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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 20 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: human resource management, Industry 4.0, economics, production management, knowledge management, quality management, public management and Smart City.

Radosław Wolniak

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2023
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COLLABORATIVE CONSUMPTION: PROPENSITY OF GENERATION 'Z' TO SHARE PRODUCTS (CASE IN POLAND)

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Purpose: The aim of the article was to examine Generation Z's propensity to share products in the context of the growing trend of collaborative consumption in the Polish market.
Design/methodology/approach: The objectives were achieved by conducting a theoretical review of the sharing economy, complemented by direct research on the propensity of young consumers to share selected products. The study was conducted using an online survey technique among 600 Polish consumers from generation 'Z' in 2023.
Findings: The research results indicate various motives driving Generation 'Z' towards collaborative consumption, encompassing economic, social, and environmental aspects. They also reveal the types of products this generation is more likely to share.
Research implications: In the future, it would be interesting to expand this research to include other countries (e.g. in Europe), different demographics (e.g. seniors), and the role of various factors influencing product sharing (e.g. social media, education).
Social and practical implications: The findings of this article contribute to understanding consumer trends among young people, which influence the behavior of future generations and demonstrate a concern for sustainability. They underscore the importance of educating young people about pro-environmental behavior, crucial for a sustainable future. The results provide insights into young people's propensity for pro-environmental actions and highlight the potential need for education in this area. Additionally, these findings can be valuable for enhancing the effectiveness of sales processes and methods businesses use to communicate with young consumers.
Originality/value: This article presents a unique contribution to the field of consumer behavior by specifically focusing on Generation 'Z' in the Polish market, a demographic often overlooked in collaborative consumption research. Its originality lies in its comprehensive examination of the multifaceted motives (economic, social, and environmental) that drive this generation towards shared consumption.

Keywords: collaborative consumption, sharing product, generation 'Z', Poland.

Category of the paper: research paper.

1. Introduction

In recent years, collaborative consumption has been at the heart of sustainability. "Sustainable development" was written in the Brundtland Report (1987, p. 16) and stressed the need to meet the needs of present generations without limiting the ability to meet the needs of future generations. To this day, the importance of the three dimensions of sustainable development, namely ecological, economic and socio-cultural, is underlined. Sustainable development is about conscious and sustainable consumption, i.e. consumption that saves resources.

In the concept of sustainable development there is room for collaborative consumption. Conscious and responsible consumption is one of the activities (directions) of the Green Economy. The aim of this course is to reduce environmental risks and the consumption of natural resources. In its document COM(2019)640 the European Commission proposes - in line with the assumptions of the Green Economy - increasing productivity while using fewer raw materials, reducing costs and reducing environmental impact. (http://ec.europa.eu/ environment/basics/green-economy/sustainabledevelopment/index _pl.htm). A decisive aspect of the definition of the Green Economy is the scarcity of resources. Resources are scarce and therefore consumption choices have to be made. This means at the same time giving up on other, less important, needs (Ryszawska, 2013; Spangenberg, 2014).

The concept of collaborative consumption is based on the scarcity of resources in order to develop a sustainable approach to their use and product sharing. The concept of sustainable consumption also draws inspiration from one of the latest economic trends, the sharing economy. This economy is based on the possibilities of new technologies of distance communication. With the development of the Internet, people are able to communicate with each other faster and more efficiently. Collaborative consumption is a form of green consumer mobilization. Product sharing, which began a few years ago, first in the United States, is spreading to other countries and involves a growing range of consumer products and services. For several years, we can observe a growing interest of the young generation growing ecological awareness. People born after 1995 belong to generation 'Z'. This generation has a stronger interest in sustainable consumption than previous generations. Ecological sensitivity is a characteristic of this generation, which affects their participation in product sharing.

In the interpretation of collaborative consumption, important are ecological aspects. In this perspective, the focus is primarily on issues related to the use of resources so as not to violate the well-being of the environment, but to ensure an adequate quality of life (Spodarczyk, 2018, p. 78). Collaborative consumption is a fundamental trend shaping individual consumer behaviour patterns (Bylok, 2013). The paradigm of this consumption is conscious consumption based on environmental responsibility. Consumers in sustainable economies are (should be) aware of their purchasing decisions (Jaros, 2015). The conscious consumer exposes in his

behavior characteristics such as: sufficiency of consumption, self-restraint, consumer abstinence, reduction of waste when meeting needs, sharing products, recovering products, repairing products, etc. (Czaja, Becla 2011, p. 48). In this consumption there is an important ecological aspect, which is to maximize the usefulness of consumption while preserving the usefulness and quality of natural resources and the natural environment. Sustainable development policies prefer forms of consumption that are least harmful to the environment (Kiełczewski, 2004, p. 57-58; Łuczka, 2016, p. 139).

The umbrella for the conscious consumer is the determinants of sustainable consumption. Under this umbrella are human needs, as well as fair distribution of goods and services, quality of life, resource intensity, waste minimization, product lifecycle thinking, consumer health and safety, consumer sovereignty, and collaborative consumption (Mont, Plepys, 2008).

Demographic, social, political and economic changes are shaping new consumption trends. This trend is collaborative consumption among Generation 'Z'. New trends shaped by Generation Z are conditioned by an increase in education, health education, the effect of imitating the lifestyle of reference groups, an increase in the quality requirements of consumers reported in relation to the offer of goods and services on the market, higher ecological sensitivity than other generations, etc. It should be noted that an important prerequisite for the spread of collaborative consumption among the 'Z' generation is the development of information and communication technologies, which facilitate the matching of supply and demand for 'free' goods and services. Increasingly widespread consumer access to the Internet, social networks, the possession of modern mobile devices and access to online payment systems enable collaborative consumption initiatives. The rapid development of computer technologies (ICTs) and the Internet is a determinant of collaborative consumption. Technology has an impact on the creation of collaborative consumption platforms.

Collaborative consumption has been growing over the last decade with the development of the Internet and computer technologies (ICTs). Mobile devices are used for communication in collaborative consumption. The group of computer and mobile device users is increasing along with access to the Internet and computers. According to data, there were already about 1.5 billion users worldwide in 2010. By 2020, there were 4.66 billion, or 59.5 per cent of the population - using the Internet. In the last decade, the number of Internet users has increased by more than 3 billion users. Young people belong to generation 'Z' use the mobile devices often then aothers. More and more people are spending their time online, doing more things there than ever before (the average internet user spends 6 hours and 43 minutes online every day, or more than 100 days a year and more than 40% of their life (Digital Report, 2020). In modern society, the collaborative consumption very often start from contact by Internet, where people inform what they need.

Collaborative consumption involves making connections between strangers, through different forms of communication, in order to participate in the exchange of products (Schor et al., 2014, pp. 4-6; Schor, 2014). Many countries have exchange platforms, e. g. pet care,

exchange of expensive electronic equipment, renting a bike, surfboard, snowboard (Spinlister), exchange of prepared food, WiFi network, exchange of work done, car sharing, neighbourhood help, home repair services, etc. (Camilleri, 2021; Kumar et al., 2020).

The aim of the article is to draw attention to the approach of Generation 'Z' to the concept of collaborative consumption and lending of products. Collaborative consumption is supposed to refer to the concept of sustainable development and provide an alternative to consumerism. Sharing products by individual consumers can help to reduce the negative effects of mass consumption.

This paper consists of two key sections. The first part of this paper presents the concept of collaborative consumption and compares it with the consumer attitudes of Generation 'Z'. The second part of the paper presents the results of direct research. The orientation of consumers – Generation 'Z' – towards collaborative consumption is a phenomenon that is the subject of research. The study was conducted in Poland among 600 representatives of Generation 'Z' in 2023. The survey questionnaire was used as a research tool.

Such research questions (RQ) were stated:

RQ1: What are the main attributes of Polish Generation 'Z'?

RG2: What the most popular attitudes of Generation 'Z' consumers towards diverse market phenomena, life, environment, ecology and sharing?

RG3: Which benefits motivate Generation 'Z' consumers to engage in product sharing?

RQ4: What are the preferences of Generation 'Z' consumers for sharing selected products?

2. Collaborative consumption vs Generation 'Z'

Today, consumption is the use of material goods and services to satisfy human needs, as well as a determinant of the standard of living and a criterion of the structuring of society and a way of communicating the identity of individuals (Sobczyk, 2014, p. 88). Changes in the market for consumer goods lead to positive as well as negative social, economic and cultural phenomena. In recent years, worldwide, including in Poland, consumption known as collaborative consumption has grown in strength and importance. It is a consumer response to global environmental and social problems. Collaborative consumption is part of sustainable development and a form of organic consumption (Bylok, 2016; Łuczka, 2016). The goal of collaborative consumption is to reduce external negative environmental effects. Collective consumption is also referred to as "consumer cooperation", "cooperative consumption" or "collaborative consumption, sharing economy". Collective consumption is a model of consumption based on free and paid sharing, resale, exchange and lending of goods and services (Sobczyk, 2014, p. 100). The point of this idea is to save money on the purchase of new items. Moreover, this consumption is geared towards more rational use of products and flexibility in

meeting consumer needs. The market of collaborative consumption, exchange of goods, displaces property, creates temporary property, has recently been developing particularly dynamically in the USA, where the subject of trade are real estate (e.g. converting holiday homes, renting accommodation), cars, sports equipment (Mróz, 2013, p. 147).

Collaborative consumption is one of the consumer initiatives that fits into the form of the sharing economy. The forms of this economy are: sharing, bartering (from barter), lending, renting, recycling, do it yourself, open gardening, (visiting in private gardens), voluntary help, shareownership, repairing, common buying (Słupik, 2015). Collaborative consumption is a form of social movement against excessive consumption. It is one form of de-consumption. Deconsumption on the one hand (Zrałek, 2012) and collective consumption on the other. Opposite trends are emerging, focusing on de-consumption and a move away from hyper-consumption. Sharing consists in consciously and purposefully limiting the volume of goods consumed. It is simply consumption based on sharing products. Moreover, collaborative consumption is an alternative lifestyle: this approach involves promoting a new lifestyle, contrary to consumerism (Kryk, 2011). This consumption forms part of a holistic approach to sustainable consumption, which takes into account social and economic aspects as well as environmental aspects.

The benefits of the decision to share products are, on the one hand, for the environment, on the other, for the consumer himself, his budget and even well-being, as well as for the local community in which he functions (building social bonds). There is also a cost aspect to collaborative consumption, sharing is cheaper than the price of new products. Consumers are consciously giving up on previously purchased products in favour of sharing. Sharing products is an alternative to buying more products. Collaborative consumers are also aware of the costs they incur in making decisions consistent with the adopted attitude (Spodarczyk, 2018, p. 79).

Collaborative consumption changes its course: from a grassroots initiative to an organized one. In order to fully exploit the potential of sharing, it is necessary to combine spontaneous social practices with sustainable development programs for cities and municipalities. Incorporating collaborative consumption into policies means integrating social activities and embedding product sharing practices in the political and legal order. The implementation of collaborative consumption patterns by households requires active state policies tailored to specific national, regional and local conditions.

An important direction in terms of efforts to increase the role of this consumption in economies seems to be an emphasis on increasing social awareness aimed at saving products and thus the resources needed to produce them (Seyfang, 2009). Consumer awareness is shaped by generally accepted social norms, information in the mass media, formal and informal environmental education and government actions. The main function of awareness in collaborative consumption is to enable other consumers to use a product without having to buy a new one, especially when the product is seldom used (consumed). Conscious consumers are adjusting their needs and shopping habits and are increasingly choosing sharing products.

