difficulties in standardizing processes across different systems.	Advocate for industry-wide standards and interoperability. Collaborate with technology providers that adhere to widely accepted standards. Develop clear protocols for integrating diverse technologies.
<b>Data Security and Privacy Concerns</b>	The increased connectivity and data sharing in Industry 4.0 raise concerns about data security and privacy. Quality circles must navigate these issues to ensure the protection of sensitive information.	Implement robust data encryption and access controls. Adhere to data protection regulations and standards. Conduct regular audits to assess and enhance data security measures. Educate members on data privacy best practices.
<b>Complex Change Management</b>	Integrating Industry 4.0 technologies represents a significant organizational change. Quality circles may encounter resistance and challenges in managing the cultural shift within the organization.	Develop a comprehensive change management plan that includes clear communication, employee involvement, and leadership support. Address concerns proactively and highlight the long-term benefits of the changes.
<b>Integration with Legacy Systems</b>	Organizations may have existing legacy systems that are not easily compatible with modern Industry 4.0 technologies. Quality circles may struggle with integrating these systems for seamless collaboration.	Invest in middleware solutions or APIs that facilitate communication between legacy systems and new technologies. Consider phased upgrades or replacements of legacy systems to align with Industry 4.0 standards.
<b>Scalability Challenges</b>	Industry 4.0 initiatives often begin on a smaller scale and expand gradually. Quality circles may face challenges in scaling up their initiatives to cover the entire organization, limiting the impact of improvements.	Plan for scalability from the outset. Implement pilot projects to test and refine processes before scaling up. Ensure that technologies and processes can adapt and scale with the growth of the organization.
<b>Vendor Lock-In Risks</b>	Depending heavily on specific technology vendors may lead to vendor lock-in risks. Quality circles may find it challenging to switch to alternative solutions or face limitations in customization.	Prioritize technologies with open standards and interoperability. Negotiate flexible contracts that allow for the adoption of alternative solutions. Regularly assess the market for emerging technologies and consider diversifying vendor relationships.



Cont. table 4.

<b>Regulatory Compliance Complexity</b>	Industry 4.0 integration may involve compliance with various regulations and standards. Quality circles must navigate the complexity of ensuring adherence to regulatory requirements.	Stay informed about relevant industry regulations and compliance standards. Collaborate with legal and regulatory experts to ensure a comprehensive understanding of compliance requirements. Implement robust documentation and reporting processes.
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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 quality circles with the Industry 4.0 concept presents a transformative synergy, leveraging modern technologies and data-driven strategies to enhance continuous improvement initiatives within organizations. Industry 4.0, synonymous with the Fourth Industrial Revolution, introduces smart technologies, data analytics, and connectivity into manufacturing processes, providing a fertile ground for quality circles to thrive.

The alignment of quality circles with Industry 4.0 principles allows for the seamless utilization of advanced analytics and real-time monitoring systems. This empowers quality circle members to make informed decisions, identify hidden patterns, and elevate the problem-solving process. By integrating quality circles with Industry 4.0, organizations forge a holistic and technologically advanced framework for continuous improvement, positioning themselves to excel in the era of digital transformation and smart manufacturing.

Rooted in Total Quality Management (TQM) principles and inspired by quality gurus like W. Edwards Deming and Kaoru Ishikawa, quality circles have evolved into a cornerstone of modern organizational management. Originating in Japan during the 1960s, these collaborative groups of employees actively engage in problem-solving to enhance product quality and streamline processes. The success of quality circles in Japan quickly spread globally, becoming an integral part of the Total Quality Management movement in the United States and Europe during the 1980s.

Table 1 elucidates the key principles of quality circles, emphasizing voluntary participation, training and skill development, management support, continuous improvement, employee involvement, open communication, recognition and rewards, data-driven decision-making, team collaboration, and adaptability. The integration of quality circles with Industry 4.0 introduces a plethora of advantages, as outlined in Table 3. From data-driven decision-making to proactive issue identification, improved product quality, and streamlined quality management, this collaborative approach enhances efficiency and positions organizations for sustained success.

Moreover, as explored in Table 2, quality circles can seamlessly integrate with Industry 4.0 and Quality 4.0 concepts. Leveraging data analytics, IoT devices, automation, digital twin technology, smart quality management systems, blockchain, AR and VR technologies, and AI, quality circles can propel organizations towards operational excellence, continuous improvement, and adaptability to dynamic market demands. However, the integration journey is not without challenges, as highlighted in Table 4. Data overload, technological resistance, integration complexity, high initial costs, skills gap, cybersecurity concerns, lack of standardization, data security and privacy issues, complex change management, legacy system integration, scalability challenges, and vendor lock-in risks pose hurdles. Overcoming these challenges requires strategic planning, comprehensive training programs, clear communication, and collaboration with regulatory experts.

It can be stated that, the integration of quality circles with Industry 4.0 is a transformative endeavor that demands a harmonious blend of human intelligence and cutting-edge technologies. It is a journey towards continuous improvement, enhanced product quality, and organizational excellence in the evolving landscape of smart manufacturing. As organizations embrace this integration, they position themselves to not only thrive in the present but also adapt to the challenges and opportunities of the future.

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## THE USAGE OF LEAN MANAGEMENT IN INDUSTRY 4.0 CONDITIONS

Radosław WOLNIAK<sup>1\*</sup>, Wies GREBSKI<sup>2</sup>

<sup>1</sup> Silesian University of Technology, Organization and Management Department, Economics and Informatics Institute; [rwolniak@polsl.pl](mailto:rwolniak@polsl.pl), ORCID: 0000-0003-0317-9811

<sup>2</sup> Penn State Hazletonne, Pennsylvania State University; [wvg3@psu.edu](mailto:wvg3@psu.edu), ORCID: 0000-0002-4684-7608

\* Correspondence author

**Purpose:** The purpose of this publication is to present the usage of Lean Management 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:** This paper explores the transformative integration of Lean Management, Industry 4.0, and Quality 4.0 in modern manufacturing, presenting a convergence of efficiency-focused Lean principles with cutting-edge technologies. Originating from post-World War II Japanese manufacturing, Lean Management has evolved globally, embracing automation and data analytics to remain relevant in the digital age. The strategic alignment of Lean Management with Industry 4.0 brings numerous advantages, enhancing operational efficiency, flexibility, quality control, and cost reduction. Digital twin technology aligns with Lean's Kaizen philosophy, while Quality 4.0 introduces advanced analytics, complementing Lean's waste-minimization commitment. Interconnected systems provide end-to-end visibility, supporting Lean's value stream optimization. Despite significant advantages, challenges such as data standardization, resistance to change, and technology compatibility must be addressed through strategies like common data standards and change management programs. The exploration of Six Sigma's integration with Industry 4.0 reveals specific challenges and overcoming strategies. Ultimately, the integration of Lean Management and Six Sigma with Industry 4.0 presents immense potential for organizations striving for excellence, adaptability, and competitiveness in the dynamic landscape of smart manufacturing. Addressing challenges and implementing effective strategies positions organizations for sustained success in the digital era.

**Keywords:** Industry 4.0; Quality 4.0, quality management; quality methods, Lean Management.

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

## 1. Introduction

As industries undergo rapid technological advancements, the integration of Lean Management, Industry 4.0, and Quality 4.0 has become a strategic imperative for organizations seeking to enhance efficiency, responsiveness, and product/service quality. Each of these concepts brings unique strengths, and their convergence can lead to a synergistic approach that propels organizations into the future of smart and adaptive manufacturing.

The integration of Lean Management with Industry 4.0 and Quality 4.0 represents a powerful synthesis of traditional efficiency-focused methodologies with cutting-edge technologies. This convergence not only enhances operational excellence but also positions organizations to thrive in an era of rapid technological evolution and dynamic market demands. The collaborative approach of these concepts fosters a culture of continuous improvement, adaptability, and innovation.

The purpose of this publication is to present the usage of Lean Management approach in industry 4.0 condition.

## 2. The basics of Lean Management approach

Lean Management has its roots in the post-World War II Japanese manufacturing industry and particularly in the innovative practices developed by Toyota. The concept emerged in the 1950s and was refined over subsequent decades. The history of Lean Management is characterized by a commitment to efficiency, waste reduction, and continuous improvement.

After World War II, Japan faced economic challenges and resource constraints. Toyota, under the leadership of Taiichi Ohno, faced the need to rebuild and compete in a challenging economic environment. In the 1950s, Toyota developed the Toyota Production System (TPS), which became the foundation for Lean Management (Alrabadi et al., 2023). TPS aimed to optimize efficiency, reduce waste, and enhance productivity in manufacturing. Central to TPS was the concept of Just-in-Time (JIT) production, emphasizing the delivery of products or components just when they are needed, minimizing inventory costs and reducing waste. The philosophy of Kaizen, meaning continuous improvement, became a fundamental principle of Lean Management. It encouraged small, incremental changes to improve processes over time (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

In the 1980s, Western companies, particularly those in the automotive industry, started to take notice of the success of Japanese manufacturing practices. The term "Lean" was coined to describe the efficient, waste-reducing methods employed by Toyota. James Womack, Daniel

Jones, and Daniel Roos played a crucial role in popularizing Lean Management in the West through their influential book, "The Machine That Changed the World" (1990). They identified key Lean principles and highlighted how they could be applied outside of manufacturing (Liu et al., 2023). While Lean Management initially gained prominence in manufacturing, its principles were successfully applied in diverse industries, including healthcare, services, and software development. Lean Management became closely associated with Six Sigma methodologies, forming a comprehensive approach to business improvement. This integration allowed organizations to address both efficiency and quality concerns (Bousdekis et al., 2023).

In recent decades, Lean Management has become a globally recognized and widely adopted management philosophy. Many organizations across different sectors have integrated Lean principles into their operations (Yanamandra et al., 2023). The digital age has seen the integration of technology into Lean practices, with advancements such as automation, data analytics, and software tools enhancing the application and impact of Lean Management (Jokovic et al., 2023).

Lean management is a business approach that originated from the manufacturing practices of Toyota in the 1950s. It has since been widely adopted across various industries and sectors to improve efficiency, reduce waste, and enhance overall productivity. The core concept of lean management revolves around the idea of delivering value to customers with the least amount of resources possible (Barsalou, 2023; Maganga, Taifa, 2023).

Table 1 contains description of Lean Management values. These values collectively form the foundation of Lean Management and guide organizations in their pursuit of operational excellence, waste reduction, and customer-centric practices.

**Table 1.**  
*Values of Lean management*

<b>Lean Management Value</b>	<b>Description</b>
<b>Value</b>	Focuses on understanding and delivering what customers truly value in terms of products or services. Emphasizes customer satisfaction and meeting their needs.
<b>Value Stream Mapping</b>	Analyzes and optimizes the entire process or value stream of a product or service, identifying and eliminating non-value-added steps to enhance efficiency.
<b>Flow</b>	Promotes the smooth and efficient flow of work through the value stream, minimizing delays, bottlenecks, and interruptions in the production or service delivery process.
<b>Pull System</b>	Shifts from a push system to a pull system, where work is based on customer demand. Prevents overproduction and reduces excess inventory.
<b>Continuous Improvement (Kaizen)</b>	Encourages a culture of continuous improvement, where organizations regularly seek ways to enhance processes, eliminate waste, and optimize efficiency.
<b>Just-in-Time (JIT)</b>	Aims to produce or deliver items just in time to meet customer demand, minimizing inventory holding costs and reducing the risk of producing excess or obsolete goods.
<b>Respect for People</b>	Recognizes the importance of the people involved in the process. Emphasizes creating a supportive and collaborative work environment that values the contributions of all team members.

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 Lean Management approach can be integrated with Industry 4.0 and Quality 4.0 concept**

Lean Management's focus on value stream mapping aligns seamlessly with Industry 4.0 principles. By leveraging advanced data analytics and sensors, organizations can gain real-time insights into their processes. This allows for more precise identification of bottlenecks, optimization of workflows, and minimization of non-value-added activities, thereby streamlining operations. Industry 4.0 technologies enable more accurate demand forecasting and dynamic production adjustments (Singh et al., 2023). This complements Lean's just-in-time manufacturing by providing the agility to respond swiftly to changes in customer demands or market conditions.

Digital twin technology, a hallmark of Industry 4.0, aligns with Lean Management's Kaizen philosophy. Organizations can create virtual replicas of physical processes, products, or systems, allowing for continuous monitoring, analysis, and improvement without disrupting actual operations (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

Quality 4.0 emphasizes the use of advanced analytics, machine learning, and artificial intelligence in quality control. Integrating Lean Management with Quality 4.0 allows organizations to implement data-driven quality control measures. This ensures that defects are identified and corrected in real-time, aligning with Lean's goal of minimizing waste. Quality 4.0 introduces predictive analytics for risk management. By analyzing historical data and potential risk factors, organizations can proactively address issues before they escalate (Maganga, Taifa, 2023). This preventative approach resonates with Lean Management's emphasis on preventing defects rather than detecting and fixing them after production (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).

Quality 4.0 promotes enhanced traceability throughout the production process. Integrating this with Lean Management ensures transparency and accountability in the value stream. Any deviations from quality standards can be quickly identified and rectified, maintaining a smooth flow in operations (Almeida, Abreu, 2023).

IoT plays a crucial role in the integration of these concepts. Connected devices and sensors provide real-time data that can be analyzed to optimize processes, improve quality, and reduce waste. Big data analytics enable organizations to make informed decisions based on large datasets. When applied to Lean and Quality practices, this leads to more accurate predictions, better resource allocation, and continuous process improvement. Cloud computing facilitates seamless collaboration and data sharing. This is particularly beneficial for organizations implementing Lean, Industry 4.0, and Quality 4.0, as it ensures that relevant data is accessible

to all stakeholders, fostering a holistic and integrated approach Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Gajdzik, Wolniak, 2023; Swarnakar et al., 2023).

Table 2 is listing examples of integration of Lean Management approach with industry 4.0. This integration enhances operational excellence, fosters a culture of continuous improvement, and positions organizations to thrive in the evolving landscape of smart manufacturing and dynamic market demands.

**Table 2.**

*Lean management integration with industry 4.0*

Aspect	Description
<b>Value Stream Optimization</b>	Utilizes Industry 4.0 technologies such as real-time data analytics and sensors to continuously monitor and optimize the entire value stream. This enables organizations to identify and eliminate bottlenecks, reduce cycle times, and enhance overall operational efficiency, aligning with Lean's focus on delivering maximum value with minimal waste.
<b>Just-in-Time Manufacturing</b>	Industry 4.0's capabilities in accurate demand forecasting, data-driven decision-making, and adaptive production align seamlessly with Lean's just-in-time manufacturing philosophy. This integration allows organizations to dynamically adjust production schedules, minimize inventory holding costs, and respond promptly to changing customer needs.
<b>Continuous Improvement through Digital Twins</b>	Digital twin technology, a hallmark of Industry 4.0, supports Lean's Kaizen philosophy by creating virtual replicas of physical processes. This enables organizations to simulate, analyze, and optimize operations in real-time without disrupting actual production, fostering a culture of continuous improvement and innovation.
<b>Data-Driven Quality Control</b>	Quality 4.0's emphasis on advanced analytics, machine learning, and artificial intelligence in quality control enhances Lean Management by ensuring real-time detection and correction of defects. This proactive approach reduces waste, improves product quality, and aligns with Lean's commitment to delivering high-quality products efficiently.
<b>Risk Management and Preventive Measures</b>	Quality 4.0's predictive analytics for risk management aligns with Lean Management's focus on preventing issues before they arise. By analyzing historical data and potential risk factors, organizations can implement preventive measures, reducing the likelihood of defects, disruptions, and quality issues in the production process.
<b>Enhanced Traceability and Transparency</b>	Quality 4.0's promotion of enhanced traceability integrates with Lean Management by ensuring transparency and accountability in the value stream. Real-time tracking of components and products throughout the production process allows for quick identification and resolution of quality deviations, supporting a smooth and efficient flow of operations.
<b>Internet of Things (IoT)</b>	IoT technologies play a crucial role in Lean-Industry 4.0 integration by providing a network of interconnected devices and sensors. This real-time data is utilized in Lean Management for optimizing processes, reducing downtime, and improving overall equipment efficiency (OEE), contributing to Lean's goal of maximizing value with minimal resources.
<b>Big Data Analytics</b>	Big data analytics, when integrated with Industry 4.0 technologies, enhances Lean Management by providing organizations with actionable insights. Analyzing large datasets enables more accurate predictions, better resource allocation, and continuous process improvement, supporting Lean's commitment to data-driven decision-making and operational excellence.
<b>Cloud Computing</b>	Cloud computing facilitates seamless collaboration and data sharing across different departments and locations. This ensures that relevant data is accessible to all stakeholders in real-time, supporting the holistic and integrated approach of Lean Management with Industry 4.0. The cloud enables efficient communication, collaboration, and accessibility of critical information, fostering a culture of agility and adaptability in the organization.