Through their choices, they influence manufacturers and somehow force changes in product life cycles (Słupik, 2015).

The noticeable trend towards decreasing consumption among some groups of society is due not only to the fad for a healthy, economical lifestyle. Such behaviour is also stimulated by recession and fears of its consequences, dematerialization of consumption, increasing qualitative aspirations in consumption, lowering of the status of consumption in the system of human values, protection of natural resources (Bywalec, 2007, p. 151; Dąbrowska et al., 2015).

The importance of this consumption for Generation Z is linked, on the one hand, to an increase in environmental awareness and, on the other hand, to an increase in environmental responsibility. Being a responsible consumer means being aware of the consequences of their decisions, wanting to limit their negative effects and, as a result, reaping the benefits of doing so.

The way Generation 'Z' is defined, and in particular the range of birth years attributed to it, varies depending on the type of source. However, the most common assumption in research is that Generation Z is generally composed of people who were born from 1995 to 2010, choosing this range due to different consumer experiences, such as new technological developments, socioeconomic trends (Jaciow et al., 2021; Dimock, 2019; Ismail et al., 2021).

Although the term "Generation Z" has no formal basis, it is widely accepted and used. In addition, other names are also used to highlight the age group's deep ties to new technologies, especially the internet and mobile devices. These terms include Digital Natives, iGeneration, Screeners, Selfie Generation (Grabiwoda, 2019). Studies also sometimes use the term "Generation C", which refers to the word connected, thus indicating a constant connection to the network of this group of consumers (Aniszewska, 2015).

In 2020, Generation 'Z' accounted for about 1. 3 billion young people worldwide (EY Report, 2021) and includes people between the ages of 14 and 24. EY's research shows that Generation Z is different from previous generations (especially millennials growing up during the economic boom). Generation Z formulated its identity during the Great Depression, then the global pandemic. This generation has also experienced growing political polarization in a world dominated by digital technologies such as smartphones, social media and the constant flow of information. Faced with an unpredictable global economy and the challenges of climate change, this generation must adapt to a rapidly changing technological world. This requires them to develop new skills and ways of thinking that will be adapted to new contexts and shaped by their educational experiences.

Generation 'Z' is characterized by distinct preferences and behaviours in terms of: technology used (dominant: MacBook, iPad, Facebook, Twitter, Wiki, Android), factors influencing them (primary sources of information and inspiration are: online forums, online communities), trends and values in education (their learning styles are based on multimedia, multiculturalism, e-learning, interactivity), leadership approaches (referring to inspiration, creativity, financial management (prone to impulse purchases, especially online, getting into

debt) and response to marketing communication (preferred interactive and new media campaigns, engaging in digital marketing) (Mazurek-Lopacińska, Sobocińska, 2015; Aniszewska, 2015, www[1]).

Generation 'Z' representatives have specific characteristics in terms of consumption that are closely related to their technological, educational and social experiences (Mazurek-Łopacińska, Sobocińska, 2015, p. 146). Very good knowledge of the latest gadgets and technologies influences their way of consumption, preferring products that are technologically advanced and easily available online. They base their purchasing decisions on online reviews, forum discussions and social media recommendations. They choose products and services that are consistent with the values conveyed by educational applications, online courses and products that support multiculturalism. The generation is characterized by mobility, openness to other cultures and willingness to experiment. She prefers teamwork and diversity, avoiding routine and career stability. They are capable of multitasking, but have difficulty concentrating on a single task. This generation expects personalization and values experience more than material possessions, while demonstrating ecological awareness and social responsibility (Hysa, 2016, p. 389). Understanding the unique characteristics and conditions in which Generation Z grows up is key to predicting their impact on future social, economic and technological trends. Their adaptability, digital literacy and early experience may have long-lasting implications for how future societies, labour markets and the forms and ways of consuming goods and services are shaped (EY Report).

Growing up in the digital age and facing global challenges such as climate change and economic uncertainty, Generation 'Z' tends to seek more sustainable and flexible forms of consumption. Sharing products and services responds to their needs for sustainable living and flexibility, while offering an alternative to traditional ownership models.

3. Research approach

In the context of the increasing trend of collaborative consumption in the Polish market, direct research was conducted to understand the propensity of young consumers to participate in the sharing economy.

The survey was conducted in 2023 (September - October), utilizing an online survey method with a sample of 600 Polish Generation Z consumers. Participants in the study were born between 1995 and 2009. The age distribution within the sample was maintained. The link to the questionnaire was made available on the "Webankieta" page and disseminated through the most popular websites, social media, and email targeting young people (born after 1995). In this

[1] Generations defined, Mccrindle Research, www.mccrindle.com.au/app/uploads/2018/03/Generations-Defined-Sociologically.pdf, 12.12.2023.

study, respondents were selected using a non-random selection method and the selection criterion was age. Consequently, nearly 800 respondents participated, out of which 600 fully completed questionnaires were qualified for further statistical analysis. The average time taken by the respondents to complete the questionnaire was 11 minutes.

The online survey questionnaire was constructed primarily of closed-ended questions and those containing measurement scales. Respondents, while answering the questions, had the option to select one or several responses, but they could continue with the questionnaire while skipping any question, and they were not able to return to questions to which they had already responded. Additionally, they were only permitted to participate once in completing the questionnaire.

In the research sample, 64.2% of the participants were women, and 35.8% were men. The respondents were aged between 14 and 28 years, with an average age of 20 years. The largest group of respondents was 19 years old, accounting for 23.5%. Almost the same number of respondents declared that they were either working or not working professionally. For those not working, the primary source of income was pocket money from parents (40.8% of respondents). One-third of the respondents came from a four-person household, and one-fifth from a three-person household or larger than five-person household. Most of the respondents who were students reported living with their parents in an apartment/house (60%), while others rented an apartment or a room (18.3% and 8.5%, respectively), 6.1% lived in student dormitories, and 7.1% in their own apartment. Over 3/5 of the survey participants rated their household's situation as "very good" and "good", while 1/3 rated it as satisfactory. Table 1 presents an overview of the characteristics of research samples.

Table 1.
Characteristics of research sample (N = 600)

Item			**in %**
Gender	women		64.2
	men		35.8
Age	minimum	in years	14.0
	maximum		28.0
	average age		20.0
Activity professional	working		49.8
	not working		50.2
Income source	work		49.8
	scholarship		4.7
	pocket money from parents		40.8
	pocket money from others		4.7
Number of household members	1 person		3.6
	2 persons		11.8
	3 persons		25.4
	4 persons		34.2
	5 persons and more		25.0
Residence status	with parents		60.0
	rent an apartment		18.3
	rent an room		8.5
	in student dormitories		6.1
	own apartment		7.1

Cont. table 1.

Self-assessment of the material situation	very good	14.1
	good	48.2
	sufficient	33.1
	bad	3.6
	very bad	1.0

Source: own study.

The propensity of Gen 'Z' consumers to share a variety of products was examined using data analysis software - SPSS Statistics. The attitudes of consumers towards the growing trend of shared consumption and the tendency to share selected products were examined using a 5-step measuring scale – Likert. The Likert scale motivated respondents to identify their characteristics by choosing one of two opposing options. The scale used was considered reliable (internal consequence acceptable) because the Cronbach alpha value was 0.77 (George, Mallery, 2016, p. 240).

4. Propensity of Generation 'Z' to share products in Poland - results of direct research

This research was aimed at recognizing the Polish Generation Z's propensity to share selected products, focusing specifically on identifying the following: psychographic characteristics of Generation Z, the perceived benefits that would motivate them to share products, and the respondents' preferences for sharing different types of products (such as borrowing from someone, lending to someone, and group purchasing).

Complementing the demographic and social profile of Generation 'Z' consumers is a collection of personality traits researched in Poland (an element of their psychographic profile). On a five-point intensity scale, the respondents evaluated the extent to which the specified traits apply to their personalities.

Researchers from Generation 'Z' assessed their personality traits. All average scores of the listed personality traits are above 3.15 (rather positive). The study participants rated loyalty the highest (average 4.58), and trust in others the lowest (3.15). Respondents also rated their resourcefulness highly (4.14). Studies show that the largest percentage of respondents are characterized by loyalty, resourcefulness, assertiveness and innovation (Table 2).

Table 2.
Personality traits of Generation 'Z' Consumers - survey participant evaluations

Item	in %*					Average ratings	Item
	1	2	3	4	5		
Disloyal	1.3	0,7	5.4	23.8	68.8	4.58	Loyal
Not resourceful	2.9	6.3	11.8	32.3	46.8	4.14	Resourceful
Not assertive	6.2	12.0	19.9	30.5	31.4	3.69	Assertive
Traditionalist	6.1	11.5	28.3	27.2	27.0	3.57	Innovative

Cont. table 2.

Selfish	6.8	12.5	29.1	29.4	22.3	3.48	Altruistic
Spendthrift	10.3	15.9	22.1	26.0	25.8	3.41	Frugal
Reserved	11.8	18.9	17.0	25.3	27.0	3.37	Open
I don't trust others	13.2	18.4	25.2	26.4	16.9	3.15	I trust others

* Evaluations on a Scale from 1 to 5.

Source: own study.

The psychographic characteristics of Generation 'Z' consumers also consist of their attitudes towards life, environment, ecology and sharing. Pro-ecological attitudes are declared by most respondents although they have different approaches to sharing products. More than 86% of respondents care about the environment naturally by saving, for example, energy, water. A healthy and sporty lifestyle leads almost 58% of respondents, regularly practicing sports. Nearly 3/4 of consumers are willing to lend their things to others but prefer to use new things than those already used by others. About 2/3 of the surveyed Generation Z do not like to use things borrowed from other people. Almost the same percentage of participants prefer to own products rather than just have access to them. One in two respondents likes to keep up with current trends and fashions (58.3%). The decisions made by Gen 'Z' consumers are circumstantial. More than 73% of respondents make decisions depending on the situation and not based on critical thinking. Despite the fact that about 66% of respondents easily connect with other people, more than 55% of them care about what other people think of them. More than half of respondents easily adapt to changes (57%) and do everything at the last minute (51.9%) (Table 3).

Table 3.
Approach to Life of the Generation 'Z' Consumers in the opinion of survey participants (in %)

Item	in %
I complete my tasks ahead of schedule.	48.1
I leave everything until the last minute.	51.9
I easily establish connections with other people.	66.3
I have difficulty making contact with other people.	33.7
I willingly use items borrowed from others.	31.7
I dislike using items borrowed from others.	68.3
I take care of my physical condition. regularly engage in sports.	58.3
I don't take care of my physical condition.	41.7
I make decisions based on rational criteria.	26.2
I make decisions based on the situation.	73.8
I care about what other people think of me.	55.8
I don't worry about what others think of me.	44.2
I easily adapt to changes.	57.9
I am reluctant to embrace any changes.	42.1
I prefer using new things.	74.3
I prefer using items that have already been used by others.	25.7
I care about the natural environment (e.g. I save energy/water. sort waste).	86.5
I don't consider the natural environment.	13.5
I willingly lend my belongings to others.	76.1
I never lend my belongings to others.	23.9

Cont. table 3.

I like to keep up with current trends and fashion.	58.3
I'm not interested in new market trends.	41.7
I only need access to the product.	35.1
I prefer to own products.	64.9

Source: own study.

Generation 'Z' consumers surveyed were asked to identify the perceived benefits that motivate them to engage in product sharing. All of these product-sharing aspects are relevant to the study participants (means above 3). For the respondents, the most important is to improve the standard of living and comfort of life (mean 4.18), to save money from buying a product (4.11) and to feel sensible and responsible (4.06). The least important, though important, is for them to participate in the wider movement against excessive consumption. The majority of study participants rated the individual benefits of sharing highly on 4.0 (Table 4).

Table 4.
Respondents' Motivation for Product Sharing - survey participant evaluations

Item	in %*					Average ratings
	1	2	3	4	5	
Improving your quality of life and comfort	1.4	3.2	9.3	48.0	38.0	4.18
Saving money on buying the product	3.3	3.5	7.1	50.8	35.3	4.11
Feeling sensible and responsible	3.7	4.3	11.8	42.4	37.8	4.06
Saving money on maintaining and servicing the product	2.6	3.8	12.7	54.5	26.4	3.98
Experience something interesting	3.6	8.9	19.4	46.4	21.7	3.74
Producing less electronic waste	6.8	7.7	15.9	46.5	23.2	3.71
The opportunity to meet new people	7.6	8.2	15.8	45.7	22.7	3.68
The ability to use a product that you could never afford to buy	4.5	8.2	26.0	40.8	20.5	3.64
Reducing CO2 emissions	8.9	7.8	17.7	42.7	22.9	3.63
The ability to immediately satisfy your needs without buying a product	5.3	13.9	23.7	44.9	12.1	3.45
Limiting your own consumption	4.4	10.8	35.4	39.7	9.8	3.40
Being part of a broader movement against excessive consumption	10.9	13.2	36.1	29.5	10.4	3.15

* Evaluations on a scale from 1 to 5. where 1 means 'Definitely Not Important' and 5 means 'Definitely Important.

Source: own study.

Respondents also stated their preferences for sharing different products in the context of borrowing products from someone, lending products to someone and common purchase of products. Consumers admitted that they would consider borrowing items such as a tent (average 4.41), car accessories such as a roof box, bike rack (4.18) and printer (3.93). They would be reluctant to lend someone products such as laptop and tablet (2.38 and 2.7 respectively), car and motorcycle (2.56 and 2.50). Respondents are more negative about borrowing something from someone (most average ratings lower than when lending individual products, except laptops and cars). Joint purchases of these products are rated lowest by them. Respondents admitted that only a printer and a caravan are more willing to co-purchase than to lend their private one to someone or from someone (Table 5).

Table 5.
Sharing selected products in the opinion of survey participants (average rating)*

Item	borrowing from someone	lending something to someone	buying together
laptop	2.43	2.38	2.00
Printer	3.64	3.93	3.80
Tablet	2.55	2.77	2.19
Tent	4.07	4.41	3.90
Camping trailer	3.21	3.37	3.49
Bicycle	3.53	3.79	2.30
Skis/snowboard	3.27	3.63	2.47
Windsurfing/kitesurfing equipment	3.23	3.59	2.69
Electric scooter	3.22	3.34	2.75
Car	2.61	2.56	2.40
Motorcycle	2.25	2.50	2.14
Car accessories such as a roof box. bike rack	3.93	4.18	3.63
Other**	3.11	3.27	2.88

* Evaluations on a Scale from 1 to 5. where 1 means 'Definitely No' and 5 means 'Definitely Yes'.
** Other indications included: writing and sports accessories, e-book reader, wireless speaker, phone, headphones, helmet, roller skates. hair dryer. tools. lawn mower, books, clothing (borrowing from someone); camera, wireless speakers, clothing, subscriptions i.e. access to electronic products, headphones, phone and charger, instruments, household appliances, lawn mower, books (lending something to someone), home/flat, tools rarely used at home (buying together).

Source: own study.

It was also cognitively interesting to identify with whom the survey participants would be willing to share products or purchase them together. The vast majority of respondents (more than 80%) are willing to lend something to their friends, extended family members, colleagues, acquaintances or neighbors. When borrowing something from someone, on the other hand, the majority of respondents prefer unknown people such as those found on the Internet (over 58%). One in three respondents deciding to shop for products together would do so only with immediate family, e.g. parents siblings (Figure 1).

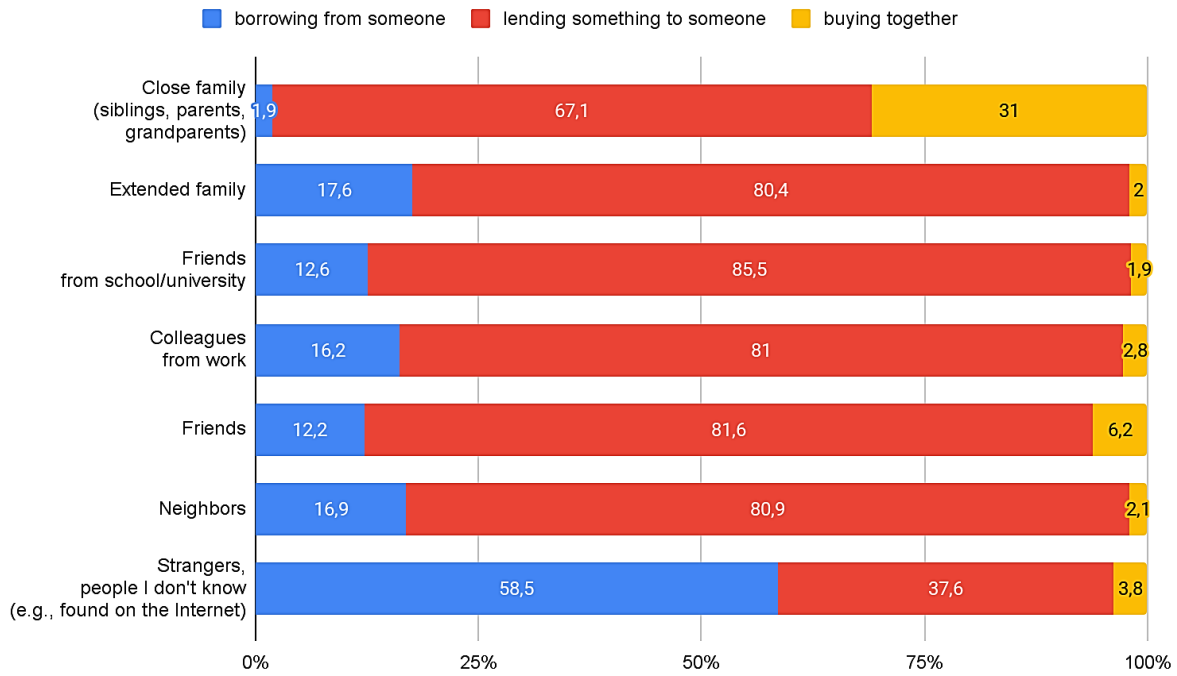

Figure 1. People with whom respondents would be willing to share products (in %).

Source: own study.

Participants in the survey listed online applications/websites they use to share products with others or make joint purchases. When making joint purchases, almost 2/3 of surveyed consumers use sites such as Aliexpress, Allegro, Amazon, Temu, Ebay, Gumtree. As many as 1/3 of them co-use movie streaming services (Disney+, HBO, Amazon Prime, Player, Netflix) and music streaming services (Youtube, Spotify). One in four respondents use websites and apps dedicated to sales (OLX, otomoto, Selling) and clothing products (e.g., Vinted, Bershka, Zalando). Respondents are least likely to use social media or apps/websites dedicated to cosmetics, electronics, accommodation, food and transportation for this purpose (Figure 2).

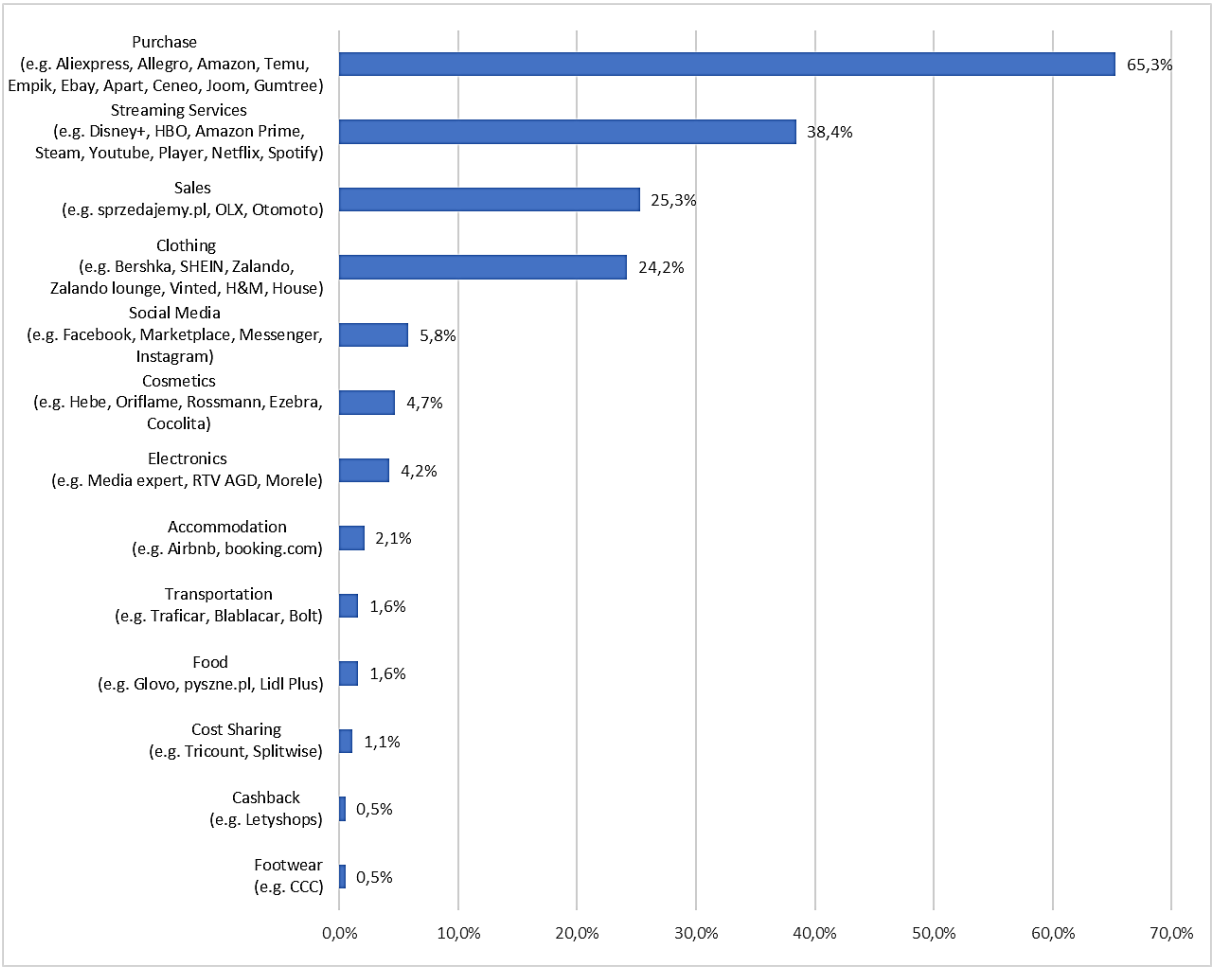

Figure 2. Online applications/websites for joint purchases (product sharing) used by respondents (N = 190, in %).

Source: own study.