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; 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 of Lean Management a approach usage in Industry 4.0. The integration of Lean Management with Industry 4.0 brings about a powerful synergy, unlocking numerous benefits that contribute to organizational competitiveness, sustainability, and resilience in the face of evolving market dynamics.

**Table 3.**

*The advantages of Lean Management integration with industry 4.0*

<b>Advantage</b>	<b>Description</b>
<b>Operational Efficiency</b>	The integration enhances operational efficiency by leveraging Industry 4.0 technologies such as IoT, automation, and data analytics to optimize processes. Lean principles combined with real-time insights lead to streamlined workflows, reduced lead times, and improved resource utilization.
<b>Enhanced Flexibility and Agility</b>	The combination of Lean and Industry 4.0 allows organizations to adapt quickly to changes in demand or market conditions. Agile production processes, enabled by dynamic adjustments based on real-time data, support Lean's goal of just-in-time manufacturing and responsiveness to customer needs.
<b>Improved Quality Control</b>	Industry 4.0's advanced analytics and quality monitoring systems, integrated with Lean Management, provide real-time detection and correction of defects. This leads to improved product quality, reduced waste, and better compliance with quality standards, aligning with Lean's focus on delivering high-quality products.
<b>Cost Reduction through Waste Minimization</b>	Lean Management's emphasis on waste reduction, when integrated with Industry 4.0 technologies, results in more accurate demand forecasting, optimized inventory levels, and reduced production downtime. This leads to cost savings through minimized waste, improved resource allocation, and efficient use of assets.
<b>Data-Driven Decision Making</b>	The integration leverages data analytics, big data, and AI to support informed decision-making. This aligns with Lean Management's commitment to data-driven continuous improvement, enabling organizations to identify areas for optimization, enhance processes, and drive strategic initiatives based on real-time insights.
<b>Predictive Maintenance and Asset Utilization</b>	Industry 4.0's predictive maintenance capabilities, integrated with Lean principles, ensure optimal utilization of assets and reduce unplanned downtime. Proactive maintenance based on data analytics helps prevent equipment failures, aligning with Lean's goal of maximizing operational efficiency.
<b>Improved Customer Satisfaction</b>	The integration supports Lean's customer-centric focus by enabling organizations to respond quickly to changing customer demands, deliver products with higher quality, and reduce lead times. This leads to increased customer satisfaction and loyalty, contributing to long-term business success.
<b>Employee Empowerment and Skill Development</b>	Lean Management's emphasis on continuous improvement and employee involvement aligns with Industry 4.0's focus on human-machine collaboration. Integration encourages employee empowerment, skill development, and a culture of innovation, fostering a workforce capable of leveraging advanced technologies for improved efficiency.
<b>Holistic View of Operations</b>	The combination provides a holistic view of operations, from the supply chain to production to delivery. This end-to-end visibility, facilitated by interconnected systems, supports Lean's value stream optimization, allowing organizations to identify and address inefficiencies across the entire value chain.

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; 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 Six Sigma approach usage in industry 4.0 and methods to overcome them.

**Table 4.**  
*The problems of Six Sigma integration with industry 4.0*

Problems	Description of Problem	Overcoming Strategies
Lack of Data Standardization	Integration challenges arise due to the absence of standardized data formats and communication protocols across Lean and Industry 4.0.	Establish a common data language and standards. Implement protocols like OPC UA for interoperability. Ensure compatibility between Lean and Industry 4.0 data structures.
Resistance to Change	Lean principles may clash with the transformative nature of Industry 4.0, leading to employee resistance.	Implement a robust change management program. Provide comprehensive training and communication. Highlight the benefits of Industry 4.0 in terms of efficiency and quality. Involve employees in the integration process.
Technology Compatibility Issues	Existing Lean systems may struggle to integrate with advanced Industry 4.0 technologies like IoT and AI.	Invest in compatible technologies or retrofit existing systems. Collaborate with technology providers to develop middleware solutions. Ensure seamless integration of Lean principles with Industry 4.0 technologies.
Data Security Concerns	Industry 4.0's extensive data sharing raises security concerns, conflicting with Lean's focus on minimizing complexity.	Implement robust cybersecurity measures, including encryption and access controls. Conduct regular security audits. Educate stakeholders on security protocols. Emphasize the importance of secure practices in data handling.
Scalability Challenges	Lean methodologies optimized for specific processes may struggle to scale and adapt to Industry 4.0's dynamic nature.	Design flexible Lean processes adaptable to Industry 4.0. Implement modular approaches for scalability without compromising efficiency. Regularly assess performance and identify areas for improvement in scaling Lean practices.
Lack of Skill Sets	Integrating Lean with Industry 4.0 requires a workforce with diverse skills in data analytics, IoT, and digital technologies.	Invest in employee training programs to bridge skill gaps. Collaborate with educational institutions for specialized training. Encourage continuous learning and development to ensure the workforce is well-equipped for Industry 4.0 integration.
Lack of Cross-functional Collaboration	Siloed organizational structures may hinder collaboration between Lean and Industry 4.0 teams, leading to inefficiencies.	Foster a culture of cross-functional collaboration. Establish interdisciplinary teams with members from both Lean and Industry 4.0 domains. Encourage open communication and knowledge sharing to break down organizational silos.
Inadequate Infrastructure	Outdated infrastructure may pose challenges in supporting the connectivity and automation requirements of Industry 4.0.	Invest in upgrading infrastructure to support Industry 4.0 technologies. Ensure the availability of high-speed networks, robust hardware, and scalable systems. Conduct a thorough assessment of existing infrastructure and plan for necessary upgrades.
Complexity in Implementation	Integrating Lean Management with Industry 4.0 involves complex processes, and organizations may struggle with the intricacies.	Break down the integration process into manageable phases. Develop a detailed implementation plan with clear milestones. Seek expertise from consultants or industry partners with experience in both Lean and Industry 4.0 for guidance and support.
Lack of Clear Metrics for Industry 4.0	Traditional Lean metrics may not align with the Key Performance Indicators (KPIs) relevant to Industry 4.0 initiatives.	Define new metrics that align with the goals of Industry 4.0, such as real-time data analytics, predictive maintenance, and overall equipment efficiency (OEE). Ensure that these metrics are integrated into performance measurement systems.
Integration Cost and Return on Investment	Implementing Industry 4.0 technologies can be costly, and organizations may struggle to demonstrate a positive return on investment (ROI).	Conduct a thorough cost-benefit analysis before implementation. Identify areas where cost savings or efficiency improvements can be realized. Leverage pilot projects to test the feasibility and demonstrate ROI before full-scale integration.

Cont. table 4.

Lack of Standardized Processes	Variability in processes across different departments or locations can hinder the seamless integration of Lean and Industry 4.0.	Standardize processes across the organization to create a common foundation. Implement Lean principles for process optimization and standardization. Ensure that Industry 4.0 technologies are aligned with standardized processes for smooth integration.
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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; 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 Lean Management, Industry 4.0, and Quality 4.0 represents a transformative approach for organizations navigating the complexities of modern manufacturing. This convergence not only combines the efficiency-focused methodologies of Lean with cutting-edge technologies but also fosters a culture of continuous improvement, adaptability, and innovation.

The history of Lean Management, rooted in the post-World War II Japanese manufacturing industry, has evolved into a globally recognized philosophy applied across diverse sectors. With advancements in technology, Lean has embraced automation, data analytics, and software tools to enhance its impact and relevance in the digital age.

The integration of Lean Management with Industry 4.0 is a strategic alignment that brings forth numerous advantages. Through the seamless incorporation of Industry 4.0 technologies like IoT, data analytics, and automation, Lean principles can be applied more dynamically. This integration results in enhanced operational efficiency, flexibility, quality control, and cost reduction. Digital twin technology aligns with Lean's Kaizen philosophy, while Quality 4.0 introduces advanced analytics and AI in quality control, complementing Lean's commitment to minimizing waste.

The holistic view of operations, facilitated by interconnected systems, provides end-to-end visibility from the supply chain to delivery. This supports Lean's value stream optimization and allows organizations to identify and address inefficiencies across the entire value chain.

While the advantages are significant, challenges in integrating Lean Management with Industry 4.0 are not negligible. Issues such as data standardization, resistance to change, technology compatibility, and scalability challenges must be addressed. Strategies like establishing common data standards, implementing change management programs, and investing in employee training are essential for overcoming these obstacles.

Additionally, the exploration of Six Sigma's integration with Industry 4.0 brings to light specific problems, including data standardization, resistance to change, and inadequate infrastructure. Overcoming these challenges involves strategies such as implementing common



data standards, fostering cross-functional collaboration, and investing in infrastructure upgrades.

The integration of Lean Management and Six Sigma with Industry 4.0 holds immense potential for organizations striving for operational excellence, adaptability, and competitiveness in the rapidly evolving landscape of smart manufacturing. By addressing challenges and implementing effective strategies, organizations can unlock the synergies between these methodologies and technologies, positioning themselves for sustained success in the digital era., and competitiveness while navigating the challenges posed by the digital transformation.

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## ENSURING FOOD SECURITY FOR THE POPULATION THROUGH PLANT-BASED NUTRITION: COLLABORATION BETWEEN POLAND AND UKRAINE

Alina YAKYMCHUK<sup>1\*</sup>, Tadeusz POMIANEK<sup>2</sup>

<sup>1</sup> Platon Shupyk National University of Health Care of Ukraine, Kyiv, Ukraine; alinayakim@ukr.net,  
ORCID: 0000-0002-5038-5215

University of Information Technologies and Management, Rzeszów, Polska

<sup>2</sup> University of Information Technologies and Management, Rzeszów, Polska; tpomianek@wsiz.rzeszow.pl,  
ORCID: 0000-0001-9945-8385

\* Correspondence author

**Purpose:** This scientific study explores the potential for collaboration between Poland and Ukraine to enhance the supply of plant-based food products in Poland. By leveraging the agricultural resources and expertise of Ukraine, this partnership aims to identify and cultivate new plant varieties that can be grown on Ukrainian soil and exported to EU countries. The research focuses on analyzing the suitability of Ukrainian soil for growing specific crops, assessing market demand, and evaluating the potential economic and environmental benefits of such cooperation.

**Design/methodology/approach:** The study involves a comprehensive review of scientific literature, agricultural research, and market analysis to identify promising crops with nutritional value, high productivity, and adaptability to various climates and growing conditions. The findings offer insights into the diversification of food production systems and the promotion of sustainable diets. The methodology was based on the official data of Statista published in 2010-2023. Combining multiple methods provided a more comprehensive and nuanced understanding of the complex interactions between plant-based nutrition development and ensuring food security for the population.

**Findings:** The findings contribute to the development of sustainable agriculture practices, food security, and economic growth in both Poland and Ukraine. The authors investigate the potential of cultivating novel plant varieties to ensure an adequate food supply for the population. By exploring diverse crops beyond conventional staples, such as asparagus, this research aims to identify new plant species and varieties that can contribute to sustainable agriculture and meet the evolving dietary needs of the population.

**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 plant-based nutrition development and ensuring food security for the population.

**Originality/value:** The value of the article is in the analysis of key factors influencing the impending crisis and analyzes its potential implications on food availability, affordability, and access. The findings suggest that the growing demand for food, coupled with various environmental, economic, and policy challenges, may lead to significant food supply

disruptions and pose serious threats to the well-being of citizens in the region. These results could be especially interesting for researchers whose studies are interdisciplinary.

This investigation examines the potential emergence of a food security crisis in Poland and other European Union (EU) countries.

**Keywords:** food security, sustainable development, plant-based food products.

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

**JEL:** O52, A19, A10, E21.

## 1. Introduction

Food security is a critical aspect of any nation's well-being, and ensuring a steady supply of nutritious food is a shared responsibility. Poland and Ukraine, neighboring countries in Eastern Europe, have recognized the importance of collaboration to address the challenge of providing plant-based nutrition to their populations. By working together, they can leverage their agricultural resources, enhance food production capabilities, and promote sustainable practices. This article explores the cooperation between Poland and Ukraine in ensuring food security through plant-based nutrition.

Ensuring a stable and diverse supply of plant-based food products is essential for meeting the dietary needs of the population and promoting a healthy lifestyle. Poland, as a member of the EU, has a significant demand for such products. Collaboration with Ukraine, a neighboring country with extensive agricultural potential, presents an opportunity to expand the range of crops cultivated and enhance food security in Poland.

Both Poland and Ukraine possess significant agricultural potential, with fertile lands and favorable climatic conditions for plant cultivation. Poland has a well-developed agricultural sector known for its diverse production, including cereals, fruits, vegetables, and livestock. Similarly, Ukraine is recognized as the "breadbasket of Europe" due to its extensive grain production. Collaborating on plant-based nutrition allows the countries to capitalize on their strengths and optimize resource allocation for maximum productivity.

In addition, Poland and Ukraine can greatly benefit from the exchange of expertise in plant-based nutrition. Poland has made notable advancements in organic farming, sustainable agricultural practices, and value-added food processing. Sharing these practices with Ukraine can help enhance productivity while minimizing the environmental impact. On the other hand, Ukraine's experience in large-scale agricultural production and grain processing can provide valuable insights to Poland. By fostering knowledge transfer, both countries can strengthen their agricultural systems and improve food security.

Poland and Ukraine can collaborate on promoting the cultivation of a wide range of plant-based foods because of that fact that diversifying crop production is crucial for maintaining a balanced and nutritious diet. This includes expanding the production of fruits, vegetables, legumes, and oilseeds. By diversifying crop cultivation, the countries can reduce their dependence on imports and provide their populations with a rich variety of nutritious food options. Collaborative research and development initiatives can also focus on identifying and promoting indigenous crops suitable for local conditions.

Sustainability plays a vital role in ensuring long-term food security, that is why Poland and Ukraine can collaborate on adopting sustainable practices in agriculture, such as precision farming, organic farming, and water management techniques. By implementing these practices, the countries can minimize resource wastage, reduce the use of chemical inputs, and protect the environment. Additionally, joint efforts in research and innovation can focus on developing climate-resilient crops and improving post-harvest storage and processing techniques. Collaboration in plant-based nutrition can also strengthen trade and economic ties between Poland and Ukraine. By enhancing agricultural production and ensuring a steady supply of plant-based food products, both countries can meet domestic demand and explore opportunities for export. Joint ventures and partnerships between agricultural businesses can facilitate technology transfer, increase investment, and stimulate economic growth. Strengthening trade relationships can contribute to the overall development of the agricultural sector in both countries.

Safeguarding food security and promoting balanced nutrition are critical challenges in modern times. Expanding the range of cultivated plant varieties beyond traditional staples can contribute to a diversified and resilient food supply. This study focuses on identifying novel plant species and varieties that possess favorable agronomic characteristics, nutritional value, and market potential. The exploration of new crops aims to address environmental constraints, increase agricultural productivity, and offer consumers a wider selection of nutritious plant-based foods (Satija et al., 2017; European Environment Agency, 2020).

For Ukraine, especially in the modern conditions of martial law, it is very important to provide the population with food, although this is an extremely difficult task. This can be achieved only thanks to international cooperation and implementation of non-standard solutions in practice. That is why the main objectives of this study is the search for new ways of cooperation in providing the population with products, the study of the prospects for growing non-traditional crops for agriculture with the justification of the possible impact on the environment, economic costs and effects of the proposed measures. In Poland, the agricultural sector plays a significant role in ensuring the population's access to plant-based food. The country has a well-developed agricultural system that encompasses a wide range of crops and livestock. According to data, Poland is one of the largest wheat producers in Europe. It also cultivates other grain crops such as corn, barley, and oats. Additionally, the country has a significant production of vegetables, fruits, berries, potatoes, and other plant-based crops.

Poland is also experiencing growth in viticulture and wine production. Poland actively promotes the development of organic farming and encourages farmers to adopt environmentally friendly cultivation methods (European Food Safety Authority, 2021). This contributes to improving the quality of agricultural products and provides the population with healthier and ecologically safe food. Poland is also known for its advanced meat processing and dairy industry. The country has a substantial livestock population and produces meat, milk, cheese, and other dairy products. Overall, Poland has a diverse agricultural production that allows the country to provide its population with a variety of plant-based food products.

## 2. Aim of the research and methods

The purpose of this study is to investigate the feasibility and benefits of collaboration Poland and Ukraine and identify potential new crops that can be grown in Ukraine and exported to EU markets. The prospective food security crisis in Poland and EU countries demands urgent attention and proactive measures. Addressing the complex challenges of population growth, climate change, and economic disparities is essential to ensure food security for all citizens (Pomianek, 2022; Vermeulen et al., 2012). Sustainable agricultural practices, policy coherence, and social safety nets are integral components of a comprehensive strategy to secure a prosperous and food-secure future for EU.