5. Discussion

The results of the study are in line with other ongoing studies on the growing trend of sustainable consumption. They show that Polish consumers are showing more and more conscious and sustainable consumer behaviour on the market, especially for economic and environmental reasons. For the vast majority of Poles (about 85%), it is important to take care of the environment, which is reflected in the saving of resources (e. g. water, plum) and the preference to do some things yourself instead of buying them (Gajdzik, Jaciow, Wolny, 2023). A similar phenomenon is observed among young Poles aged 16-24 representing Generation 'Z', for whom the issue of climate and environmental protection is very important. Their ecological commitment is reflected in such declassified behaviours as, among others: buying organically produced products, limiting the use of aerosols and meat consumption, cycling, drinking water or saving energy. Young people's ways of taking care of the

environment when shopping are mainly buying second-hand clothes, buying products that reduce the use of plastic (Mediahub Report, 2022).

There are also phenomena related to the limitation of consumption and the non-purchasing of new products due to the purchase of "second-hand" products or the sharing of certain categories of products/services. It is becoming increasingly popular to use services that are part of the sharing economy trend, especially those related to transport. This is confirmed by studies relating to the sharing and use of means of transport. Research results show that the idea of ridesharing is becoming increasingly popular among young consumers in Poland (Stolecka-Makowska, Wolny, 2018). Although this trend is more developed in Western markets (e.g. Italy) than in Poland, studies show that sharing economy services will develop in a similar direction among young Poles (Kowalska, 2019).

Studies show that polish young consumers aged 18-38 are also increasingly interested in redistributing second-hand goods (buying and using second-hand products). The most frequently purchased product category are cars, books, clothing and hobby products (Wilczak, 2019). While the degree of acceptance of co-consumption behaviour (exchanging products with others, renting less-used items, sharing them for a fee, group shopping) is high among the 18 to 40 year olds surveyed, most of them do not practice such behaviour. The exception is young people, among whom sharing products/services is much more common (Sobczyk, 2018). Studies show that the higher the value of goods, the less likely younger consumers are to be willing to share them. They are primarily interested in collaborative consumption because of their ability to earn money and wider access to a wide range of goods and services (Zalega, 2018). Other studies confirm the positive attitude of Polish consumers of Generation 'Z' to the concept of co-consumption and its most popular manifestations. They point out that the Generation 'Z' consumer is becoming a conscious and responsible buyer who cares about the environment. This is reflected in the behaviour of consumers of this generation who are increasingly giving up property (negative attitudes towards consumer lifestyles) and choosing alternative ways of meeting their needs (based on exchanging, lending and sharing their own resources with others through platforms and apps) (Paczka, 2020).

Moreover, recent studies in the US show that sustainability drives consumer demand and loyalty for clothing products, especially those representing Generation 'Z'. Among this group of consumers, the service of renting clothes (shared consumption of clothes) is very popular (McCoy, Wang, Chi, 2021).

Following the trends emerging on the American, European and Polish markets, it can be assumed that the phenomenon of co-consumption will develop more and more. Collaborative consumption can be a viable solution for reducing the production of certain categories of products (e. g. clothing, books) and a new, innovative business model for companies.

6. Conclusions

In modern economies, governments are increasingly calling for conservation of natural resources, more and more everyone hears about the Green Economy. Every one of us can be a responsible consumer. There are different types of consumers on the market (Gajdzik et al., 2023). Among them are those who are interested in high-quality products, saving money, saving shopping time, and enjoying the shopping experience. In each groups we can meet responsible consumers (Gajdzik et al., 2023; Jaciow et al., 2022). One form of responsible consumption is sharing consumption. The aim of the study was to determine the degree of participation of Generation 'Z' in cooperative consumption. The authors conducted direct research among people born after 1995. Based on the studies carried out, it has been established that the 'Z' generation is interested in what happens in the environment, and therefore also in cooperative consumption. Tested products (writing and sports accessories, e-book reader, wireless speaker, phone, headphones, helmet, roller skates, hair dryer, tools, lawn mower, books, clothing (borrowing from someone); camera, wireless speakers, clothing, subscriptions i.e. access to electronic products, headphones, phone and charger, instruments, household appliances, lawn mower, drill, books (lending something to someone), home/m tools rarely used at home (buying together) are most often shared (rented). For the participants of the study (means above 3 values), many aspects of cooperative consumption were involved. People exchange products over the Internet, which is today the primary source of communication. For the respondents, the most important thing is to improve the standard of living and comfort of life (mean 4.18) by sharing products. In second place is the saving of money related to the purchase of unnecessary products (4.11) and in third place the sense of being reasonable and responsible (4.06). Generation 'Z' highly rated the idea of cooperative consumption and the benefits associated with it.

Collaborative consumption based on the sharing of goods (products) is part of the new Industry 40/5.0 development concept (Gajdzik et al., 2021). Societies, according to the requirements of the new concept, must engage more strongly in environmental responsibility. Therefore, it is worthwhile to carry out research among the youngest generation in the consumption market, which is the 'Z' generation. This generation will, over the next few years, adopt attitudes (behaviors) that are important for responsible development. However, there are many temptations or barriers to cooperative consumption, and one of them is the happening personalization of products and services (Saniuk et al., 2020). Generation 'Z', despite being sensitive to changes in the environment, is at the same time being heavily 'bombarded' with products just for it/us.

Our further research will seek to determine how the bipolarity of consumption, i.e., sustainable consumption on the one hand, and strong personalization of products and ease of online purchase on the other, affect the young consumer base.

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References

1. Aniszewska, G. (2015). Zmiany pokoleniowe a decyzje i wybory konsumenckie. *Marketing i Rynek, 1,* 4-6.
2. Bylok, F. (2013). *Konsument. konsumpcja i społeczeństwo konsumpcyjne we współczesnym świecie*. Katowice: Śląsk.
3. Bylok, F. (2016). Konsumpcja hedonistyczna a konsumpcja etyczna. Czy potrzebna jest społecznie odpowiedzialna konsumpcja. *Studia i Prace WNEiZ US. 44/2*, 39-55.
4. Bywalec, Cz. (2007). *Konsumpcja w teorii i praktyce gospodarowania*. Warszawa: PWN, 151.
5. Camilleri, M.A. (2021). E-commerce websites, consumer order fulfillment and after-sales service satisfaction: The customer is always right, even after the shopping cart check-out. *Journal of Strategy and Management*, https://doi.org/10.1108/JSMA-02-2021-0045.
6. Czaja, S., Becla, A. (2011). Czterech jeźdźców ekologicznej zagłady we współczesnym świecie. In: B. Kryk (ed.), *Trendy i wyzwania zrównoważonego rozwoju.* Szczecin: Zapol.
7. Dąbrowska, A., Bylok, F. Janoś-Kresło, M., Kiełczewski, D., Ozimek, I. (2015). *Kompetencje konsumentów. Innowacyjne zachowania. Zrównoważona konsumpcja*, Warszawa: PWE, 81-96.
8. *Digital 2020 Global Digital Overview* (January 2020). Available online: https://www.slideshare.net/DataReportal/digital-2020-global-digital-overview-january-2020-v01-226017535.
9. Dimock, M. (2019). Defining generations: Where Millennials end and Generation Z begins. *Pew Research Center*, *17*(1), 1-7.
10. Dreyer, Ch., Stojanova, H. (2023). How entrepreneurial is German Generation Z vs. Generation Y? *Procedia Computer Science, 217*, 155-164.
11. European Green Deal. Komunikat Komisji do Parlamentu Europejskiego. Rady Europejskiej. Rady. Komitetu Ekonomiczno-Społecznego i Komitetu Regionów. Bruksela 11.12.2019. COM(2019)640 Final. Available online: https://eur-lex.europa.eu/legal-content/pl/TXT/?uri=CELEX%3A52019DC0640, 15 June 2021.
12. Gajdzik, B., Grabowska, S., Saniuk, S. (2021). Key socio-economic megatrends and trends

in the context of the Industry 4.0 framework. *Forum Sci. Oeconomia*, *9*, 5-22.
13. Gajdzik, B., Jaciow, M., Wolny, R. (2023). Types of E-Consumers and Their Implications for Sustainable Consumption-A Study of the Behavior of Polish E-Consumers in the Second Decade of the 21st Century. *Sustainability*, *15(16)*, 12647, https://doi.org/10.3390/su151612647.
14. George, D., Mallery, P. (2016). *IBM SPSS statistics 23 step by step: A simple guide and reference*. New York: Routledge.
15. Grabiwoda, B. (2019). *E-konsumenci jutra. Pokolenie Z i technologie mobilne*. Łódź: Wydawnictwo Nieoczywiste.
16. Green Economy, EU. Retrieved from: http://ec.europa.eu/environment/basics/green-economy/sustainable development/index _pl.htm
17. Hysa, B. (2016). Zarządzanie różnorodnością pokoleniową. *Zeszyty Naukowe Politechniki Śląskiej. Seria: Organizacja i Zarządzanie*, *97*, 389.
18. Ismail, A.R., Nguyen, B., Chen, J., Melewar, T.C., Mohamad, B. (2021). Brand engagement in self-concept (BESC). value consciousness and brand loyalty: a study of generation Z consumers in Malaysia. *Young Consumers*, *22*(1), 112-130.
19. Jaciow, M., Wójciak, M., Poradowska, K. (2021). Ecological behaviour of generation Z in Poland. *Acta Sci. Pol. Oeconomia, 20(3),* 15-22.
20. Jaciow, M., Wolny, R. (2022). *Polski e-Konsument. Dekada Zmian*. Gliwice: Helion.
21. Jaros, B. (2015). *Koncepcja zrównoważonej konsumpcji - problemy implementacji w Polsce [The concept of sustainable consumption - problems of implementation in Poland]*. Rozprawa doktorska. Faculty of Economics. Management and Tourism. Retrieved from: https://wir.ue.wroc.pl/info/phd/WUTc98a41239d264848afb7414d37d6f1b9/
22. Kiełczewski, D. (2004). *Konsumpcja a perspektywy trwałego i zrównoważonego rozwoju*. Białystok: Wydawnictwo Uniwersytetu w Białymstoku.
23. Kowalska, S. (2019). Zachowania Konsumentów w obliczu rozwoju sharing economy. *PTiL, 3*(47), 39-52.
24. Kryk, B. (2011). Konsumpcja zrównoważona a proekologiczne style życia. *Studia i Materiały Polskiego Stowarzyszenia Zarządzania Wiedzą, 51,* 206-218.
25. Kumar, V., Ramachandran, D., Kumar, B. (2020). Influence of new-age technologies on marketing: a research agenda. *Journal of Business Research. 125*(3), DOI: 10.1016/j.jbusres.2020.01.007.
26. Łuczka, W. (2016). Zrównoważona konsumpcja i uwarunkowania jej rozwoju/ Sustainable Consumption and Determinants of Its Development. *Handel Wewnętrzny*, *6*(*365*), 136-145.
27. Mazurek-Łopacińska K., Sobocińska M. (2015). Wirtualizacja komunikacji marketingowej w kontekście przemian pokoleniowych i zmian stylów życia. *Zeszyty Naukowe Uniwersytety Szczecińskiego. Problemy Zarządzania, Finansów i Marketingu, 39*, 146.
28. McCoy, L., Wang, Y.-T., Chi, T. (2021). Why Is Collaborative Apparel Consumption Gaining Popularity? An Empirical Study of US Gen Z Consumers. *Sustainability, 13*, 8360,

https://doi.org/10.3390/su13158360
29. Mont O., Plepys, A. (2008). Sustainable consumption progress: should we be proud or alarmed? *Journal of Cleaner Production, 16*.
30. Mróz, B. (2013). *Konsument w globalnej gospodarce. Trzy perspektywy*. Warszawa: Oficyna Wydawnicza SGH.
31. *Our Common Future* (1987). Report of the World Commission on Environment and Development. Retrieved from: http://www.un-documents.net/our-common-future.pdf
32. Paczka, E. (2020.). Zmiana zachowań rynkowych pokolenia *Z. Ekonomia - Wroclaw Economic Review, 26, 1*.
33. *Raport EY*, www.ey.com/en_gl/corporate-responsibility/how-business-and-education- can-help-gen-z-reframe-the-future, 12.12.2023.
34. Raport Mediahub, Instytut Badawczy Pollster (2022). *Generacja Z – Rzeczywistość młodych w kontrze do utrwalonych stereotypów*, 10.01.2023.
35. Ryszawska, B. (2013). *Zielona gospodarka - teoretyczne podstawy koncepcji i pomiar jej wdrażania w Unii Europejskiej*. Wrocław: Wydawnictwo Uniwersytetu Ekonomicznego.
36. Saniuk, S., Grabowska, S., Gajdzik, B. (2020). Personalization of Products in the Industry 4.0 Concept and Its Impact on Achieving a Higher Level of Sustainable Consumption. *Energies*, *13*, 5895.
37. Schor, J.B., Craig, J.T. (2014). *Sustainable Lifestyles and the Quest for Plenitude. Case Studies of the New Economy*. Yale University Press.
38. Schor, J.B. (2014). *Debating the Sharing Economy*. Retrieved from: http://www.greattransition.org/publication/debating-the-sharing-economy.
39. Seyfang, G. (2009). *The New Economics of Sustainable Consumption. Seeds of Change*. New York: Palgrave Macmillan.
40. Słupik, S. (2015). Świadomy konsument energii w województwie śląskim w świetle badań ankietowych [Conscious energy consumer in the Silesian voivodship in the field of survey]. *Studia Ekonomiczne. Zeszyty Naukowe Uniwersytetu Ekonomicznego w Katowicach, 232*, 215-224.
41. Sobczyk, G. (2014). Zachowania konsumentów wobec nowych trendów konsumpcji – wyniki badań. *Annales Universitatis Mariae Curie-Skłodowska, sectio H – Oeconomia, LII,* 171-180.
42. Sobczyk, G. (2018). Współczesna konsumpcja – nowe trendy na polskim rynku [Contemporary consumption – new trends in the Polish market]. *Zeszyty Naukowe WSEI seria: Ekonomia, 9(2*), 87-104.
43. Spangenberg, J.H. (2014). Institutional change for strong sustainable consumption: sustainable consumption and the degrowth economy. *Sustainability: Science. Practice & Policy, 10*(*1*).
44. Spodarczyk, E. (2018). Gotowość konsumenta do ponoszenia kosztów odpowiedzialnej konsumpcji w świetle wyników badania [Readiness of a consumer to bearing costs of

responsible consumption in the light of research results]. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu [Research Papers of Wrocław University of Economics]*, *516*, 76-86.

45. Stolecka-Makowska, A., Wolny, R. (2018). The Idea of Car Sharing as a Manifestation of Sustainable Consumption. *Problemy Zarządzania, 3(75), t. 1*, 182-196.
46. Wilczak, A. (2019). Młodzi dorośli Polacy wobec redystrybucji dóbr używanych. *Marketing i Rynek [Journal of Marketing and Market Studies], 26(2),* 16-30.
47. Zalega, T. (2018). Collaborative consumption in consumer behavior of Polish young people. *Journal of Economics and Management*, *33*(3), 136-163.
48. Zrałek, J. (2012). Dekonsumpcja jako przejaw proekologicznych zachowań konsumentów. *Handel Wewnętrzny*, *maj-czerwiec, t. II*.

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DIGITAL TRANSFORMATION OF THE STEEL DISTRIBUTION SECTOR IN THE CONTEXT OF INDUSTRY 4.0

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Purpose: Process digitization and artificial intelligence are the needs of today's industry. The Fourth Industrial Revolution along with the concept of Industry 4.0 provides a huge opportunity for the development of many industries. Industry 4.0 imposes high demands on production and logistics in cyber-physical systems. Therefore, the primary objective of this publication is to present the concept of Industry 4.0, with particular emphasis on the impact of its technological solutions on the process of distribution of industrial goods. The challenges and benefits of the concept of Industry 4.0 are also presented in the article.
Design/methodology/approach: The work consists of two parts, the review of literature and the research part. The theoretical part presents the impact of technological solutions on the evolution of the distribution process. The empirical part focuses on the importance of technological solutions in the segment of Polish steel product distributors. In Poland, 9.7 million tons of steel is produced on average annually. In the world, according to the analyzes of the World Steel Association, 1781.5 million tons of steel was produced in 2022. Steel is an important construction and industrial material used in the production of cars, machines, ships, appliances, etc. Research was realized in Polish sector of companies. The questionnaire was build according the structure of Industry 4.0 based on pillars. In the questionnaire was used Likert scale from 1 to 5 with 5 being the highest.
Findings: Steel sector companies are aware of the importance of the technology of Industry 4.0 in improving the course of the process and communication with the market. The respondents highly assessed the importance of the pillars of Industry 4.0 in the processes of storage and distribution of steel products, most often choosing 4 in the Likert scale from 1 to 5.
Originality/value: Studies presented in this paper are strongly linked to the current concept of industrial development, which is Industry 4.0.

Keywords: product distribution, Industry 4.0, steel industry.

Category of the paper: research paper.

1. Introduction

Industry 4.0 is another version of technological progress, better than the previous one, arising in the Fourth Industrial Revolution. Changes taking place in the digitization of processes affect intelligent manufacturing and logistics processes in supply chains. Automation and digitization of production lines and warehouses are supported by global digital technologies that enable the development of cyber-physical systems (Lasi et al., 2014).

The term "Industry 4.0" (originally *Industrie 4.0*) was entered in the high-tech strategy project by the German government, promoting the computerization of manufacturing processes in 2011. It was first used at the Hannover fair (Kagermann et al., 2013) and more and more companies are implementing the latest technologies, which are called the "pillars" of Industry 4.0 (Lu, 2017; Senn, 2019; Erboz, 2017).

The digitization of processes is considered the basis for the development of Industry 4.0 (Kagermann, 2015; Stareček et al., 2023). Information and computer technologies (ICTs) are an opportunity to maintain the flexibility of enterprises, at every level of business activity, in a dynamic environment. In the case of the process of product distribution, the company must take into account flexibility from the moment of planning the warehouse layout (warehousing systems, the possibility of expanding or changing the warehouse design) to the course of logistics processes (the ability to adapt the activity to handle seasonal peaks). Therefore, let's take a closer look at the ongoing transformation of the digital distribution of goods in the conditions of Industry 4.0.

This study consists of the theoretical part - the review of literature, and the empirical part - the results of direct research in the steel product distributor sector in Poland. The research was carried out in enterprises selling steel products. The research architecture was constituted by the pillars of Industry 4.0: Big Data and analytics, AI (Artificial Intelligence), Cloud Computing, AR - Augmented Reality, IIoT - Industrial Internet of Things, 3D printing and additive manufacturing, autonomous robots, horizontal and vertical integration, simulation and digital twin, and cybersecurity. The research sought to determine the importance of the digital transformation of the Polish market for the distribution of steel products in the conditions of strong popularization of the concept of Industry 4.0.

2. Literature review

2.1. Distribution of goods and warehouse management in Industry 4.0

The determinants of the distribution process evolution are strong economic, technological, and social trends. One of them is the digital transformation of business combined with Industry

4.0 technologies (Gajdzik et al., 2021). The ongoing technological transformation, which is attributed to the Fourth Industrial Revolution, concerns every element of the process of goods distribution: people, warehouses, devices, software, transport (Blaik, 2018). Companies that do not take up the challenge of transition to a new stage of operation may lose the market competition for increasingly demanding customers who efficiently use mobile devices, which makes them active partners of the logistics company (Nambisan, 2017).

The distribution of goods in the conditions of Industry 4.0 is increasingly integrated with production and sales, as well as with customer service systems - especially strategic ones (Barreto et al., 2017; Hofmann et al., 2017). This integration of processes and computer systems is made possible by access to Big Data and the Internet of Things. Data collection and processing allow companies to optimize processes in real time (Tabakow et al., 2014; Aamer, and Sahara, 2021; Boyes et al., 2018; Wachnik, 2022). Moreover, based on data collected in sales processes, companies can profile a very accurate picture of a potential customer and their behavior. Access to data also helps companies predict periods of increased sales and effectively manage the needs generated by the market (Ruijgrok et al., 2002; Baber et al., 2019).

The distribution process evolves in the conditions of market economy. B. Ślusarczyk (2019), based on Ibarra et al. (2018, p. 7) describes three basic directions in goods distribution processes. The first is the service and customer service-oriented approach. In the digital world, services are inextricably linked to the product. Smart products need free access to service platforms (Grönroos, Ravald, 2011). The second direction is the network approach with horizontal and vertical integration of the value chain and the related interoperability. In processes, there must be the exchange of information between people, machines, and IT systems. Information flow can take place both within the factory and among supply chain entities. The third direction is based on the user (consumer) and their needs. This approach is called customization and consists in an individual approach to customer needs. New capabilities of technology make manufacturing more responsive to user-centered design and better suited to the processes and contexts of customer value creation (Vargo et al., 2008).

Modern distribution of goods is conducted in a global environment, leading to an increased scale of complexity in distribution processes. There are more and more physical streams of goods and more and more distribution channels in distribution processes. Supply chains must be able to flexibly adapt to changes in market needs. The spatial development of distribution channels is influenced by new possibilities of communicating via the Internet. With the development of knowledge and technology, the efficiency of logistics processes (resource management) is also increasing. The development of the Internet and advanced solutions of telecommunications have created good conditions for obtaining cheap sources of resources (materials, labor) and realizing the orientation towards sales and meeting diversified customer requirements. Quality standards and logistics procedures are being improved internationally.

The spatial and temporal scopes of goods distribution have no limits. Due to the use of increasingly sophisticated tools resulting from technical and technological development, enterprises can organize operational activities on many global markets (Szyszka, 2023). The Industry 4.0 environment supports the global nature of distribution processes, guaranteeing access to any information, at any time and from anywhere. All data regarding process planning, efficiency and quality management are available in real time. Additionally, they can be supplemented using AR (augmented reality) and optimized in the company's integrated IT network (Bieńkowski, 2018).

A. Bujak (2017) emphasizes that modern logistics can quickly respond to customer needs and is characterized by process flexibility (cost-service level) and a high ability to optimally use company resources, including data and information. W. Torbacki (2018a, 2018b), in the presented Industry 4.0 model, states that the actual stock of goods in a store or warehouse, as well as information on the consumption of goods recorded using cyber-physical systems may launch the production process via a cloud-based ERP system (Pohludka et al., 2018). In goods distribution processes, the scope of cooperation between business partners through direct involvement in management processes and creating added value is becoming increasingly stronger and easier.