The main methods on which this investigation has been built:

**Economic and Environmental Impact Assessment.** The economic viability and environmental sustainability of cultivating and exporting new crops are evaluated. This involves analyzing production costs, potential revenue, environmental footprint, and compliance with EU agricultural regulations.

**Crop Suitability Assessment.** The suitability of Ukrainian soil for specific crops is evaluated based on factors such as climate conditions, nutrient availability, and pest resistance. This assessment involves consulting with agricultural experts and utilizing scientific literature.

**Market Research.** Market demand for plant-based food products in Poland and other EU countries is analyzed through surveys, interviews, and market data analysis. Potential export opportunities for new crop varieties are identified.

**Soil Analysis.** Soil samples from various regions in Ukraine are collected and analyzed to determine their composition, fertility, and suitability for different crop types.

A model for ensuring the quality of plant-based food products for the population and its impact on health can be outlined as follows:

**Step 1: Supplier and Producer Selection.** Conduct a thorough analysis and selection of suppliers of plant-based products that meet quality, safety, and standards requirements. Establish long-term partnerships with reliable producers who guarantee the quality of their products.

Step 2: Quality Control System. Develop a quality control system that includes standards, procedures, and methodologies for assessing the quality of plant-based products. Implement systematic monitoring of the production process, including cultivation, harvesting, processing, and packaging of the products.

Step 3: Certification and Standards. Utilize international quality certifications and standards such as ISO, HACCP, and Organic to ensure high quality and safety of the products. Certify the products according to established standards and ensure their compliance.

Step 4: Quality Control at All Stages. Conduct regular inspections and testing at various stages of production to ensure the high quality of the products. Monitor the supply chain and maintain quality control at each stage, including cultivation, harvesting, transportation, and storage of the products.

Step 5: Thorough Product Analysis before Delivery. Perform final product analysis, including laboratory testing, to verify the quality, safety, and nutritional content of the plant-based food products. Implement stringent quality checks before the products are delivered to the market or consumed by the population.

Some formulas that can be associated with the model outlined above:

Formula for Supplier and Producer Selection:

Supplier and Producer Selection = Analysis + Evaluation + Criteria Assessment

Formula for Quality Control System:

Quality Control System = Standards + Procedures + Methodologies + Monitoring

Formula for Certification and Standards:

Certification and Standards = ISO + HACCP (Hazard Analysis and Critical Control Point) +  
Organic + Compliance

Formula for Quality Control at All Stages:

Quality Control at All Stages = Inspections + Testing + Monitoring + Compliance

Formula for Thorough Product Analysis before Delivery:

Thorough Product Analysis = Laboratory Testing + Quality Checks + Verification

It's important to note that these formulas represent the key components and elements of the model and are meant to provide a conceptual understanding of the processes involved.

The quality assurance algorithm outlined in this model aims to ensure that plant-based food products meet high-quality standards, which directly impact the health of the population. By adhering to rigorous quality control measures, including supplier selection, certification, and continuous monitoring, the risks associated with contaminated or substandard products can be minimized. Ensuring the quality of plant-based food products promotes healthier dietary choices, contributes to overall well-being, and reduces the potential adverse effects on health that may arise from consuming low-quality or unsafe food products.

### 3. An overview of the literature

There is considerable research in the scientific literature on ensuring sufficient plant-based foods, which is critical to promoting healthy diets, sustainable agriculture, and addressing global food security challenges. Such key studies on how to effectively meet the nutritional needs of the population with the help of plant food in modern times are the works of such scientists as A. Jones (Jones et al., 2017) and D. Tilman et al. (Tilman et al., 2018). These studies highlight the importance of sustainable agriculture practices, including crop diversification, efficient resource management, and reduced environmental impacts, in ensuring long-term food security and addressing nutritional challenges. The authors pay attention to a importance of sustainable agriculture and food security.

The data of Market insights, 2023 shows the rapid growth of consumer demand in the Polish plant-based food retail market. Sales of herbal products increased by 109% between 2020 and 2022 to PLN 729 million. Plant-based categories are growing faster than animal-based categories. In 2022, growth in unit sales of plant-based milk, yogurt, and cheese categories outpaced growth in animal-based categories. In 2022, plant-based milk sales were PLN 387.1 million (€82.5 million), and the category continues to grow. The fastest-growing categories were plant-based milk, plant-based cheese, plant-based yogurt and plant-based desserts, all of which saw sales at least double in 2022. Additionally, it should be noted that the increase in sales value between 2020 and 2022 was significantly driven by the inclusion of the plant-based meat category for the first time in NielsenIQ plant-based meat retail sales. Excluding the plant-based meat category, plant-based foods grew by 59% between 2020 and 2022.

Plant-Based Diets and Health Benefits are represented by scientists A. Satija et al. (Satija et al., 2017) and M. Springmann et al. (Springmann et al., 2018), they emphasize the positive health impacts of plant-based diets, including reduced risks of chronic diseases such as heart disease, obesity, and certain cancers, while also considering the environmental sustainability of food production systems. Food Supply Chains and Distribution have been investigated by M. Canali et al. (Canali et al., 2019) and S. Vermeulen et al. (Vermeulen et al., 2012). These studies explore the potential benefits of shortening food supply chains, promoting local and regional food systems, and reducing the environmental footprint associated with long-distance food transportation. C. Grainger et al. (rainger, et al., 2017) and R. Rattanawong et al. (Rattanawong et al., 2020) discuss the important role of technological advancements, including precision agriculture, genetic engineering, and digital farming, in optimizing crop production, improving resource efficiency, and promoting sustainable farming practices.

Sustainable agriculture practices, promotion of plant-based diets, efficient food supply chains, and technological innovations all play crucial roles in addressing global food security challenges, enhancing human health, and mitigating environmental impacts. All this underscores the importance of ensuring a sustainable supply of plant-based food products to meet the dietary needs of the population.

Professor T. Pomianek (Pomianek, 2022) draws attention to the fact that if humanity does not reduce meat consumption, then we will face a catastrophe, especially since certain negative factors add up, or rather reinforce each other. Cutting down tropical forests for fodder, oil, etc. greatly reduces CO<sub>2</sub> absorption by trees. Industrial food production is killing biodiversity. The scientist emphasizes that the loss of biodiversity is a measurable loss for the global economy, as under such conditions we could lose up to 2.7 trillion dollars a year by 2030 if we continue to destroy biodiversity. The scientist concludes that human civilization is now faced with the following choice: if we maintain the existing pattern of consumption, it will lead to catastrophe, but as an alternative, we disciplinedly and consistently at least reduce the consumption of animal protein in favor of vegetable protein. In this way, according to the author, we will save a good tomorrow for our children and grandchildren (Pomianek, 2022).

The loss of biodiversity leads to the deterioration of the environment, the loss of genetic material, but also causes a decrease in the number of plant species that can be suitable for food for the population (Yakymchuk et al., 2017, 2023). This applies to such rare species that are currently under protection as Bear onion (cheremsha) (*Allium ursinum*), *Scopolia carniolica* (*Scopolia carniolica*), *Cimicifuga europaea* (*Cimicifuga europaea*), White foxglove (*Potentilla alba*), Sarmatian incense (*Melittis sarmatica*), *Gladiolus imbricatus* (*Gladiolus imbricatus*), Broad-leaved bells (*Campanula latifolia*), Species of the genus *Aconitum* (*Aconitum*) and many others. Some of these species are simultaneously valuable medicinal plants, for example *gladiolus imbricatus* and *polemonium caeruleum*. The authors came to a conclusion that now plantation cultivation can be used for such species. Continued research, policy support, and international collaborations are essential to effectively implement strategies for providing the population with high-quality plant-based food products in modern times. This study aims to analyze data on plant-based food production and consumption in Poland and Ukraine in order to assess the current state of plant-based food production and consumption in both countries and outline the prospects for joint cultivation of crops to expand the food assortment.

The researchers Sikhalazo Dube, Robert J. Scholes, Gerald C. Nelson and others, rightly believe that understanding trends in agricultural production and trade in relation to climate change and population growth is vital for national planning and the development of adaptation and mitigation strategies (Dube, Scholes, Nelson et al., 2013).

#### **4. Fund healthy plant-based nutrition by countries**

This study analyzed the sources of financing healthy food for the population, which are used by the governments of the developed countries of the world. Most states have special programs for financing healthy food as a tool for promoting a healthy lifestyle, many involve grant projects as a means of stimulating the development of plant-based food. Table 1 shows the main funds and sources of funding for healthy nutrition in various developed countries.

**Table 1.***Instruments of funding of healthy plant-based nutrition of different countries*

Country	Program/Initiative	Source of Funding
Australia	Healthy Eating Initiative	Federal and local funds
Brazil	Farmer Support Program	Government subsidies
Canada	Healthy Eating Program	Federal and provincial funds
India	National Subsidy Program	Government funds
Japan	Organic Farming Development Program	Government financial support
Netherlands	Crop Support Fund	Private and public donations
Sweden	Subsidies for organic farms	Government budget
Switzerland	Grants for Plant-Based Nutrition Research	National funds
USA	Federal Subsidy Program	Government budget
Poland	Subsidies for organic farms	National funds
Ukraine	National Subsidy Program	Government budget

Source: The data is based on the latest available statistics from Market insights, 2023; International cooperation, 2021; European Commission, 2021, 23.11.2023.

GFI Europe's analysis of Nielsen IQ data in European countries shows that sales of plant-based products have grown by approximately 21% between 2020 and 2022, reaching a record €5.8 billion (Market insights, 2023). Based on the provided table 1, scientific and practical interest is the study of production and consumption of plant-based food products in Poland and Ukraine. In Poland, the production of plant-based food products is significant due to its well-developed agricultural sector. The country cultivates a wide range of crops, including grains (such as wheat, corn, barley, and oats), vegetables, fruits, berries, and potatoes. Poland is also known for its meat processing and dairy industry, which contributes to its overall food production. In terms of consumption, Poland's population relies on plant-based food products as a significant part of their diet. This includes grains, fruits, vegetables, and other plant-based items.

Ukraine is recognized as the "breadbasket of Europe" due to its vast agricultural potential. The country is a major producer of grains, including wheat, barley, and corn. It also cultivates other plant-based crops, such as sunflower seeds, rapeseed, vegetables, and fruits. Additionally, Ukraine has a significant livestock sector, contributing to its overall food production. Regarding consumption, the population of Ukraine relies heavily on plant-based food products. Grains, vegetables, fruits, and other plant-based items form an essential part of the Ukrainian diet. By comparing the production and consumption data, we can assess the self-sufficiency and dependency on imports for plant-based food products in both countries. If the production exceeds consumption, it indicates that the country has surplus produce that can potentially be exported. Conversely, if consumption surpasses production, it suggests a higher dependency on imports to meet the domestic demand (The Impact of the Conflict in Ukraine, 2022).

Further analysis would require filling in the production and consumption figures for each category in the table to draw more specific conclusions about the plant-based food production and consumption patterns in Poland and Ukraine (table 2).



**Table 2.**  
*Production and Consumption of Plant-Based Food Products in Poland and Ukraine*

Country	Tys. tonnes			
	Grains	Vegetables	Fruits	Other Plant-Based Products
Poland	5000	2500	1200	3000
Ukraine	8000	3000	1500	2500

Source: FAOSTAT, 2023; European Commission, 2021, 23.11.2023.

Poland and Ukraine, as significant agricultural countries in the European region, play a vital role in the production and consumption of plant-based food products. Data of Table 2 indicate that Ukraine surpasses Poland in the production of grains, with a considerable margin of 8000 thousand tonnes compared to Poland’s 5000 thousand tonnes. This difference could be attributed to several factors, such as differences in climate, agricultural practices, and government policies. The higher grain production in Ukraine may indicate a stronger emphasis on cereal crops and potential export opportunities. In the category of vegetables, Poland produces 2500 thousand tonnes, whereas Ukraine produces 3000 thousand tonnes. Although Ukraine’s production exceeds Poland’s, the difference is relatively small. Both countries demonstrate a significant focus on vegetable cultivation, indicating the importance of this food group in their diets and agricultural sectors. Poland and Ukraine both show substantial fruit production, with 1200 thousand tonnes and 1500 thousand tonnes, respectively. While Ukraine maintains a lead in fruit production, it is noteworthy that both countries prioritize the cultivation of fruits, likely due to their nutritional value, economic value, and versatility in various food products. Other Plant-Based Products: The category of "Other Plant-Based Products" encompasses a diverse range of items, including legumes, nuts, seeds, and processed plant-based foods. In this category, Poland’s production stands at 3000 thousand tonnes, while Ukraine’s is at 2500 thousand tonnes. The relatively balanced production in this category suggests that both countries recognize the importance of diversifying their plant-based food offerings.

It’s important to note that European Union as a whole has a highly integrated agricultural system, with countries specializing in different crops based on their comparative advantages. This allows for efficient allocation of resources and trade within the Union, ensuring a diverse range of plant-based food products is available to the population. The specific production figures for each country may vary depending on factors such as crop rotation practices, government policies, and market dynamics. Additionally, consumption patterns, import/export data, and other factors are essential for a comprehensive analysis of plant-based food production within the European Union (tab. 3).

**Table 3.**

*Production of key agricultural crops in Poland and Ukraine over recent years (2017-2021), k. tonnes*

Years	Poland					Ukraine				
	2017	2018	2019	2020	2021	2017	2018	2019	2020	2021
1	2	3	4	5	6	7	8	9	10	11
Wheat	11,000	10,500	9800	10,200	10,700	26,200	24,500	28,000	25,800	27,500
Corn	4500	4200	4500	4800	4300	24,500	35,000	35,500	33,800	34,500
Barley	2900	2800	2600	2900	2700	7800	8500	7200	7500	7600
Oats	1700	1500	1700	1600	1800	-	-	-	-	-
Potatoes	7800	8000	8500	8200	8700	20,000	21,500	21,000	19,800	20,500
Apples	3200	3500	3300	3800	3600	-	-	-	-	-
Sunflower	-	-	-	-	-	12,000	13,500	15,500	14,800	15,200
Sugar Beets	-	-	-	-	-	13,500	14,200	15,800	14,500	15,200

Source: The data is based on the latest available statistics from FAOSTAT, 2023, 23.11.2023.

The analysis of the production of key agricultural crops in Poland over recent years demonstrates that the growing of wheat has shown a slight decrease from 11 million tonnes in 2017 to 10.7 million tonnes in 2021 (tab. 3). However, the production quantities have remained relatively stable throughout this period. Corn production in Poland has seen a gradual increase over the years, indicating the growing importance of this crop in the country's agricultural sector. The production quantities range from 4.2 to 4.8 million tonnes. Barley production in Poland has also shown slight fluctuations but has generally remained within a similar range in recent years. The production quantities range from 2.6 to 2.9 million tonnes. Oats production in this country has remained relatively stable, with minor variations from year to year – the production quantities range from 1.5 to 1.8 million tonnes. Potato production has shown a consistent level of production, with slight variations. Poland has a long history of potato cultivation, and the production quantities range from 8 to 8.7 million tonnes. The production of apples in Poland has shown some variations, ranging from 3.2 to 3.8 million tonnes. Poland is one of the leading apple producers in Europe. These production figures highlight the stability and consistency of Poland's agricultural sector. The country has maintained a strong position in the production of key crops, such as wheat, corn, barley, oats, potatoes, and apples. These crops are vital for both domestic consumption and export purposes.

The analysis of the production of key agricultural crops in Ukraine over the past few years shows that wheat production has fluctuated but generally remained within a similar range, ranging from 24.5 to 28 million tonnes, a twice as much as grown in Poland. Ukraine is one of the largest wheat producers in the world. Corn production in Ukraine has remained consistently high, ranging from 33.8 to 35.5 million tones, that is six times more than grown in Poland. Ukraine is a major global exporter of corn. Barley: Barley production in Ukraine has shown slight variations, ranging from 7.2 to 8.5 million tonnes, it is an important crop for livestock feed and brewing industries. Sunflower production in Ukraine has remained stable, with production quantities ranging from 12 to 15.2 million tonnes. Ukraine is one of the leading producers of sunflower oil. Potato production in Ukraine has shown slight fluctuations, ranging

from 19.8 to 21.5 million tonnes. Potatoes are a staple food crop in Ukraine. Sugar beet production in Ukraine has remained relatively stable, ranging from 13.5 to 15.8 million tonnes, now sugar beets are a significant crop for the sugar industry. It's important to note that agricultural production can be influenced by factors such as weather conditions, market demand, and changes in cultivation practices and government policies.

The data of table 3 demonstrate Ukraine's strong position as an agricultural powerhouse. The country has favorable climatic conditions and fertile soil, enabling the production of a wide range of agricultural crops. Ukraine is known for its large-scale production and export of grains, oilseeds, and other agricultural commodities. But the war in Ukraine has had a significant impact on the cultivation of agricultural crops in the country (The Impact of the Conflict in Ukraine, 2022). The large-scale war disrupted agricultural activities, leading to various challenges and changes in production levels.

Here are some key points highlighting the effects of the war on agricultural crop cultivation in Ukraine (Ukraine: Conflict's Toll on Agriculture, 2022; War in Ukraine, 2023):

**Land Disputes and Occupation:** the war has resulted in land disputes and occupation of agricultural areas, particularly in the regions affected by the conflict; this has led to the displacement of farmers and disruption of farming operations, resulting in decreased production.

**Decreased Cultivated Area:** due to the security risks and displacement of farmers, the cultivated area for agricultural crops has decreased in certain conflict-affected regions; farmers have been forced to abandon their land or reduce their agricultural activities, impacting overall production levels.

**Economic Instability:** the war has led to economic instability in Ukraine, with fluctuations in currency value and inflation rates; this has impacted the affordability of agricultural inputs and affected farmers' ability to invest in their crops, leading to reduced production levels.

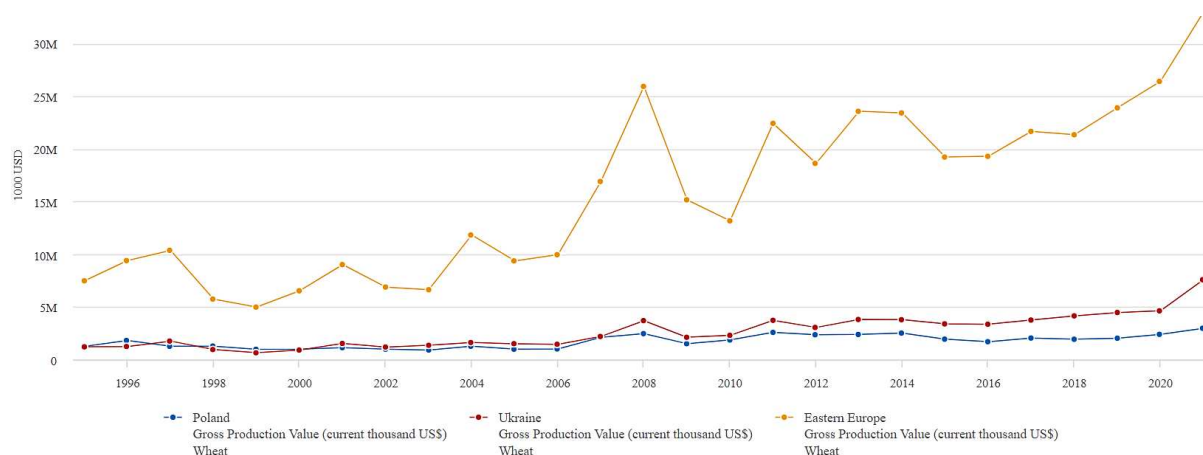
**Damage to Infrastructure:** the war has caused significant damage to agricultural infrastructure, including irrigation systems, machinery, storage facilities, and transportation networks; the destruction of infrastructure has hampered agricultural operations and logistics, affecting crop production and distribution.

**Disrupted Supply Chains:** the conflict has disrupted supply chains and trade routes, making it difficult for farmers to access necessary inputs such as seeds, fertilizers, and machinery; this has further hindered agricultural production and productivity.

**Environmental Consequences:** the conflict has resulted in environmental damage, including landmines and destruction of farmland; landmines pose a significant risk to farmers and limit their ability to cultivate agricultural crops safely.

It is important to recognize that the war in Ukraine has had detrimental consequences on the agricultural sector, exacerbating food security concerns and economic challenges in the affected areas. Unfortunately, obtaining accurate and up-to-date data specifically quantifying the impact of the war on agricultural crop production in Ukraine is challenging. The war's effects are complex and multifaceted, varying across different regions and crop types. Efforts to rebuild agricultural infrastructure, provide support to affected farmers, and restore stability in the region are crucial for revitalizing agricultural production and ensuring food security in Ukraine.

In the structure of agricultural cultivation, wheat occupies the leading position among crops, and in Poland and Ukraine its volume is significant compared to production in Eastern Europe (Fig. 1).



**Figure 1.** Wheat agricultural cultivation in Eastern Europe, 1995-2021, USD.

Source: constructed by authors based on results of model development and Statista data (FAOSTAT, 2023), 23.11.2023.

This study analyzed the value of gross production of agricultural wheat in Poland (Fig. 2) and Ukraine (Fig. 3), which proved the unevenness of its value and the significant influence of the economic and financial development of the states, as well as the level of technical support for collection and soil cultivation. The equations are described by a polynomial function and have the following form (1):

$$y = 1061,4x^2 - 17971x + 2E + 06; y = 4392,3x^2 - 75935x + 3E + 06 \quad (1)$$

In this work, on the basis of the data of (FAOSTAT, 2023), the value gross production of agricultural wheat in the period of 1995-2021 are analyzed (Fig. 2, Fig. 3).

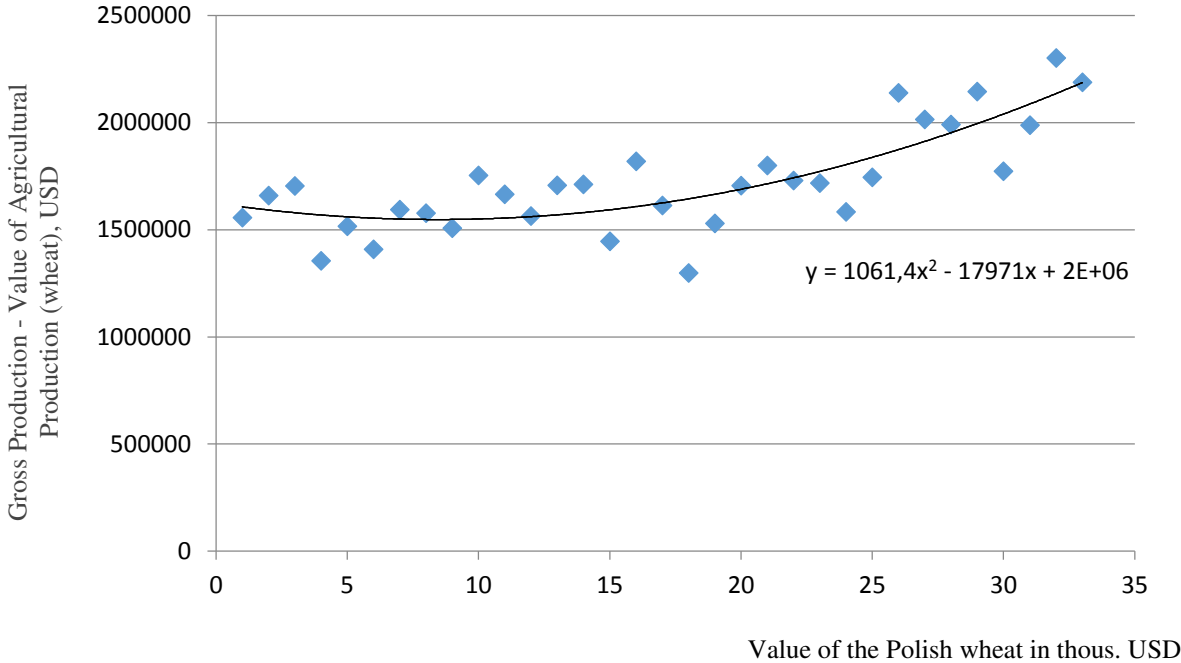


Figure 2. Polynomial distribution of the Gross Wheat Production in Poland 1995-2021, USD.

Source: constructed by authors based on results of model development and Statista data (FAOSTAT, 2023), 23.11.2023.

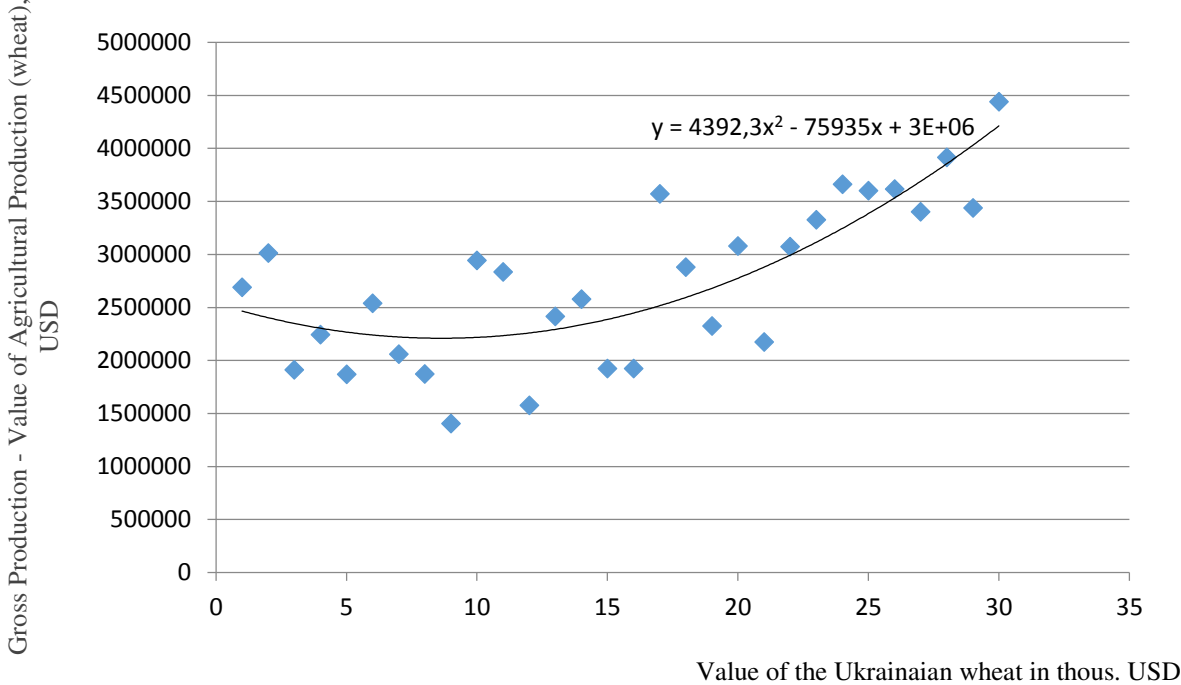


Figure 3. Polynomial distribution of the Gross Wheat Production in Ukraine, 1995-2021, USD.

Source: constructed by authors based on results of model development and Statista data (FAOSTAT, 2023), 23.11.2023.

According to the data, wheat production in Poland and Ukraine occupies a prominent place in the agricultural economy. In Ukraine, the war had a negative impact on cultivated areas due to mined fields, which significantly reduced productivity and affected the economic efficiency of agricultural production and the supply of bread and other products to the population.

## 5. Results of the research

Preliminary findings indicate several promising opportunities for collaboration between Poland and Ukraine in expanding the range of plant-based crops. The analysis of Ukrainian soil composition reveals its suitability for cultivating crops such as quinoa, buckwheat, chia seeds, amaranth, and various legumes. These crops have a high nutritional value and are in growing demand in EU markets. Additionally, the market research highlights the potential for increased export of these crops from Ukraine to Poland and other EU countries, providing economic benefits to both nations.

Preliminary findings reveal several promising novel plant species and varieties that can contribute to food security and nutrition (T.Bohn, et al., 2017). Apart from asparagus, which offers high nutritional value and adaptability, other potential crops include:

Amaranth – a versatile grain crop rich in protein, fiber, and micronutrients.

Chia Seeds – a nutrient-dense seed with high omega-3 fatty acid content and antioxidant properties.

Quinoa – a protein-rich pseudo-grain known for its adaptability to diverse climates and soil conditions.

Buckwheat – a gluten-free grain alternative that provides essential amino acids and minerals.

Pulses (legumes) – diverse legume varieties such as lentils, chickpeas, and black beans, known for their protein content, soil-enhancing properties, and nutritional benefits.

The exploration and cultivation of novel plant species and varieties offer opportunities to enhance food supply, promote sustainable agriculture, and diversify diets. The identified crops, including asparagus, amaranth, chia seeds, quinoa, buckwheat, and various legumes, exhibit favorable agronomic traits, nutritional value, and market potential. Their cultivation can contribute to increased agricultural productivity, improved nutrition, and the resilience of food systems. Further research, breeding programs, and market-oriented initiatives are essential for the successful integration of these novel crops into mainstream agriculture and ensuring a sustainable and diverse food supply for the population.

**Table 4.**

*Cultivation and Consumption of Asparagus in Ukraine and Poland*

Year	Ukraine		Poland	
	Volume, mln tonnes	Value*, mln \$	Volume, mln tonnes	Value, mln \$
2018	2,500	23450	4,000	64872
2019	3,000	32940	4,500	70556
2020	3,500	39456	5,000	67778
2021	4,000	40131	5,500	90500

\*Approximate prices that were market oriented.

Source: The data is based on the latest available statistics from FAOSTAT, 2023; European Commission, 2021, 23.11.2023.

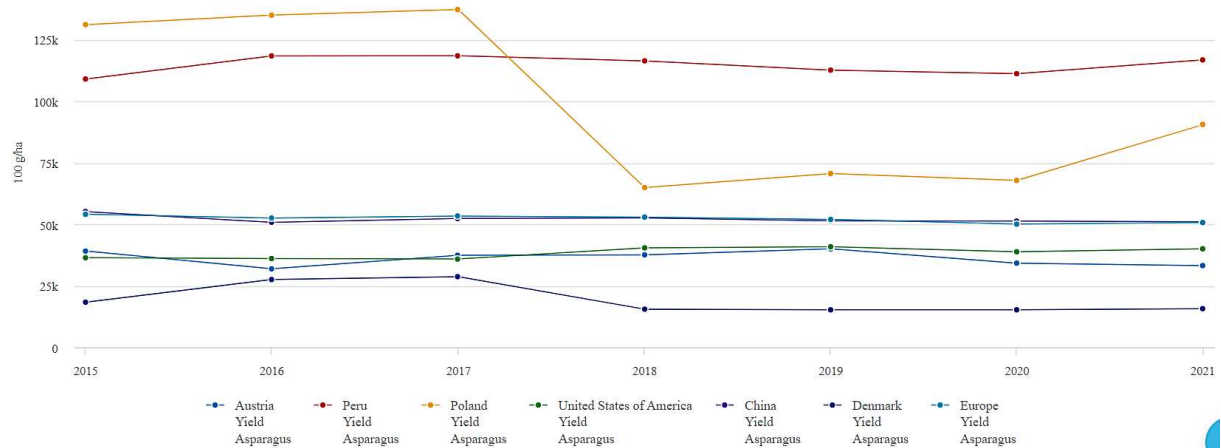
Asparagus, scientifically known as *Asparagus officinalis*, is a versatile and nutritious vegetable that has been cultivated and consumed for centuries. This article aims to explore the health benefits of asparagus, supported by scientific research and evidence. By understanding its nutritional composition and bioactive compounds, we can appreciate the positive impact it can have on human health. Asparagus is a nutrient-rich vegetable that offers various health benefits. It is low in calories and high in essential vitamins, minerals, and dietary fiber. Additionally, it contains a unique combination of phytochemicals and antioxidants, contributing to its potential positive effects on the human body. Also asparagus is a good source of folate, vitamin K, vitamin C, vitamin E, and several B vitamins, including thiamin, riboflavin, and niacin. It also provides essential minerals such as potassium, calcium, magnesium, and iron. Moreover, it is rich in dietary fiber, which aids in digestion and promotes satiety (Hwang, 2014; Kim et al., 2014).

Asparagus contains various phytochemicals with antioxidant and anti-inflammatory properties. These include flavonoids, saponins, and polyphenols. These compounds help combat oxidative stress and reduce inflammation, which are associated with chronic diseases such as cardiovascular disease, diabetes, and certain types of cancer (Geoffrey Cannock, 2011). The high fiber content in asparagus supports digestive health by promoting regular bowel movements, preventing constipation, and maintaining a healthy gut microbiota. Additionally, it contains a prebiotic fiber called inulin, which acts as food for beneficial gut bacteria, thus promoting a healthy gut environment. Asparagus contains folate, a B vitamin that plays a crucial role in brain health and cognitive function. Adequate folate intake has been associated with a reduced risk of age-related cognitive decline and neurodegenerative diseases such as Alzheimer's disease. Asparagus has diuretic properties that can aid in detoxification by increasing urine production and flushing out toxins from the body. It also contains compounds that support liver function and enhance the body's natural detoxification processes. Asparagus is a nutrient-dense vegetable that offers a range of health benefits. Its nutritional composition, antioxidant properties, and impact on digestive health, cognitive function, and detoxification make it a valuable addition to a balanced diet. Incorporating asparagus into meals can contribute to overall well-being and support a healthy lifestyle. However, further research is needed to explore specific mechanisms and the long-term effects of asparagus consumption on human health (Lee, 2017; European Food Safety Authority, 2022).