As already mentioned, one of the megatrends of contemporary goods distribution is customization of products and services offered and the need to shorten the time necessary to meet customer needs (Ruijgrok et al., 2002). Modern market participants expect deliveries of customized products immediately after concluding commercial transactions, most often electronically. Growing market needs require the existence of effective, flexible, and fast distribution channels, as well as fully automated and smart warehouses (Khan et al., 2022; Grondys, 2015). Software helps optimize warehouse space and improve communication with production and logistics. Through warehouse management systems (WMSs) and IoT, sales departments gain direct access to storage systems to quickly ship another batch of goods. With the development of digital technology, "on-stock" production is giving way to "made-to-order" production with direct deliveries. Access to data and integrated IT systems improve the management of the entire supply chain (Domingo Galindo, 2016). Huge data sets and real-time event analysis make it possible to determine the best mode to process and deliver orders and prevent possible difficulties in its course. An important element supporting the functioning of the distribution network are electronic platforms, defined as the distributed environment of functionally integrated IT systems and tools for the purposes of delivering services provided electronically (Rozados, Tjahjono, 2014; Waller et al., 2013; Wang, 2016; Witkowski, 2017).

In the digital space, it is also worth remembering about solutions in terms of visualizing distribution channels and managing them in real time (Brettel et al., 2014). Digital technologies allow for the creation of analytical tools that allow for obtaining data from various, sometimes distant sources (e.g., sales stories, weather forecasts, local news or tracking conversations on social media) and analyze them in order to predict purchasing trends.

The digitization of processes is an opportunity for strong cooperation between the supplier and the customer, and communication with the customer is interactive. Therefore, the ability of the company to co-create value with customers may be demonstrated by the ability to develop existing or initiate new relationships with customers. Mobile devices make it easier for customers to express their opinions about products and service quality, and the Internet is a key medium of interaction between the consumer and the company. The Internet space is an excellent place to disseminate the market offer. Additionally, companies may stimulate customers to express their opinions, share ideas and rate their satisfaction with their relationship with the company through surveys, social media, auctions, etc. (Mitręga, Laskowska-Witek, 2015; Sawhney et al., 2005; Shah et al., 2006; Wind et al., 2001; Shkurupskaya, Litovchenko, 2016).

The objects of distribution processes are warehouses of goods, which are fully automated in Industry 4.0. Modern warehouse systems are the central place of business in goods distribution processes. The warehouse can be managed better, faster, and cheaper using appropriate digital solutions. State-of-the-art warehouses are managed by computers that provide coordinates to forklift operators regarding the order. Products are identifiable, solutions such as RFID (electric identifiers used to mark cargo) (Barcik, 2019) are used. They provide the necessary information on the current condition and location of goods, as well as ensure the standardization of data transferred in production and distribution processes (Lv et al., 2012).

There is new equipment in warehouses, such as barcode and QR code readers and autonomous carts. Storage, admission, and release processes are supported by computer systems (WMS). Due to such a solution, various parameters are known, for example: duration of product storage in the warehouse, product rotation or product warranty coverage. The systems must be connected to devices used in the warehouse or production center. Machines, robots, devices using the concept of IoT (Internet of Things) need a WMS (warehouse management system) to communicate with each other (Mostafa et al., 2019).

The concept of blockchain technology is also increasingly used in the distribution process. Data blocks are the basis for full process transparency and greater security of goods (Ayan et al., 2022). Access to data throughout the entire product lifecycle on global markets makes it easier to report socially responsible business (Breese et al., 2019, Munir et al., 2022; Nitsche, Straube, 2021).

The evolution of goods distribution processes is a construct of Logistics 4.0, which was created by adapting Industry 4.0 technologies to the specificity of logistics processes within enterprises and in supply chains. The determinants of the acceleration of changes are: access to large sets of data and commercial information, the dominance of virtual tools in promoting a comprehensive structure of integrated marketing communications; interactive nature of relationships between chain participants and reduction in indirect connections, chain participants' access to IoT applications; switching to a new form of customer service (virtual seller), development of "social" communication channels and monitoring digital data about consumers (Bujak, 2016; Pfohl, 2016; Bracik, 2019).

3. Digital transformation in the steel product distribution process

3.1. Scope of research

The steel sector in Poland consists of 14 large manufacturers of steel products, with raw steel produced in 7 steel companies (HIPH, 2023). Distribution is dealt with by enterprises belonging to capital groups of steel producers or enterprises that are financially independent from steel producers (Gajdzik, 2011). In PKD (Polish Classification of Activities), manufacturers and distributors of steel products belong to the following sections: processing industry, metal and metal product manufacture section. Steel product distribution centers, in addition to organizing the distribution process, deal with processing steel products and provide services at the customer's request, e.g., cutting steel products, applying protective coatings, etc.

The research presented in this part of the study was carried out in companies dealing with the distribution of steel products. The authors' own survey questionnaire was used for the purposes of the research (Gajdzik, 2022). The questions in the questionnaire were used to determine the degree of digital transformation based on the technology of Industry 4.0. The research was conducted on a sample of 79 enterprises from the Silesian Voivodeship, selected using a non-random method. The results are presented in the author's monograph (Gajdzik, 2022). According to the data from the Steel Distributors' Union, the steel product distribution segment consists of 25 companies. Of these, 22 participated in the research. The survey questionnaire concerned the importance of key Industry 4.0 technologies in the entire value chain of the steel market in Poland. The impact of technology was marked TF: Technological Factor and was measured on a 5-point Likert scale.

3.2. Research results

This part of the publication presents the results of the research conducted in the Polish sector of steel product distributors. The examined technological factors were grouped according to the pillars of Industry 4.0.

The first scope of technological transformation was related to the degree of warehouse automation, from partial and incomplete automation, through full automation with integrated and autonomous warehouse management systems equipped with devices belonging to the category of autonomous robots and vehicles (TF_1). The respondents (enterprise management staff) indicated the high importance of full automation of steel product warehouses in the ongoing digital transformation of the process. The majority (74% of the respondents) rated the impact 4 or 5 (Figure 1). None of the respondents rated 1, which means that all the respondents are aware of the importance of the influence of automation of steel product warehouses on the development of the steel distribution market in Poland.

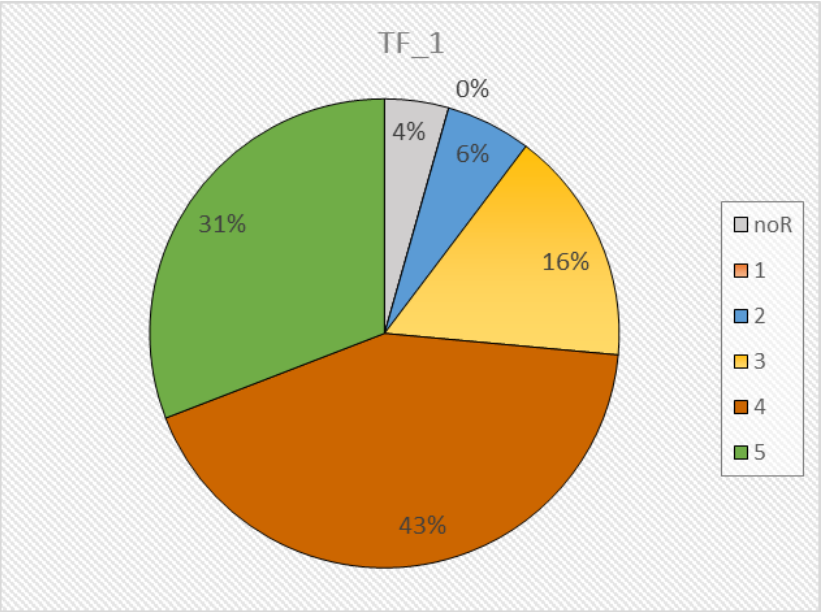

Figure 1. Warehouse automation.

Source: own research.

Another research area concerned network (chain) integration by integrating IT and computer systems of the process participants (TF_2), equipping warehouses with RFID and intelligent sensors (TF_3), and using logistics platforms, Cloud Computing and IIoT (TF_4). The research results are presented in the following figures (Figure 2 and Figure 3).

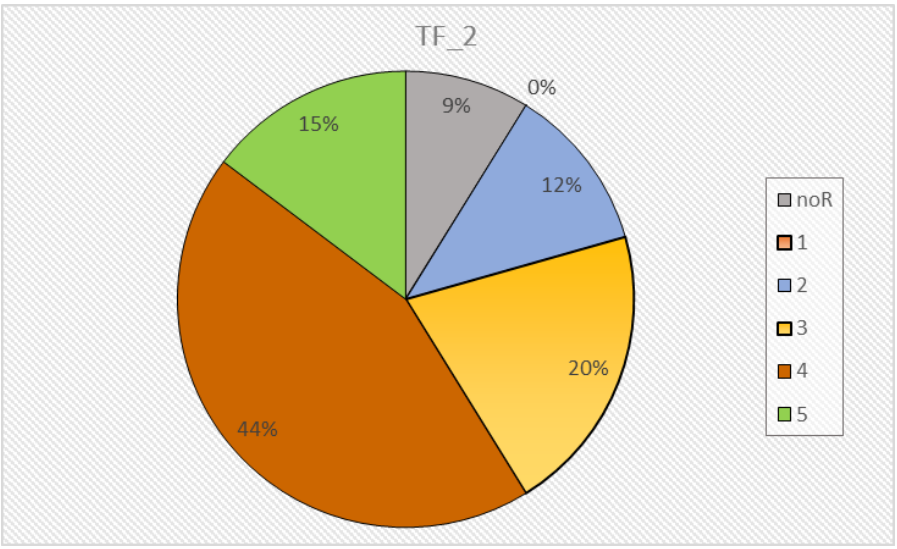

Figure 2. Compatibility and integration of IT and computer systems.

Source: own research.

The respondents most often assessed the impact of the integration of computer systems between participants of the distribution process rating 4. It can be assumed that after two decades of process digitization, the IT and computer systems used have already been refined. The respondents emphasized the growing importance of the ERP system in the product distribution process and the WMS system in warehouse management.

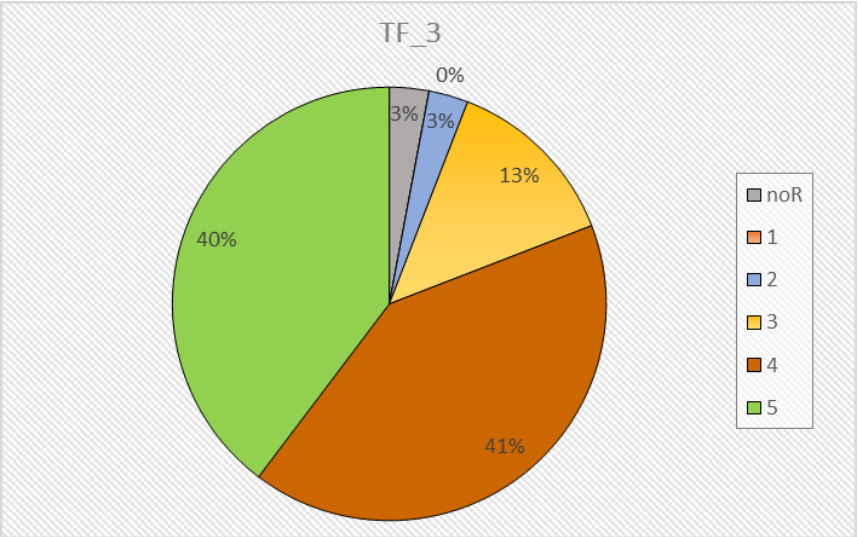

Figure 3. Equipment: RFID, intelligent sensors, autonomous vehicles and other solutions.
Source: own research.