*Asparagus officinalis* is the most common of all approximately 212 species of the asparagus family. This includes the – most common- green, the white and the lesser known violet asparagus. The colour is determined by the sort of crop used and the way of growing and harvesting the crop. White and violet asparagus grows underneath foil, so that it doesn't get any contact with sunlight and the white asparagus is cut underneath the soil, whereas the violet and green asparagus are cut above the soil. It best grows in loose, sandy and not too wet soil (Asparagus Production - Worldmapper, 2023). The country that is considered the world's largest producer of asparagus is China (89%, near 6 mld \$), followed by Peru (4.3%, near 300

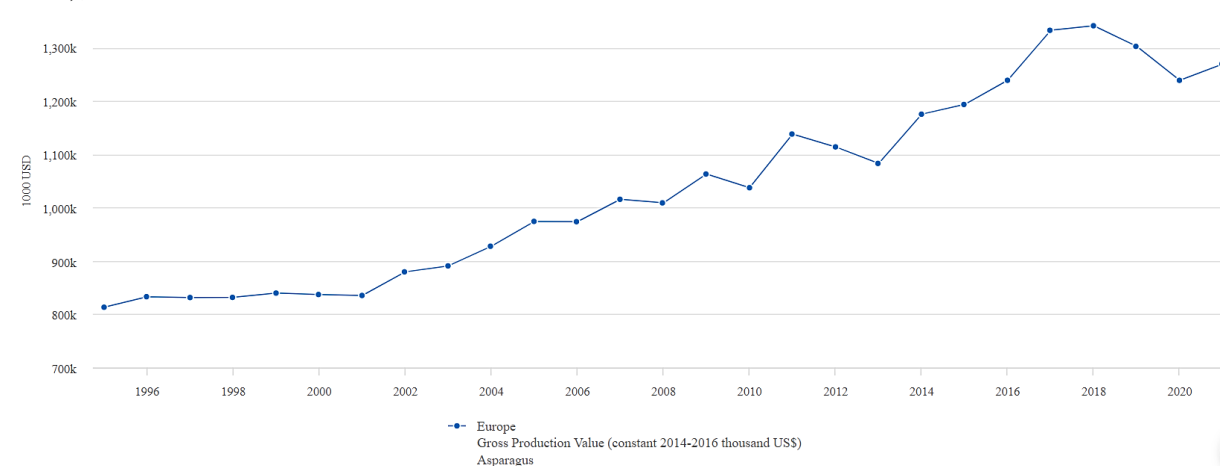
mln \$). The main export markets (US and EU) also have an important domestic production sector (European Commission, 2021; Cannock, 2011). It is actively consumed mainly in Europe, the USA and Asia.

Based on the official information, Figure 3 shows a comparison of the yield of asparagus in different countries of the world from 2015 to 2021. The data was constructed by the authors using results from a model development and information from Statista data, specifically FAOSTAT for the year 2023. The main focus of this analysis appears to be the yield of asparagus in various countries over a span of seven years. Here are some points that could be analyzed based on the given information: until 2018, Poland was the world leader in terms of asparagus productivity per unit area (Fig. 4).



**Figure 4.** Yield of Asparagus comparison in different countries of the world, 2015-2021.

Source: constructed by authors based on results of model development and Statista data (FAOSTAT, 2023), 23.11.2023.



**Figure 5.** Gross Production Value of Asparagus in Europe, 1995-2021, USD.

Source: constructed by authors based on results of model development and Statista data (FAOSTAT, 2023; European Commission, 2021), 23.11.2023.

The amount of new plant varieties required to provide food for the population in terms of tonnage can vary depending on several factors such as the size of the population, dietary patterns, and agricultural productivity. It is challenging to provide an exact figure as it would



require detailed analysis and considerations of various factors. However, according to the Food and Agriculture Organization of the United Nations (FAO), global food production needs to increase by approximately 50% by 2050 to meet the demands of a growing population. This increase includes the cultivation of new plant varieties and improved agricultural practices to enhance productivity and efficiency (FAOSTAT, 2023).

It's important to note that specific tonnage requirements for new plant varieties would depend on individual country demographics, consumption patterns, and agricultural capacities. It is recommended to refer to agricultural research, food security reports, and relevant statistical sources for more specific data related to the tonnage of new plant varieties required to meet the food needs of different populations.

## 5. Conclusions

As a result of the research conducted by the authors, the following achievements were obtained and the following conclusions were formulated.

1. The collaboration between Poland and Ukraine in ensuring food security through plant-based nutrition holds great promise. By leveraging their agricultural potential, exchanging expertise, diversifying crop production, adopting sustainable practices, and promoting trade and economic cooperation, both countries can enhance food security and improve the well-being of their populations. Continued collaboration and joint initiatives will pave the way for a sustainable and resilient food system that meets the nutritional needs of present and future generations.
2. The provision of plant-based agricultural products plays a crucial role in ensuring food security and meeting the dietary needs of the population. Cooperation between Poland and Ukraine in this area can have numerous benefits for both countries. Poland has shown significant agricultural production capacity, particularly in crops like wheat, corn, barley, potatoes, apples, and cabbages. This highlights its potential to contribute to the provision of plant-based food to its population. Additionally, fostering cooperation between Poland and Ukraine in the agricultural sector, including knowledge sharing, trade partnerships, and investment, can contribute to the development and provision of plant-based food for both populations.
3. The war in Ukraine has had a detrimental impact on agricultural activities, including the cultivation of plant-based agricultural products. Land disputes, decreased cultivated areas, damaged infrastructure, disrupted supply chains, and economic instability are some of the challenges faced by Ukraine's agricultural sector. These factors have affected the production levels and food security in the country. Efforts to rebuild agricultural infrastructure, support affected farmers, and restore stability during war are crucial to revitalizing agricultural production in Ukraine.

4. The exploration and cultivation of novel plant species and varieties offer opportunities to enhance food supply, promote sustainable agriculture, and diversify diets. The identified crops, including asparagus, amaranth, chia seeds, quinoa, buckwheat, and various legumes, exhibit favorable agronomic traits, nutritional value, and market potential. Their cultivation can contribute to increased agricultural productivity, improved nutrition, and the resilience of food systems. Further research, breeding programs, and market-oriented initiatives are essential for the successful integration of these novel crops into mainstream agriculture and ensuring a sustainable and diverse food supply for the population.
5. Collaboration between Poland and Ukraine in the field of plant-based food production offers significant opportunities to enhance food security, diversify agricultural production, and foster economic growth. By leveraging Ukraine's agricultural potential and cultivating new crops suited to Ukrainian soil, Poland can expand its range of plant-based food products and meet the evolving demands of EU markets. This collaboration can contribute to sustainable agriculture practices, strengthen bilateral relations, and improve the overall well-being of the populations in both countries. Further research, investment, and policy support are essential for realizing the full potential of this collaboration and ensuring a successful transition to sustainable and diverse plant-based food production.

Our future research will focus on effective management models of world-class ecologically balanced nutrition that work well in developed countries and help preserve and restore biodiversity. The authors of the article also propose to develop a state program for compensation of interest on loans to cover any costs of farmers who grow vegetable food products in ecological conditions according to the requirements of environmental protection related to agricultural activities. State regulation of agricultural activity is also important. All this will make it possible to adjust the structure of sown areas of ecological types of agricultural crops in accordance with the priorities of providing domestic and foreign markets with important social food products. The authors will conduct further research in the direction of improvement and implementation of the strategy of providing the population with plant-based food products based on the justification of the economic efficiency of growing types of crops that have high caloric and medicinal properties (amaranth, chia seeds, quinoa, buckwheat, legumes), are subject to protection (bear onion, *scopolia carniolica*, *polemonium caeruleum*, asparagus, *melittis sarmatica*, *gladiolus imbricatus*) as valuable species and have a positive impact on the environment. Prospective further research will also be applied when forming applications for participation in grant projects and programs.

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## ECO-INNOVATIVE SOLUTIONS IN THE OPERATION OF MUNICIPAL TRANSPORT COMPANY SP. Z O.O. IN ZIELONA GÓRA

Joanna ZAREBSKA<sup>1\*</sup>, Oskar SUCHODOLSKI<sup>2</sup>, Jacek NEWELSKI<sup>3</sup>, Andrzej ZAREBSKI<sup>4</sup>,  
Anna GAŚIOREK-KOWALEWICZ<sup>5</sup>

<sup>1</sup> University of Zielona Góra; j.zarebska@wez.uz.zgora.pl, ORCID: 0000-0002-1655-3086

<sup>2</sup> MZK Sp. z o.o. in Zielonej Górze; o.suchodolski@mzk.zgora.pl

<sup>3</sup> MZK Sp. z o.o. in Zielonej Górze; j.newelski@mzk.zgora.pl

<sup>4</sup> Maritime University of Szczecin; a.zarebski@pm.szczecin.pl, ORCID: 0000-0003-1702-5442

<sup>5</sup> University of Zielona Góra; a.kowalewicz@wez.uz.zgora.pl, ORCID: 0000-0002-3340-9318

\* Correspondence author

**Purpose:** The purpose of this article is to present implemented innovative investments and changes in management forms in Municipal Transport Company Sp. z o. o. in Zielona Góra (hereinafter: MZK). These changes contributed to improving the operation of the company and providing services at a global level from the point of view of low-emission public transport and the concept of sustainable development.

**Design/methodology/approach:** The presented innovations are implemented investments and management changes that operate in MZK in Zielona Góra and bring measurable economic, ecological and social benefits. The co-authors of the article are employees of MZK and students of the Faculty of Economics and Management of the University of Zielona Góra. The research methods used in the article are the analysis of the company documents and a review of the subject literature in the field of: eco-innovation, communication services, electromobility, management and ecology.

**Findings:** Based on the analysis of documents and implemented investments, ecological, economic and social benefits were identified that MZK in Zielona Góra can boast of. Currently, it is the most innovative public transport company in Poland in terms of sustainable development and electromobility.

**Research limitations/implications:** Analysis of the company's documents allows us to show the benefits that innovations bring to passengers, the company and the environment. They indicate directions for further changes in order to provide even better service quality and company management.

**Practical implications:** The described innovative investments and implemented organizational changes in MZK make it possible to provide other plants in the industry with an incentive to take specific actions towards sustainable development and, as a result, to achieve such good results and satisfied customers as the company in question has.

**Originality/value:** MZK in Zielona Góra is currently the most modern enterprise in Poland, whose fleet consists mainly of electric buses. Innovative solutions were initiated through the implementation of the project entitled: 'Integrated system of low-emission public transport in Zielona Góra' in 2014-2020.

**Keywords:** electric buses, improving the quality of transport services, optimization of the transport offer, electricity and energy infrastructure, low-emission transport, supporting software.

**Category of the paper:** research work, case study.

## 1. Introduction

Transport has always accompanied man. At first, goods were carried on the backs of porters, then on carts, and as progress progressed - by rail, cars, ships or planes. The development of cities also contributed to the development of transport, and it was no longer about moving goods only from city to city, but also moving people and goods within cities (transport within the so-called 'juggernaut' cities is particularly problematic). Although transport needs are secondary human needs, giving up transport, despite the large amount of pollution produced, is not taken into account. In Europe, actions are being taken to introduce sustainable transport and pro-ecological transport solutions. Many of them are intended to improve transport traffic, reduce CO<sub>2</sub> emissions, reduce noise and vibration, switch to zero-emission cars, and in cities (especially large ones) increase clean transport zones and move away from combustion cars in favour of public transport. Brzeziński and Rezwow (2007, pp. 7-25) list such activities limiting the impact of transport in the city, distinguishing: 'traffic zoning (limiting car traffic depending on the density of buildings and the availability of public transport), development of public transport and providing passengers with the possibility of connecting several transport subsystems during one trip (e.g. bus, tram, scooter)'. In addition, various types of initiatives are undertaken to promote public transport, bicycle transport and carsharing (car rental services for minutes) and carpooling (sharing places in cars, e.g. using the Blablacar application) (Szpilko, Godlewska, 2020, pp. 133-134).

In accordance with the European Union's climate policy regarding the reduction of greenhouse gas emissions, the European Green Deal, the UN Action Program for Sustainable Development until 2030, the Paris Agreement of 2015 and other declarations, it is assumed that the country will strive to achieve climate neutrality in 2050. These documents emphasize the need to limit global warming to 1.5°C above pre-industrial levels and to prevent massive loss of biodiversity. According to the ESPAS report 'Global Trends to 2030: Challenges and Choices for Europe' (ESPAS, 2019), a temperature increase of 1.5°C is the maximum that the Earth can withstand, bearing in mind that if temperatures continue to rise after 2030, humanity will face even more droughts, floods, extreme heat, as well as the poverty of hundreds of millions of people and the probable destruction of the population groups most exposed to these phenomena. Therefore, action at global, European, national, regional and local levels is very important. One of such activities is the development of electromobility, which has been recognized as an effective tool for decarbonizing the transport sector and achieving climate goals (*Polityka spójności...*, 2021).



The development and promotion of the idea of introducing electromobility in the European Union were a consequence of the provisions of documents such as: from 2019 - Directive (EU) 2019/1161 of the European Parliament and of the Council of 20 June 2019 amending Directive 2009/33/EC on the promotion of clean and energy-efficient road transport vehicles, from 2010 – ‘Europe 2020 strategy: Strategy for smart, sustainable and inclusive growth’ (COM/2010/2020 final), from 2011 – ‘WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system’ (COM/2011/0144 final). The White Paper calls for a 60% reduction in greenhouse gas emissions from transport by 2050 compared to 1990 levels. Directive (EU) 2019/1161 aimed to stimulate the market for low- and zero-emission and energy-efficient motor vehicles, thus accelerating the transition EU for low-emission transport.

The principles of operation and development of electromobility in Poland are regulated by the Act on Electromobility and Alternative Fuels of 2018 (consolidated text: Journal of Laws of 2023, items 875, 1394, art. 60), which is based on the Transport Development Strategy until 2020 of 2013 (*Transport Development...*, 2013) amended in 2019 as the Sustainable Transport Development Strategy until 2030 (*Sustainable Transport Development...*, 2019) and Electromobility Development Plan in Poland ‘Energy for the future’ ([https://climate-laws.org/documents/electromobility-development-plan-in-poland\\_8db6?id=electromobility-development-plan\\_14da](https://climate-laws.org/documents/electromobility-development-plan-in-poland_8db6?id=electromobility-development-plan_14da)). The goal of the Electromobility Development Plan in Poland is to increase the number of electric vehicle users to 1 million by 2025 (PSPA, 2021).

Pursuant to the Act on Electromobility and Alternative Fuels of 2018 (consolidated text: Journal of Laws of 2023, items 875, 1394, Article 60), electric car charging infrastructure must be established in Polish cities with over 100,000 inhabitants. The number of charging stations depends on the population and the density of the car fleet per 1000 inhabitants and ranges between 60 (in 12 smaller cities with over 100,000 inhabitants) and 1000 charging points (in Warsaw).

Many local government units have already invested in new public transport fleet, most often modern electric buses. According to the counter kept by the Polish Chamber of Electromobility Development (in pol. PIRE) and the Transinfo.pl portal, at the end of February 2022, a total of 651 fully electric buses were registered in Poland, increased by 13 units by the end of the first quarter of 2022. Following vehicles, charging infrastructure for buses has also been intensively developed in recent years. The largest investments were implemented in Warsaw and cities such as Kraków, Poznań, Zielona Góra and Lublin (*Elektromobilność w Polsce...*, 2021, pp. 9-10). The leader in the production of electric vehicle charging infrastructure is Ekoenergetyka-Polska from Zielona Góra. Ekoenergetyka-Polska has a significant share in the bus fast charging station market. Devices designed and manufactured by the Polish company operate in most European capitals, e.g. Berlin, Paris or Warsaw. They are also developing intensively on the market of fast charging stations for passenger cars

and trucks, an example of which is the receipt of an order for several hundred ultra-fast charging stations for the Ionity network (*Elektromobilność w Polsce...*, 2021, p. 10).