Improving warehouse management requires investing in new generation equipment: readers, product identification systems, etc. The respondents are aware of the importance of these new technologies in the development of the steel product distribution process, their ratings were very high, most often the respondents rated 4 or 5.

The next segment concerned Big Data, Cloud computing, IIoT (TF_4). The respondents most often rated 4. Among the solutions mentioned, the respondents particularly emphasized the importance of IIoT, without which warehouses will not be intelligent (Figure 4).

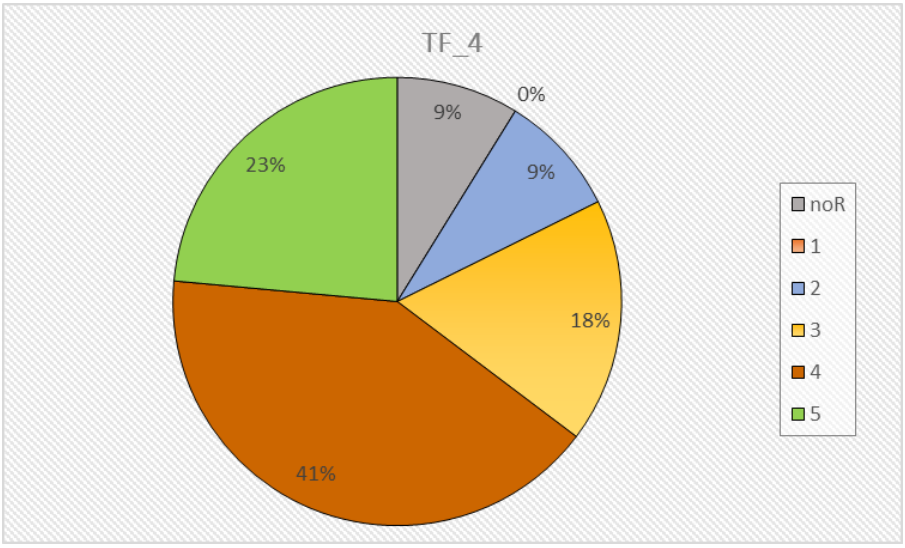

Figure 4. IIoT, cloud computing, Big Data.
Source: own research.

The respondents are aware of the importance of vertical and horizontal integration (TF_5): 85% of the respondents rated either 4 or 5 (Figure 5). Integration is a necessary mechanism enabling optimal and efficient execution of processes within the enterprise, it is a look at the functioning of the organization from the perspective of operations and activities, the so-called

process orientation, the aim of which is to increase the effectiveness of the company's activities, the quality of their results and to reduce the costs and time of task completion.

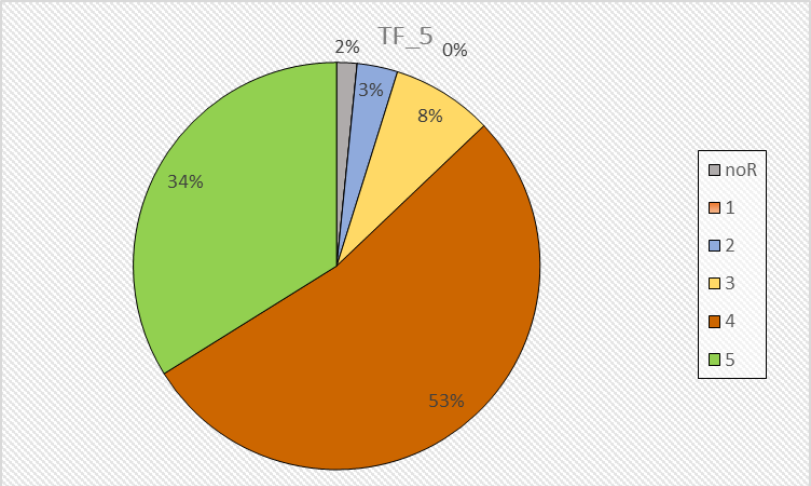

Figure 5. Vertical and horizontal integration.

Source: own research.

The next area of the research is blockchain (TF_6), which is considered a market protection instrument in the process of distribution of steel products. The respondents are aware of the transparency of data on steel products, as they most often rated 4 and 5 (Figure 6).

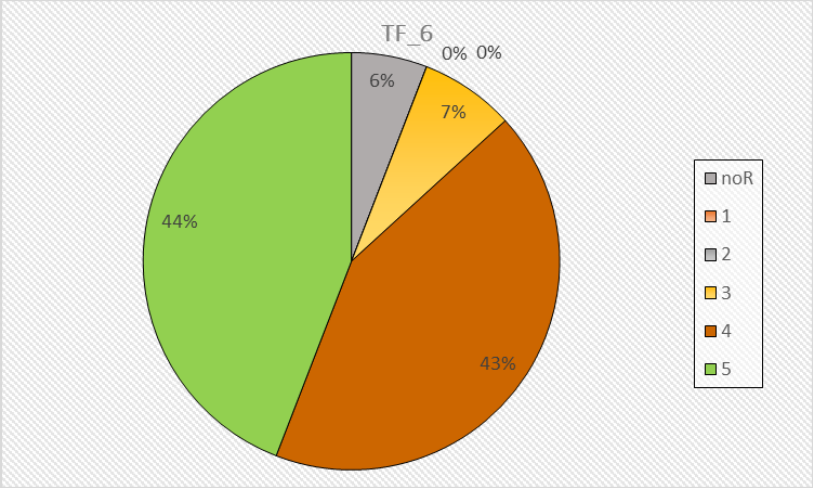

Figure 6. Blockchain.

Source: own research.

The last main area was cybersecurity, the importance of which increases with process digitization. The respondents most often rated 5 (Figure 7).

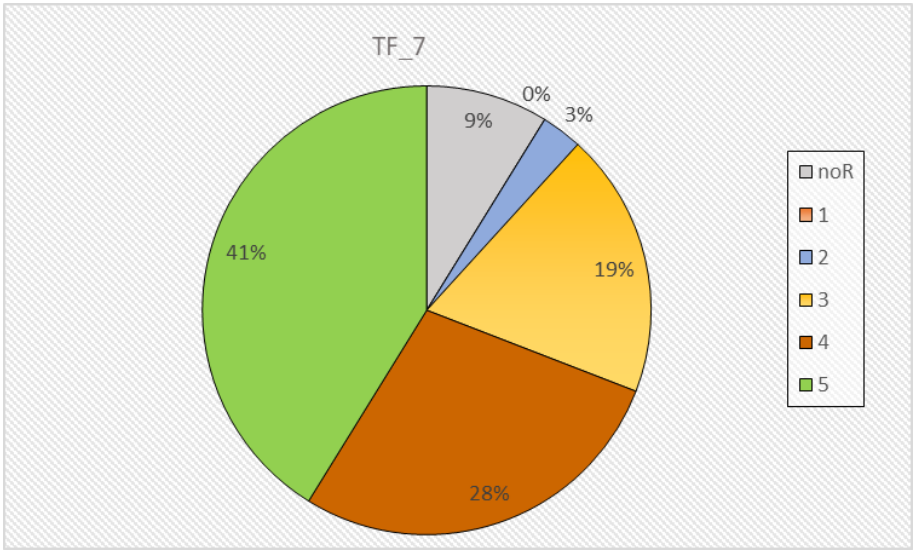

Figure 7. Cybersecurity.

Source: own research.

Since the steel distributor sector also deals with the processing of steel products (manufacturing steel structures, cutting steel products, welding, etc.), a question about additive manufacturing was added to the questionnaire (Figure 8).

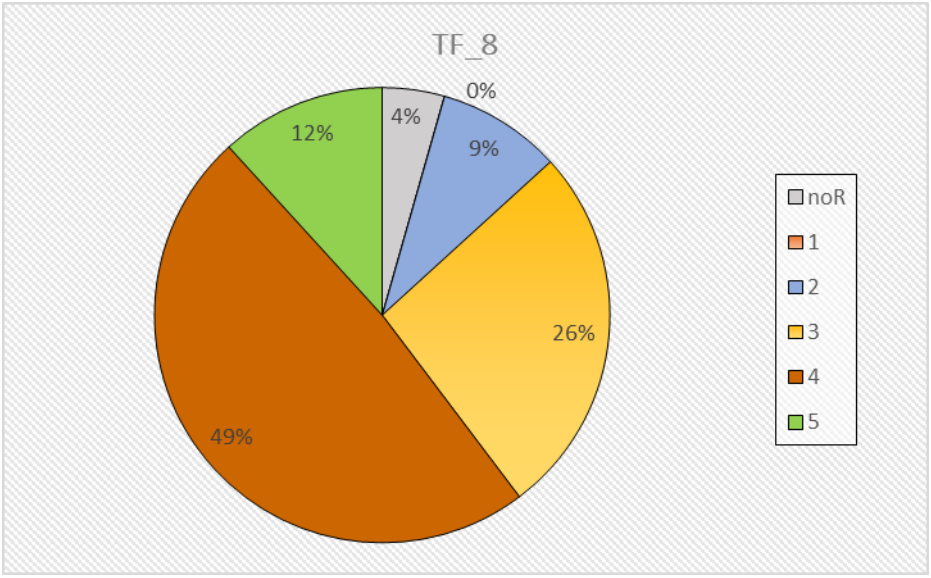

Figure 8. Additive manufacturing.

Source: own research.

4. Summary and conclusions of the research

There are many challenges that companies must face as they enter the stage of distribution of industrial goods, and one of them is the concept of Industry 4.0. The modern distribution of industrial products is a dynamic process that is constantly evolving. The ongoing transformation

concerns every element of the distribution process: people, warehouses, devices, and software used. Companies that do not take up the challenge of transitioning to a new stage of operation may lose the competition for increasingly demanding customers on the market. Industry 4.0 and digital transformation are an opportunity for development, but also a huge challenge that requires implementing the results of the Fourth Industrial Revolution. Distributors use new technologies to ensure digital communication and improve data exchange between all elements of the supply chain - people, devices, machines, products, processes. In distribution, the importance of data flow and analysis is growing, as well as the connection of information from various sources and their coordination with the work of machines, devices, storage systems, goods, and people.

In Industry 4.0, the flexibility of enterprises is possible to achieve due to continuous analysis of available data. By means of this, companies can more effectively predict periods of increased customer activity and increased demand, and thus quickly adapt logistics processes and the course of the supply chain to market requirements.

In the steel industry, which is sensitive to business cycles, any sudden change in demand may affect order fulfillment times. Hence the desire to respond quickly and adapt the distribution process to current needs (steel recipient markets). The flexibility of enterprises on the steel (steel products) distribution market is a key factor. Steel sector companies are aware of the importance of the technology of Industry 4.0 in improving the course of the process and communication with the market. The respondents highly assessed the importance of the pillars of Industry 4.0 in the processes of storage and distribution of steel products, most often choosing 4 in the Likert scale from 1 to 5.