Every 3 years, a local government unit is obliged to prepare an analysis of the costs and benefits related to the use, in the provision of public transport services, of zero-emission buses and other means of transport that use only engines whose operating cycle does not result in the emission of greenhouse gases or other substances. covered by the greenhouse gas emissions management system referred to in the Act of July 17, 2009 on the greenhouse gas and other substances emissions management system (Journal of Laws of 2022, item 673).

The use of electromobility as a local power supply will lead, as shown by the results of numerous studies and pilot solutions, to a significant improvement in energy efficiency and reduction of CO<sub>2</sub> emissions in the road transport sector, which will significantly contribute to the protection of the natural environment (Styczynski et al., 2012; Gąsiorek-Kowalewicz et al., 2023, pp. 71-92). The Electromobility Development Plan in Poland ‘Energy for the Future’ from 2014 highlights the growing use and dissemination of electric vehicles powered by renewable energy while ensuring their use for new network services, which will significantly reduce emissions of greenhouse gases, particulate matter and environmental noise, especially noise street in urban agglomerations (*Electromobility Development Plan in Poland*, 2014). An important aspect of the transition to electric transport is the fact that battery-electric vehicles emit virtually no pollutants into the atmosphere at the point of use. The noise level of BEVs is also much lower than that of combustion vehicles. All pollutants are created where electricity is produced, and the amount of pollutants depends on the way they are produced (Zarębska et al., 2019, pp. 1-11; Adamczyk et al., 2023).

The presents article shows investments and changes implemented in the MZK company in Zielona Góra, which contributed to the company's success in the form of meeting the principles of sustainable development as well as measurable financial and social benefits. Eco-innovative solutions were initiated through the implementation of the project entitled: ‘Integrated system of low-emission public transport in Zielona Góra’. This project was implemented with the support of EU funds and the city of Zielona Góra and allowed, first of all, to withdraw some combustion buses from traffic, purchase the first low-emission buses in Zielona Góra and improve the quality of transport services provided.

## **2. Materials and methods**

The article uses qualitative and quantitative analysis. The subject of the article is existing data on the operation of electric buses in the city of Zielona Góra (legal acts, available documentation of previous activities), innovations introduced in the public transport sector and the opinions of people participating in surveys conducted among city residents and users of

electric urban transport. The following research questions arise from the scope of the study defined in this way:

- To what extent does MZK in Zielona Góra implement the tasks assigned to it in the Electromobility Act?
- Do electric buses play an important role in the public transport system in public awareness?
- What have been the greatest successes during the implementation of eco-innovations in public transport so far?
- Do the inhabitants of Zielona Góra perceive the development of electric public transport as a way to improve the quality of transport services and the condition of the environment?
- Are the eco-innovations used in the case of MZK applicable in other regions of Poland?

The present research consisted of two parts. The first part of involved analysing the literature on the subject and strategic documents of the European Union. A systematic review of the literature on the subject and a critical analysis of the content of selected publications allowed us to identify the problem of air pollution caused by transport congestion and the need to invest in pro-ecological solutions in public transport and transport in general. Additional support in identifying the problem and solving it on a microregional scale was provided by the professional experience of the research co-authors (as experts and employees of MZK).

The second part of the article describes the pro-ecological investments carried out in MZK Sp. z o. o. in Zielona Góra, which is closely related to the EU countries' pursuit of an integrated low-emission public transport system under the Infrastructure and Environment Operational Program 2014-2020 (in pol. POIiŚ). The completed project called 'Integrated system of low-emission public transport in Zielona Góra' amounted to PLN 257 million (POIiŚ - PLN 167 million, city of Zielona Góra - PLN 38.5 million, PKP PLK S.A. - PLN 3.5 million). This program is an instrument for implementing the concept of sustainable development in terms of three pillars: economic, ecological and social. The main objective of the investments carried out in Zielona Góra was: elimination of harmful emissions from public transport, including reducing CO<sub>2</sub> emissions, reducing noise and vibrations related to road transport, reducing bus operating costs and improving the safety and quality of services provided, as well as making it easier for passengers to use public transport. Additionally, research by MZK in terms of analysis of the number of passengers transported (2023) and the assessment of the new rolling stock by passengers (2019) confirm the correctness of the investment.

The article formulates two hypotheses:

Hypothesis 1: MZK investments are consistent with the idea of sustainable development of the region and the pursuit of climate neutrality.

Hypothesis 2: Eco-innovative investments in public transport improve the quality of services provided, which translates into overall passenger satisfaction.

### 3. Pro-ecological investments carried out in MZK in 2014-2020

The most important pro-ecological investments implemented by the City of Zielona Góra in the area of public transport include replacement of the bus fleet, reconstruction of the electrical and energy infrastructure, reconstruction of bus loops, construction of a transfer centre and purchase of specialized supporting software. The basic goals of the implemented projects were: eliminating harmful emissions from public transport, reducing CO<sub>2</sub> emissions, reducing noise, reducing bus operating costs and, finally, improving safety and facilitating the use of public transport (MZK, 2023).

As part of the first tender for the purchase of electric buses in 2017, Ursus Bus S.A. was selected as the contractor and delivered 43 of the 47 ordered electric buses. They have batteries with a capacity of 90 kWh, which allows them to travel approximately 50 kilometres in SORT-2 conditions. In addition to air conditioning, they are equipped with a hybrid (electric and combustion) heating system. Depending on the battery charge level and ambient temperature, the heating device is powered by fuel oil or electricity. At the same time, a tender was concluded for the supply of 17 large-capacity, articulated diesel buses meeting the EURO6 exhaust emission standard. Mercedes-Benz buses were delivered by Evobus Polska Sp. z o.o.

Further electric buses, purchased in 2022, were delivered by Solaris Bus & Coach sp. z o.o. (8 12-meter buses) and Evobus Polska Sp. z o. o. (4 electric articulated buses). The buses have batteries with a higher capacity than those purchased 5 years earlier - 100 kWh and 258 kWh, respectively. The range of these vehicles is approximately 100 km on a single charge. In addition, the vehicles are equipped with a heat pump, which consumes less energy than a traditional air conditioning unit.

All electric buses are charged in two ways. The first is fast loop charging using a pantograph mounted on the vehicle (Figure 1). These chargers have a power of 200-400 kW and allow you to fully charge the bus in about 20 minutes.



**Figure 1.** Buses charging at the transfer centre.

Source: MZK Zielona Góra materials.

The second method is plug-in charging using a cable (Figure 2). There are 25 two-station chargers with a power of 80 kW at the MZK depot. This charging process is necessary to maintain the properties of the batteries by balancing them - i.e. equalizing the state of charge of individual cells in the battery.



**Figure 2.** Slow charging charger.

Source: MZK Zielona Góra materials.

The depot, which has also been completely rebuilt for the needs of electric buses, is powered by electricity produced by Elektrociepłownia Zielona Góra S.A. located directly next to the depot. Heat and Power Plant Zielona Góra S.A. is a professional energy company conducting business activities in the field of combined heat and electricity production based on domestic natural gas (Zarębska et al., 2019, pp. 1-11). The parking lot is roofed, and the bus

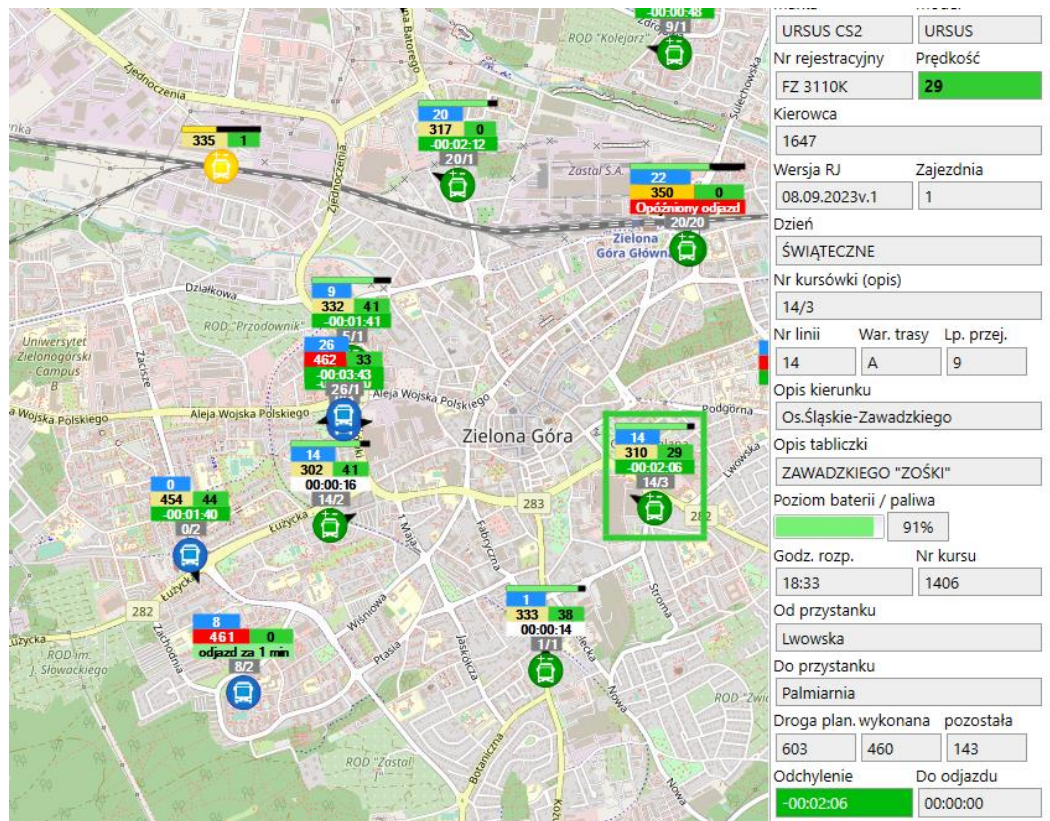
shelter structure (Figure 3) is prepared for placing photovoltaic cells on the roof. The construction of a photovoltaic farm is currently underway. It is estimated that it will cover 65.5% of the annual total energy consumption. Additionally, rainwater is collected in tanks and used to wash buses in a closed circuit. The described investments confirm hypothesis 1. The rebuilt maintenance hall uses lifts instead of channels to repair buses.



**Figure 3.** A shelter at the parking lot.

Source: MZK Zielona Góra materials.

Specialized software is used to manage the fleet of electric buses and monitor the charge level of traction batteries. It allows you to manage the power of chargers (including increasing or limiting power), monitoring their condition, remote diagnostics and reviewing data on completed charging sessions. For fleet management, a map (Figure 4) is extremely useful, which, in addition to the actual location of the vehicle, also presents information on battery charge and deviation from the timetable. The dispatcher in the MZK traffic supervision centre is able to constantly monitor and eliminate threats to the timetable by sending a reserve bus or increasing the charging power.



**Figure 4.** Map in the MZK Traffic Monitoring Centre.

Source: MZK Zielona Góra materials.

Planning timetables is a multi-stage process. The basic assumptions include full coordination of departures on individual communication routes, common timing intervals, adaptation of the type of rolling stock to the number of passengers using them and the greatest possible share of electric buses in the transport work. Regulations regarding drivers' working hours should also be taken into account. The chargers are located on 11 loops. The timetable and routes of bus lines are designed in such a way that the driver's breaks in work take place primarily on loops equipped with chargers and are thus used to recharge the traction batteries. Varying inter-stop travel times depending on the time of day allows you to reduce routes that are delayed compared to the timetable to a minimum and plan actual charging breaks. Drivers are obliged to use every break, even a few minutes, to recharge their batteries.

The route of most lines runs through the Transfer Centre, which is the heart of public transport in Zielona Góra. In addition to transfers between buses of different lines, there is a convenient transfer to regional and long-distance trains. The facility consists of four two-station stop platforms, is fully roofed and connected to the platforms of the Zielona Góra Główna railway station, and passengers have two air-conditioned waiting rooms, toilets and a customer service point at their disposal. The transfer centre serves approximately 16,000 passengers every day.

Electric buses have travelled over 13 million kilometres since the beginning of their operation. These are vehicles equipped with a large number of sensors and electronic equipment, but they are no more reliable than vehicles with traditional combustion engines. On Saturdays and Sundays, only electric buses run on the streets of Zielona Góra.

#### **4. Own research and plans for the future**

MZK Sp. z o. o. in Zielona Góra, in order to check the effectiveness of improving the quality of transport services provided by implementing electric buses, commissioned a travel satisfaction survey from an external company. The study was conducted at public transport stops and vehicles on a representative sample of passengers aged 16-75 (n = 1022), with an estimated gender and age structure corresponding to the entire population of Zielona Góra residents. According to the research design, at least 700 interviews were carried out in electric vehicles, and at least 300 - in combustion vehicles. The areas where interviews were conducted were evenly distributed throughout the entire area of operation of Zielona Góra public transport. The data were collected using the direct questionnaire interview (PAPI - Paper & Pen Personal interview) method. The research questionnaire consisted of 10 questions: 9 - closed and 1 - open, in which it was possible to provide the interviewers with their own comments regarding the newly introduced electric buses in MZK.

To summarize this study, it should be stated that: 89% of respondents were satisfied with the introduction of electric buses, these buses received an overall rating of 4.51 - on a rating scale from 2 to 5 (total transport - 4.3). In addition, the advantages of electric buses were emphasized, such as: quietness of the electric drive (39%), environmental friendliness (38%), and impact on air quality in the city (80%). Almost 89% of respondents believed that it is still necessary to invest in electric buses and replace the rolling stock with modern ones.

The next study concerned the analysis of the number of passengers transported (from March 2023). A comparative analysis of 2023 to 2013 showed an increase in the number of passengers transported by 25%. Passenger satisfaction confirmed in surveys and growing indicators in analyses of the number of passengers transported confirm that the direction of changes being introduced is correct and should be developed. The research confirms hypothesis 1. Therefore, further rolling stock replacement projects are currently being implemented. This year 2023, the following will join the Zielona Góra MZK fleet: 5 10-meter buses of the Pilea brand, 6 12-meter buses of the Solaris brand and 3 minibuses of the Karsan brand. After the buses are delivered, some of the oldest diesel buses from 2011 will be withdrawn.



When the efficiency of bus traction batteries does not allow their further use in vehicles, it is planned to use them in the form of energy storage facilities at bus depots and terminals. They will be charged from photovoltaic cells during the day and will allow the buses to be charged at night.

High quality transport services is not only about comfortable and ecological rolling stock. An equally important aspect is an attractive transport offer. The constantly changing transport needs of passengers must be compared with the financial capabilities of the city as the organizer and the availability of drivers and rolling stock. Electric bus fleet, which is expensive to purchase, should be used as efficiently as possible while taking into account the need to charge traction batteries. Specialized supporting software is used to develop timetables. When designing timetables, it checks the correctness of combining routes into tasks, takes into account the maximum distances between charging and allows for mutual coordination of departures of individual lines. The timetable is modified on an ongoing basis - most often in the case of road investments and road closures, but also based on line load analyses.

The future may belong to a different type of drives. Electric buses may be replaced by hydrogen drives over time. Some of the buses operated by MZK is adapted to change the drive in the future. The dynamic development of Zielona Góra means that more buses will be needed on the streets, and new lines and buses will run on new streets and housing estates. Employees of new workplaces in industrial zones will use public transport as a real alternative to passenger cars, to the benefit of the environment and the health of residents.

## 5. Discussion

The development of electromobility in Poland is one of the key elements of the current economic policy. A special and fastest growing area of electromobility is the public transport market (Kühne, 2010; Ajanovic, Reinhard, 2016; Tucki et al., 2019). It is still important to search for the most perfect solution and obtain the best, lasting effect in public transport (Klucininkas, 2012). According to the Polish Investment and Trade Agency, Bergman Engineering (Electromobility in Poland..., 2021), investments in the electromobility sector are located mainly in the southern and western part of the country, in the following provinces: Dolny Śląsk (12 projects), Śląsk (5 investments).

In the research conducted by Guzik et al. (2021) indicated groups of electromobility innovators in urban transport in Polish cities whose experience was based on trams and trolleybuses. Innovative cities pursued quite an intensive policy of investing in electricity or hybrid fleets (the average share was approximately 20% and was expected to double in the next 2 years). Zielona Góra was the first city to initiate the evolution of second-generation electromobility in public transport in Polish cities (Domański et al., 2016; Taczanowski et al.,

2018). Zielona Góra and Jaworzno are cities that, without previous experience, sought to quickly and completely replace their rolling stock with low-emission vehicles. In Poland in 2022, according to BGK (2023) research conducted on a group of local governments subject to the provisions of the Electromobility Act and several dozen local governments that, although not covered by the Act, have been involved in initiatives aimed at modernizing their public transport in the past (have participated in the Green Transport program). The percentage of all zero-emission buses was 6.6% in the fleets of all local governments covered by the study. The public transport fleet in Zielona Góra consists of 76% electric buses.

The role of the government and local authorities plays an important role in the process of developing electromobility in urban transport. The most important determinants of the development of low-emission public transport in Zielona Góra included, among others: the possibility of obtaining funds from the Cohesion Fund, the Green Transport Program or the Electromobility Act (appropriate energy policy, including striving for a high share of renewable energy sources in the energy mix) and fiscal policy (regulation of EU funds, system of subsidies and incentives for the purchase of low-emission vehicles).

The process of popularizing electromobility in public transport can be treated as the diffusion of technological innovation. Previous work (Taczanowski et al., 2018) identified a positive relationship between the location of the bus manufacturer and purchasing decisions regarding public transport rolling stock. A factor favouring the implementation of electromobility on a national scale was the presence of manufacturers of electric vehicles, chargers and other equipment necessary for the use of this type of vehicles. For example, the Ekoenergetyka-Polska company has been operating in Zielona Góra since 2009, which is an important factor in the development of electromobility in the city. The company is a designer and manufacturer of high-power charging stations for cars, delivery vans, buses and trucks.

Electromobility and its implementation, especially in public transport, is a promising and developing area of research. Further research may be focused on the development, optimization and stabilization of technology in electric urban transport, as well as the methods and determinants of its implementation, especially at the voivodeship and national level. The presented example of the city of Zielona Góra may be an example of good practice for cities where the development of electromobility in public transport is not so dynamic and advanced.

Reliable, up-to-date data on the implemented innovative solutions in urban transport will allow for the identification of barriers to the implementation of this concept and will provide guidance on effective solutions, benefits for public transport organizers, passengers, local communities, as well as guidelines and expected legal and financial instruments catalysing low-emission transport initiatives, especially in small towns.

## 6. Summary

Municipal Transport Company (MZK) Sp. z o.o. in Zielona Góra is currently the most modern public transport company in Poland, whose fleet consists mainly of electric buses. This is possible thanks to completed investments, but also to planned ones. Innovative solutions as part of the implementation of the project entitled: 'Integrated system of low-emission public transport in Zielona Góra' (2014-2020) are the beginning of activities towards the implementation of sustainable development tasks. The research described in the article proves that pro-ecological investments bring measurable effects not only economically (in the form of effective use of rolling stock), but also ecologically (reduced CO<sub>2</sub> emissions) and socially (passenger satisfaction). Passenger satisfaction with the quality of services provided, an increase in the number of passengers transported by 25% compared to 2013 to 2023, water and energy savings are just a few of the measurable benefits.

MZK plans to continue to develop as a modern company. An example is an investment related to the installation of photovoltaic panels on bus roofs or the use of software supporting timetable planning. The authors of the publication intend to continue monitoring MZK and city investments in the implementation of climate neutrality goals.

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## CUSTOMER ORIENTATION AND THE ACTIONS OF ENTERPRISES TOWARDS LOW-EMISSION LOGISTICS IN THE LIGHT OF RESEARCH

Danuta ZWOLIŃSKA

University of Economics in Katowice; danuta.zwolinska@ue.katowice.pl, ORCID: 0000-0003-0960-5826

**Purpose:** The main objective of the article is to identify what actions companies take in the context of customer expectations to reduce CO<sub>2</sub> emissions.

**Design/methodology/approach:** The results will be based on empirical research in the part concerning customer orientation in a research sample of 250 companies. The research was conducted in the first quarter of 2023.

**Findings:** We will indicate the activities that companies are implementing, will be implemented, and those that they will avoid, in order to meet the expectations of environmentally-oriented customers.

**Research limitations/implications:** Facing the green transition, the activities of companies in supply chains are changing dynamically. On the one hand, this is due to the fact that we adapt to changing legal regulations, and on the other hand, because of the expectations of customers. Of course, the year 2050, by which the European Union declared climate neutrality, is not without significance. Therefore, it is necessary to repeat the research presented in this article to conduct a comparative analysis, which may be the source of an interesting scientific discussion.

**Practical implications:** Identification of activities carried out by companies as part of the policy for low-carbon logistics in supply chains. The ability to observe changes introduced by other companies that are important to customers in order to gain a competitive advantage.

**Social implications:** Building awareness of the need to introduce changes in the operations of enterprises by meeting customer expectations in the field of low-carbon emissions. This is due to the fact that not only economic values, but also ecological and social values are increasingly important when deciding whether to buy the offered good / use a specific service.

**Originality/value:** The processes taking place in companies towards low emissions are important for customers, who are paying more and more attention to a pro-ecological lifestyle.

**Keywords:** low-carbon logistics, customer zero, ISO 9001:2015, sustainability.

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

## 1. Introduction

This article is a summary of some empirical research conducted at the Department of Economic Logistics of the University of Economics in Katowice. The research team took up the topic of *Determinants of the development of low- and zero-emission logistics in supply chains and networks* bearing in mind that it is still poorly recognized.

*Low carbon logistics means that the processes of logistics, based on the goals of low energy consumption, low pollution, and low emissions, use the technology of energy efficiency, renewable energy, and reducing greenhouse gas emissions to restrain the harm to environment, which would be also helpful for the purification of the logistics environment and get the full use of logistics resources* (Zhang et al., 2014).

In the first part of the research, the author analyzed the rationale for the implementation of low-emission logistics and indicated the reasons why the decision to adapt to changes that contribute to the reduction of CO<sub>2</sub> emissions is prolonged over time (see Zwolińska, 2023).

This article focuses on activities related to low-emission logistics in the surveyed enterprises, which are influenced by current and potential customers, along with an indication of the degree of their impact. It will also indicate the activities that companies are implementing, will be implemented, and those that will not be undertaken to meet the expectations of pro-ecological customers.

The research was conducted in the first quarter of 2023. The tool used was an electronic questionnaire supported by phone. A total of 250 companies were surveyed. In Poland, there has been no extensive research on the development of low-emission logistics in supply chains so far, which was an interesting research gap from a scientific point of view. One of the aspects discussed in the above-mentioned empirical research was the rationale for the implementation of processes related to low-emission logistics in supply chains, including customer orientation.

## 2. Customer orientation

The turbulence of the environment has caused modern companies to adjust their strategies in the fight for customers so as not only to meet their needs on an ongoing basis, but also to keep them in the status of "regular customers". This is not easy as the new generation of consumers, the so-called zero consumers, pay special attention to their own health and environmental issues, and at the same time they are a very selective and disloyal group. Although it should be noted that when making purchasing decisions, they are not always ready to pay more for a product with the ECO mark (see more: Kong et al., 2014; Hang, Fong, 2010; Biswas, Roy, 2016). These consumers meticulously check whether a given company has



a policy of sustainable development and cares about the environment (see RP, 2023; Ricci, Banterle, 2020).

Customers expect companies to provide them with 7W (7Right) operations, i.e. access:

- to the right product,
- in the right amount,
- in the right conditio,
- in the right place,
- at the right time,
- for the right customer,
- at the right cost.

On the other hand, companies more and more often declare and expose a pro-quality attitude and, as a consequence, implement the ISO 9001:2015 standard, which in its main part includes: organizational context, leadership, planning, support, operational activities, performance evaluation and improvement. On the other hand, the principles of quality management in the above-mentioned standard include:

- customer orientation,
- leadership,
- involvement of people,
- process approach,
- improvement,
- subtracting decisions on the basis of evidence,
- relationship management.

Thus, when analysing the requirements of ISO 9001:2015, one can see that one of its main requirements is customer orientation (Chapter 5). In this respect, the standard focuses on:

- maintaining increased customer orientation,
- identifying and taking into account the risks and opportunities that affect the compliance of products and services,
- customer's requirements to be understood and consistently met.

Analyzing the ISO 9001:2015 standard, it can be concluded that the primary goal of quality management is to meet customer requirements by creating value for them.

The European Foundation for Quality Management has developed the EFQM Excellence Model, which enables entrepreneurs to self-assess their customer satisfaction as well (Dima, Vitzilaiou, Glykas, 2022). *The EFQM Excellence Model assumes the existence of three levels of excellence, which correspond to a three-level program of awards and distinctions. By conducting a self-assessment, organizations can place themselves on one of three levels, and the existence of levels of excellence is a stimulus for further improvement* (Brajer-Marczak, 2016, p. 13). The recognized levels of excellence are: Committed to Excellence (C2E), Recognised for Excellence (R4E) and Excellence Award (EEA).

As noted by Widelska U. (cf. Widelska, 2020, pp. 4-5) *Customer orientation is part of the concept of the value chain, thus going beyond the buy-sell relationship (...)*. The concept continues to evolve and today's customer orientation is determined by:

- *Changing the role and behaviour of consumers – the consumer is becoming more and more active and has the opportunity to interact more closely with the company, boldly expressing their opinions and expectations using social networking sites.*
- *development of mobility – universal and unlimited access to the Internet enables the exchange of information on a global scale.*
- *the use of additional tools to monitor consumer behaviour.*
- *the widespread use of CRM systems that provide up-to-date knowledge about customers.*

As already mentioned, zero consumers are focused on price and quality, but companies need to demonstrate that they care about the health and well-being of people and of the planet. If two brands are similarly priced, the zero consumer will buy the one that markets itself as sustainable or purpose oriented. According to a recent study of US consumer spending by McKinsey and NielsenIQ, products with environmental, social, and governance (ESG)–related labels (such as "eco-friendly", "vegan" or "plastic free") had higher sales growth than products that made no ESG-related claims on their packaging (Das, Kalia, Kuijpers, 2023).

Therefore, from the researcher's point of view, it was interesting to analyze the activities carried out by enterprises in the context of customer expectations in terms of reducing CO<sub>2</sub> emissions.

### **3. ANALYSIS OF RESEARCH RESULTS**

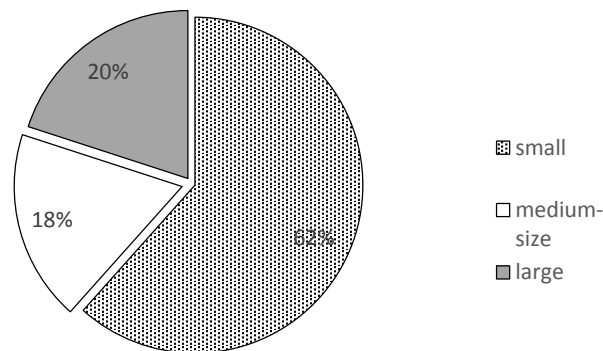
The empirical research, which included 250 enterprises, was conducted in the first quarter of 2023 using an electronic questionnaire assisted by phone. The structure of the surveyed group of companies is as follows:

- Subgroup 1-200 small and medium-sized enterprises.
- Subgroup 2-50 large enterprises.

It should be noted that within the individual subgroups, the selection to the sample was quota-based, taking into account the dominant type of activity conducted according to the Polish Classification of Activities (PKD). This means that the sample within subgroup 1 reflected the structure of the general population of small and medium-sized enterprises and within subgroup 2 large enterprises operating in Polish.

As part of the analysis of the research results, the methods of descriptive statistics (including measures of the structure of collectivity and interdependence of phenomena) and statistical inference were used.

The group of respondents was dominated by owners and representatives of senior and middle management – a total of 60% of respondents. On the other hand, 40% of the respondents were people who held specialist positions in these companies.

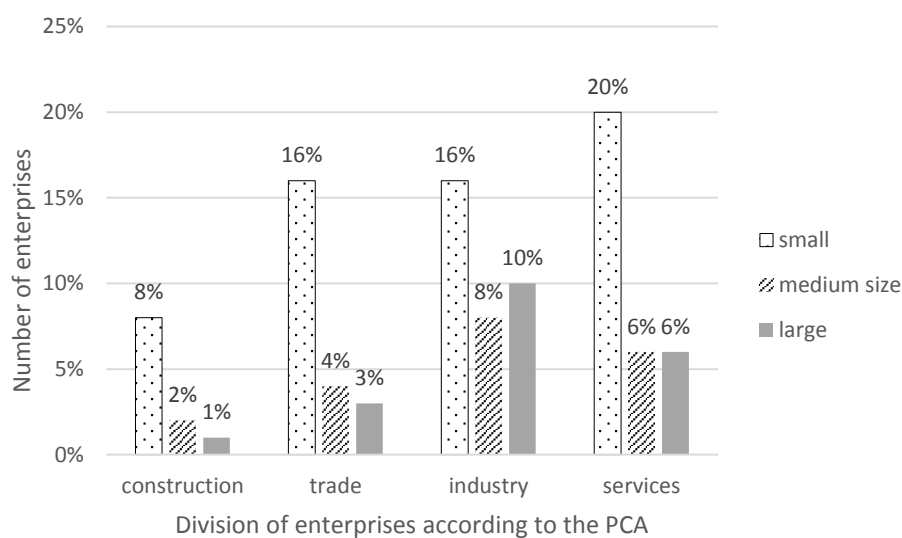


**Figure 1.** Company size.

As mentioned earlier, 250 enterprises were surveyed, of which 80% were enterprises employing between 10 and 249 people and 20% were enterprises with 250 or more employees (Figure 1).

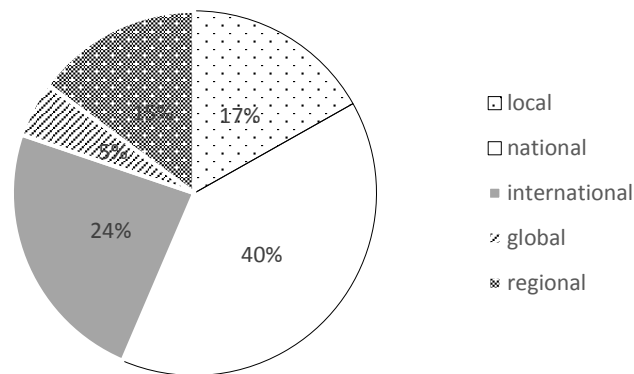
The structure of the surveyed enterprises, taking into account the PKD code sections in accordance with the principle adopted by the Central Statistical Office (GUS, 2023, p. 22), is as follows: Figure 2.

The following sections have been assigned to the term "industry": B, C, D and E – "industry", in addition, section F – "construction", G – "trade", from H to S – is included in a joint category under the name "services". 34% (86 entities) of enterprises were classified in the industry category, 11% (21 entities) in the construction category, 23% (57 entities) in the trade category and 32% (80 entities) in the services category.

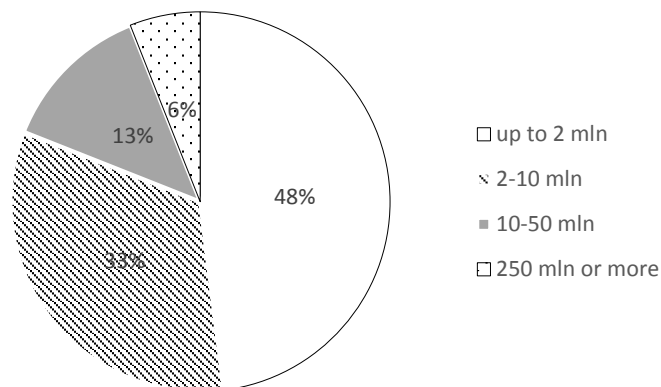


**Figure 2.** Structure of the surveyed companies.

The geographical scope of the respondents included companies from the local, regional and national markets, which accounted for 72%, i.e. 179 entities, and the remaining 28%, i.e. 71, were companies with an international and global reach (Figure 3).

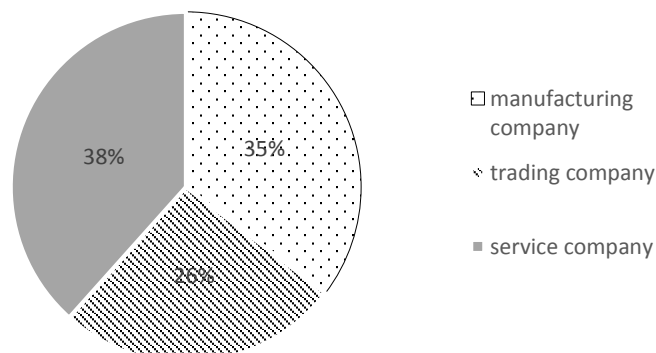


**Figure 3.** Geographical scope of the company.



**Figure 4.** Annual net turnover (in Euros).

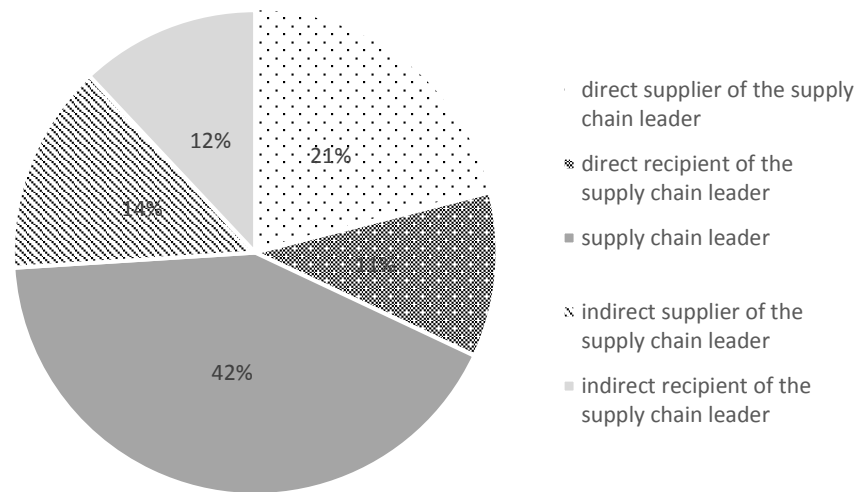
Respondents also commented on the annual net turnover (in euros). These results are shown in Figure 4. Nearly half of the surveyed companies declare a turnover of up to EUR 2 million, 33% (82 entities) a turnover of up to EUR 10 million, 13% (33 entities) a turnover of up to EUR 50 million, and the remaining 6% (15 entities) of EUR 250 million and more.



**Figure 5.** Type of company.

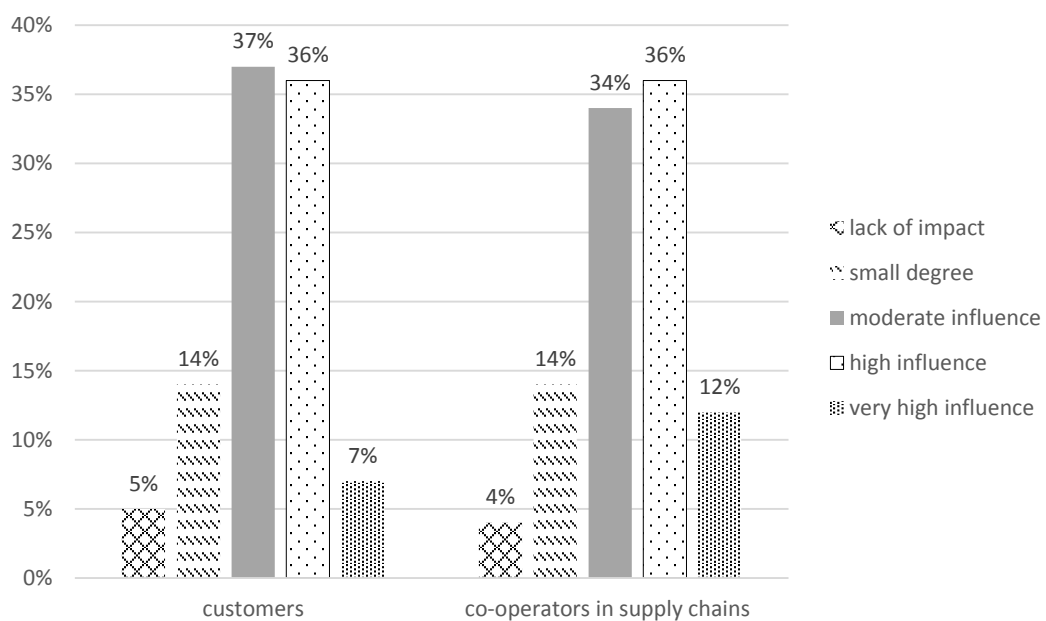
The study concerned 35% (88 entities) of manufacturing enterprises, 26% (66 entities) of commercial enterprises, and 38% (96 entities) of service companies (Figure 5).

Respondents were also asked about their position in the supply chain. The results are as follows: 14% (36 entities) are indirect suppliers of the supply chain leader, 21% (52 entities) are direct suppliers of the supply chain leader, 42% are supply chain leaders (105 entities), and 11% (27 entities) are direct recipients of the supply chain leader, indirect recipients of the supply chain leader 12% (30 entities) (Figure 6).



**Figure 6.** Position in the supply chain.

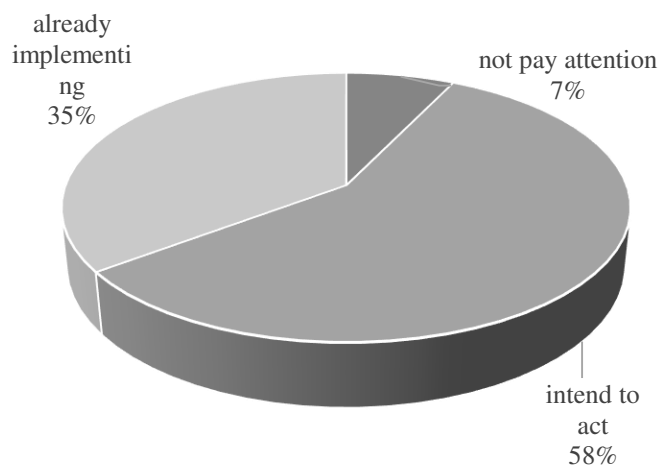
As part of the study, the surveyed representatives of 250 business entities were asked about the potential impact of the requirements of customers and partners in supply chains on decisions to implement technology that reduces CO<sub>2</sub> emissions.



**Figure 7.** Assessment of the potential impact of customer and co-operator requirements in supply chains on decisions to implement technology that reduces CO<sub>2</sub> emissions.

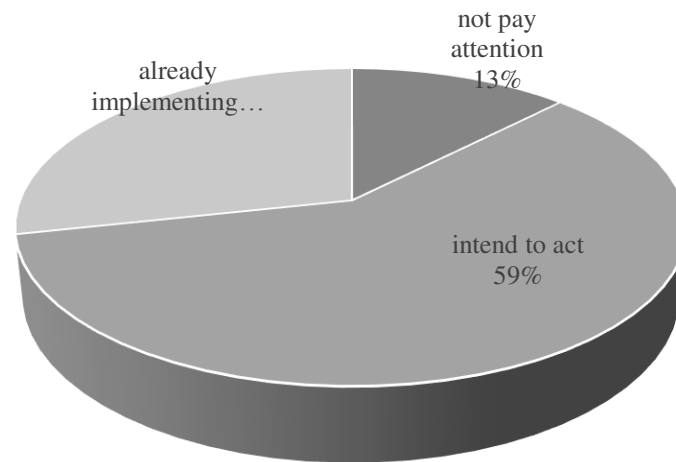
As we can see, both for the customers and supply chain partners, the answers are very similar. The strength of customers' influence to a small degree or lack thereof accounted for 19% of customers and 18% of cooperators, moderate influence of 37% and of cooperators 34%, high and very high influence of customers 43% and co-operators 48%. Therefore, regardless of whether it is a stakeholder of the supply chain or an end customer, companies take their opinions into account because the cooperators can use pressure to implement technology that reduces CO<sub>2</sub> emissions, e.g. due to the formal requirements of cooperation. In the case of customers, there is an increasingly conscious approach to the purchasing process.

The next question concerned the attitude of the respondents to caring for the image of the company as the one that operates in accordance with the principles of sustainable development. The premise for this question was the research conducted by A. Rudnicka (2018, p. 104), who states that: *the websites of companies did not contain information about activities undertaken in such currently developed areas of logistics as e.g. low-carbon warehousing or, more broadly, energy efficiency. There was also no indication of how to build relationships as part of improving environmental performance in the supply chain.*



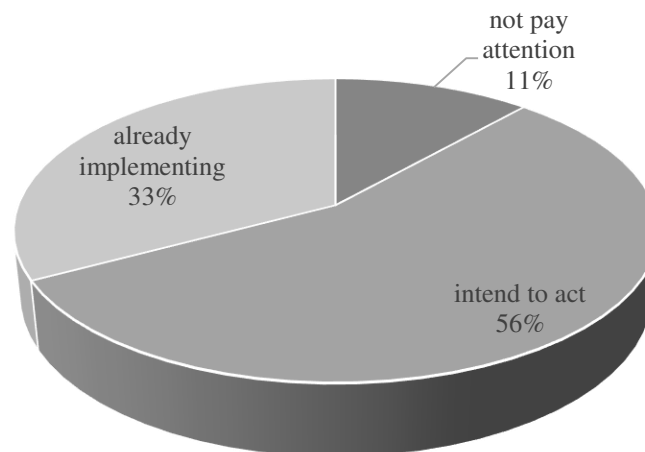
**Figure 8.** Sustainability.

58% of companies declare that they intend to act in accordance with the principles of sustainable development, and in 35% they are already implementing this policy. Only 7% of companies will not pay attention to this fact, probably due to the scope of services they provide or the sale of products that are basic goods and their purchase by the customer is necessary to satisfy them. Moreover, as Wilk I. (2018, p. 640) points out, not all pro-ecological activities will be externalized by enterprises, as *they try to be a "good corporate citizen" in the area of environmental protection, but do not focus on publicizing and promoting their pro-ecological initiatives. Instead, they aim to reduce costs and improve efficiency through environmental measures, thereby creating a cost-based competitive advantage.*



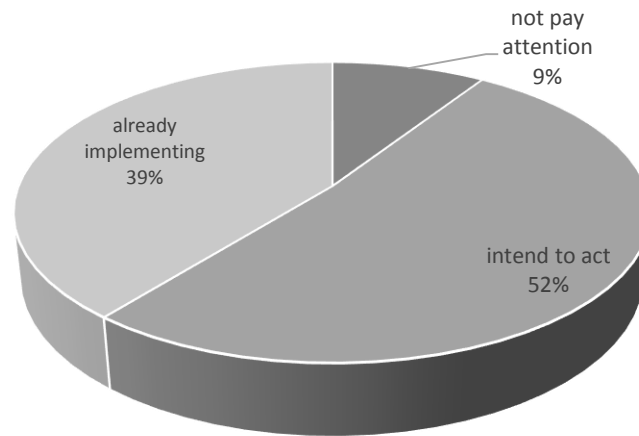
**Figure 9.** Building a community around the brand (focus on pro-ecological behaviors).

*A modern brand is a creative difference that symbolizes a person's self-image and about the environment, allowing them to strengthen their aspirations and dreams, provoking them to think* (Rybak, 2017, p. 40). Thus, 78% of the surveyed companies admit that they are implementing or intend to implement in the near future activities in the field of building relationships with external stakeholders in order to build a community around a brand that is pro-environmentally. Only 13% said they would not implement the above-mentioned activities.



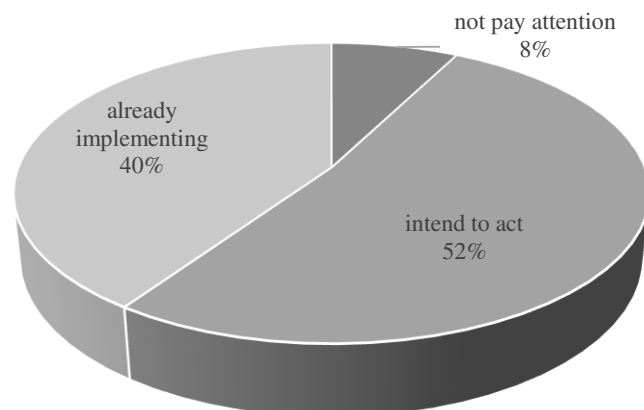
**Figure 10.** Packaging made of eco-friendly and biodegradable materials.

As mentioned earlier, customers are paying more and more attention to the pro-ecological behavior of producers, on the other hand, as Kaźmierczak M. points out *The concept of a green supply chain, which is actually difficult to achieve, is based on the assumption of "zero waste". To this end, the design of products assumes maximum use of materials and the possibility of their reuse by means of recycling, giving the products a "second life"* (Kazmierczak, 2022, p. 20). Therefore, the respondents were asked whether they use packaging made of ecological and biodegradable materials in their products. 89% of respondents already implement and will use such packaging, while 11% indicate no action in this area.



**Figure 11.** Reduction of paper documentation.

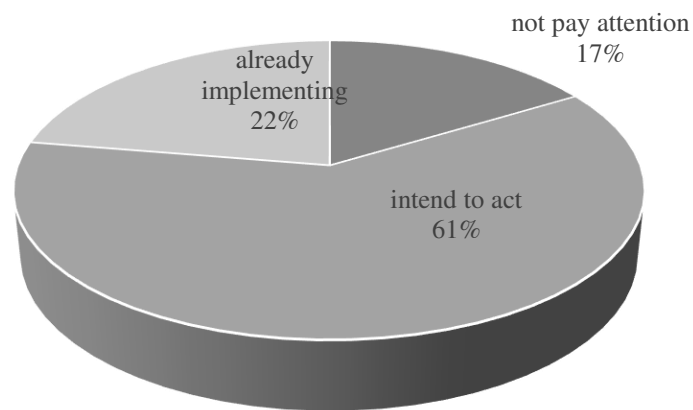
Taking into account the fact that *e-logistics in the company makes the flow of information between manufacturers, suppliers and customers better and faster. It contributes to shortening the supply chain, and thus accelerating the achievement of the intended plans and profits* (Tokarski, Grodek, 2023, p. 13) respondents were asked about reducing paper documentation and switching to electronic documentation, which is associated with low emissions. 91% of respondents declare that they will be implementing activities in this area in the near future or are already implementing them. Only a small percentage of 9% of respondents report a lack of action in this regard (Figure 11). This lack of action may be due to the policy of the top management, the lack of knowledge about these activities of the respondent or small savings in relation to the total costs of running the business.



**Figure 12.** Using environmentally friendly materials.

The European Commission points out that the inclusion and use of environmentally friendly materials in production should take place in all phases of the product life cycle. In other words, companies should act in an environmentally friendly way in each of the phases in which they can. Thus, the respondents were asked whether their companies use environmentally friendly materials (Figure 12) and the respondents indicated in 8% that they would not take action in this area.





**Figure 13.** Informing customers about changes in CO<sub>2</sub> emissions implemented in the company.

It is good practice for companies in the context of climate change to inform their customers about their activities that contribute to the reduction of greenhouse gas emissions. Undoubtedly, this translates real pro-environmental changes into image-building activities. Therefore, the respondents were asked whether they inform customers about changes in CO<sub>2</sub> emissions in the company.

83% of respondents inform or intend to inform customers about activities related to the change in CO<sub>2</sub> emissions, while 17% do not anticipate such activities (Figure 13).

#### 4. Summary of the research results

This article describes part of a larger research project focusing on the development of low-emission logistics in supply chains may constitute the basis for enterprises to compare their activities with those performed by the enterprises participating in the research. In Poland, there has been no extensive research on the development of low-emission logistics in supply chains so far, which was an interesting research gap from a scientific point of view. A total of 250 companies were surveyed.

Companies' efforts towards low-carbon logistics in supply chains undoubtedly depend on many factors, e.g. legal regulations, the requirements of suppliers in the supply chain, high and volatile energy prices, as well as high initial costs. Of course, it should be remembered that, as with other processes taking place in a company, in this case the Pareto principle should be applied, according to which only 20% of satisfied customers generate 80% of the profits. They are the source of profits for the company and have a real impact on the changes taking place in it.

On the basis of the conducted research, the respondents declare to the greatest extent the achievement of the goal of caring for the image of a company operating in accordance with the principles of sustainable development. However, these must be real actions so that the declarants are not accused of the so-called green washing (Gatti, 2019; Nyilasy, Gangadharbatla, Paladino, 2014; Aji, Sutikno, 2015), i.e. by using, for example, eco signs not necessarily implemented in the company. The good news for customers is the fact that the European Commission has announced a draft Green Claims directive in which companies will bear the consequences for green washing, i.e. fines, confiscation of sales revenues as well as temporary exclusion from participation in tenders. Moreover, regardless of whether it is a stakeholder of the supply chain or an end customer, companies take their opinions into account because the cooperators can use pressure to implement technology that reduces CO<sub>2</sub> emissions and inform customers about their activities that contribute to the reduction of greenhouse gas emissions.

To sum up, it should be crucial for companies to act towards a low-carbon economy, prioritizing achieving ecological efficiency due to climate change, as well as following the change of customers and their attitude towards environmental protection. On the one hand, this is due to the fact that we adapt to changing legal regulations, and on the other hand, because of the expectations of customers. As can be seen in this research, environment pollution affected behavioral patterns and therefore companies need to keep pace with the changes that have occurred. Companies can also implement these exceed the growing demands of customers to gain a competitive advantage.

Research should be expanded. The research did not take into account a wider context related to Corporate Sustainability Reporting Directive and ESG reporting activities, it will be discussed in the next article.

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## **REVIEWERS**

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Prof. **Grzegorz GLÓD**, Economic University in Katowice, Poland

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Phd **Judyta KABUS**, Czestochowa University of Technology, Poland

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