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References

1. Aamer, A.M., Sahara, C.R. (2021). Real-time data integration of an Internet-of-things-based smart warehouse: A case study. *Int. J. Pervasive Comput. Commun., 1.*
2. Ayan, B., Güner, E., Son-Turan, S. (2022). Blockchain Technology and Sustainability in Supply Chains and a Closer Look at Different Industries: A Mixed Method Approach. *Logistics, 6, 85*. https://doi.org/10.3390/logistics6040085.
3. Baber, W.W, Ojala, A., Martinez R. (2019). *Transition to Digital Distribution Platforms and Business Model Evolution*. January 2019. 52nd Hawaii International Conference on System Sciences HICSS-52. At: http://hdl.handle.net/10125/59937
4. Barcik, R. (2019). The importance of RFID technology in Logistics 4.0 in the automotive company. *Scientific Quarterly "Organization and Management*", *3, 47*. DOI: 10.29119/1899-6116.2019.47.2
5. Barreto, L., Amaral, A., Pereira, T.J.P.M. (2017). Industry 4.0 implications in logistics: an overview. *Procedia Manufacturing, 13*, 1245-1252.
6. Bieńkowski, M. (2018). Innowacyjne rozwiązania dla Przemysłu 4.0. *Automatyka, 5.*
7. Blaik, P. (2018). Megatrends and their influence on Logistics and supply chain management development. *Gospodarka Matriałowa i Logistyka, 4*.
8. Boyes, H., Hallaq, B., Cunningham, J. et al. (2018). The Industrial Internet of Things (IIoT): An Analysis Framework. *Computers in Industry, 101*.
9. Breese, J.L., Park, S.-J., Vaidyanathan, G. (2019). Blockchain Technology Adoption in Supply Change Management: Two Theoretical Perspectives. *Inf. Syst., 20*, 140-150.
10. Brettel, M., Friederichsen, N., Keller, M., Rosenberg, M. (2014). How virtualization, decentralization and network building change the manufacturing landscape: An Industry 4.0 Perspective. *International Journal Of Mechanical, Industrial Science And Engineering, 8(1)*, 37-44.
11. Bujak, A. (2016). Wiodące przekształcenia logistyki XXI wieku. *Gospodarka Materiałowa i Logistyka, 5*.
12. Bujak, A. (2017). Rewolucja przemysłowa – 4.0 i jej wpływ na logistykę XXI wieku. *Autobusy, 6*, 1338-1344.
13. Domingo Galindo, L. (2016). *The Challenges of Logistics 4.0 for the Supply Chain Management and the Information Technology*. NTNU.
14. Erboz, G. (2017). *How To Define Industry 4.0: Main Pillars of Industry 4.0.* 7th International Conference on Management (ICoM 2017), At Nitra, Slovakia, November 2017, https://www.researchgate.net/publication/326557388_How_To_Define_Industry_40_Main_Pillars_Of_Industry_40, 2019.06.09.
15. Gajdzik, B. (2011). Transformacja dystrybucji wyrobów hutniczych w Polsce. *Gospodarka Materiałowa i Logistyka, 10*, 20-27.

16. Gajdzik, B. (2022). Diagnoza kierunków transformacji przemysłu stalowego w Przemyśle 4.0 [Diagnosis of the steel Industry transformation direction in the Industry 4.0]. Monograph 945. ISBN 978-83-7880-850-3. Gliwice: Wydawnictwo Politechniki Śląskiej.
17. Gajdzik, B., Grabowska, S., Saniuk, S. (2021). Key socio-economic megatrends and trends in the context of the Industry 4.0 framework. *Forum Scientiae Oeconomia, 9, 3,* DOI:10.23762/FSO_VOL9_NO3_1.
18. Grondys, K. (2015). Economic and technical conditions of selection of spare parts suppliers of technical equipment. *Procedia Economics and Finance, 27*, 85-92.
19. Grönroos, C., Ravald, A. (2011). Service as business logic: implications for value creation and marketing. *Journal of Service Management, 22(1*), p. 10.
20. Hofmann, E., Rüsch, M.J.C.I.I. (2017). Industry 4.0 and the current status as well as future prospects on logistics. *Computers in Industry, 89*, 23-34. 10.1016/j.compind.2017.04.002
21. Ibarra, D., Granzarain, J., Igartua, J.I. (2018). Business Model Innovation through Industry 4.0: A Review. *Procedia Manufacturing*, *22*, 4-10.
22. Kagermann, H. (2015). Change through Digitization – Value Creation in the Age of Industry 4.0. In: H. Albach, H. Meffert, A. Pinkwart, R. Reichwald (eds.), *Management of Permanent Change* (pp. 23-45). Wiesbaden: Springer Gabler.
23. Kagermann, H., Helbig, J., Hellinger, A., Wahlster W. (2013). *Recommendations for Implementing the Strategic Initiative INDUSTRIE 4.0: Securing the Future of German Manufacturing Industry*. Final Report of the Industrie 4.0 Working Group, Forschungsunion.
24. Khan, M.G., Huda, N.U., Zaman, U.K. (2022). Smart Warehouse Management System: Architecture, Real-Time Implementation and Prototype Design. *Machines*, *10*, 150. https://doi.org/10.3390/machines10020150.
25. Lasi, H., Fettke, P., Kemper, H.G., Feld, T., Hoffmann, M. (2014). Industry 4.0. *Business & Information Systems Engineering*, *6*, *4*, 239-242.
26. Lu, Y. (2017). Industry 4.0: A Survey on Technologies, Applications and Open Research Issues. *Journal of Industrial Information Integration, 6,* 1-10.
27. Lv, Y., Lee, C.K.M., Chan, H.K., Ip, W.H. (2012). RFID-based colored Petri net applied for quality monitoring in manufacturing system. *Int. J. Adv. Manuf. Technol*., *60*, 225-236.
28. Mitręga, M., Laskowska-Witek, J. (2015). Rutyny współtworzenia wartości z klientem – konceptualizacja i pomiar . *Zeszyty Naukowe Uniwersytetu Szczecińskiego. Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania, 39, T. 2, Zarządzanie*, 25-36.
29. Mostafa, N., Hamdy, W., Alawady, H. (2019). Impacts of Internet of Things on Supply Chains: A Framework for Warehousing. *Soc. Sci*., *8*, 84.
30. Munir, M.A., Habib, M.S., Hussain, A., Shahbaz, M.A., Qamar, A., Masood, T., Sultan, M., Mujtaba, M.A., Imran, S., Hasan, M. et al. (2022). Blockchain Adoption for Sustainable Supply Chain Management: Economic, Environmental, and Social Perspectives. *Front. Energy Res.*, *10*, 899632.

31. Nambisan, S. (2017). Digital Entrepreneurship: Toward a Digital Technology Perspective of Entrepreneurship. *Entrepreneurship Theory and Practice, 41, 6,* 1029-1055.
32. Nitsche, B., Straube, F. (2021). Defining the "New Normal" in International Logistics Networks: Lessons Learned and Implications of the COVID-19 Pandemic. *WiSt—Wirtsch Stud*., *50*, 16-25.
33. Pfohl, H.-Ch. (2016). *Supply Chain 4.0, Configuration of Cooperative Networks in Disruptive Environments*. Polish Logistics Congress 2016, Poznań 18th – 20th May 2016.
34. Pohludka, M., Stverkova, H., Ślusarczyk, B. (2018). Implementation and unification of the ERP system in a global company as a strategic decision for sustainable entrepreneurship. *Sustainability, 10(8),* 2916.
35. Rozados, I.V., Tjahjono, B. (2014). *Big data analytics in supply chain management: Trends and related research.* 6th International Conference on Operations and Supply Chain Management, Bali.
36. Ruijgrok, C.J., Tavasszy, L.A., Thissen, M.J. (2002). *Emerging global logistics networks*. STELLA Focus Group 1 Meeting Globalisation, e-economy and trade. Siena, 9-10 June, 2002.
37. Sawhney, M., Verona, G., Prandelli, E. (2005). Collaborating to create: The Internet as a platform for customer engagement in product innovation. *Journal of Interactive Marketing, 19(4),* p. 4.
38. Senn, C. (2019). The nine pillars of Industry 4.0, https://www.idashboards.com/blog/2019/07/31/the-pillars-of-industry-4-0/, 2019.02.07.
39. Shah, D., Rust, R.T., Parasuraman, A., Staelin, R., Day, G.S. (2006). The path to Customer-Centricity. *Journal of Service Research*, *9*(2), 113-124.
40. Shkurupskaya, I.O., Litovchenko, I.L. (2016). The Development of Marketing Communications Under the Influence of the Industry 4.0. *Scientific Proceedings I International Scientific Conference „Industry 4.0", Year XXIV, Vol. 2,* pp. 19-22.
41. Ślusarczyk, B. (2018). Industry 4.0: Are We Ready? *Polish Journal of Management Studies*, *17*(1), 232-248.
42. Ślusarczyk, B. (2019). Potencjalne rezultaty wprowadzania koncepcji przemysłu 4.0 w przedsiębiorstwach. *Przegląd Organizacji, 1(948),* 4-10. https://doi.org/10.33141/po.2019.01.01.
43. Stareček, A., Babeľová, Z.G., Vraňaková, N., Jurík, L. (2023). The impact of Industry 4.0 implementation on required general competencies of employees in the automotive sector. *Production Engineering Archives*, *29*(3), 254-262.
44. Szyszka, G. *Sieci logistyczne –nowy wymiar logistyki*. logistyka.net.pl, 16.10.2023.
45. Tabakow, M., Korczak, J., Franczyk, B. (2014). Big data – definicje, wyzwania i technologie informatyczne. *Informatyka Ekonomiczna, 1(31).*
46. Torbacki, W. (2018). *Metodyka wyboru i wdrożenia systemu ERP w dobie rozwoju Przemysłu 4.0.* In: R. Knosala (Ed.), IZIP 2018. Opole: OW PTZP, 716-727.

47. Torbacki, W. (2018). Transformacja logistyki w dobie koncepcji przemysł 4.0. Eksploatacja i testy. *Autobusy, 6,* 751-755.
48. Vargo, S.L., Maglio, P.P., Akaka, M.A. (2008). On value and value co-creation: A service systems and service logic perspective. *European Management Journal, 26*(3), pp. 145-152.
49. Wachnik, B. (2022). Analysis of the use of artificial intelligence in the management of Industry 4.0 projects. The perspective of Polish industry. *Production Engineering Archives, 28*(1), 56-63.
50. Waller, M.A., Fawcett, S.E.J.J.O.B.L. (2013). Data science, predictive analytics, and big data: a revolution that will transform supply chain design and management. *Journal of Business Logistics, 34(2),* 77-84. DOI: 10.1111/jbl.12010.
51. Wang, G., Gunasekaran, A., Ngai, E.W., Papadopoulos, T.J.I.J.O.P.E. (2016). Big data analytics in logistics and supply chain management: Certain investigations for research and applications. *International Journal of Production Economics, 176,* 98-110.
52. Wind, J., Rangaswamy, A. (2001). Customerization: The next revolution in mass customization. *Journal of Interactive Marketing, 15*(1), 13-32.
53. Witkowski, K.J.P.E. (2017). Internet of things, big data, Industry 4.0–innovative solutions in logistics and supply chains management. *Procedia Engineering, 182,* 763-769.

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PROCEDURE FOR THE INTRODUCTION OF DIETARY SUPPLEMENTS INTO THE MARKET – THE (IN)SECURITY OF LIBERAL REGULATIONS BASED ON THE EXAMPLE OF POLAND

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Purpose: The EU and national (especially Polish) rules of law on dietary supplements' marketing are relatively liberal. This creates potential opportunities and dangers in the market, especially for consumers. The aim of the paper was to analyse and assess the current regulations and to specify the required documentation for dietary supplements' marketing in the Republic of Poland.
Methodology: The study featured an analysis of literature concerning the current national and UE legislation as well as subject literature.
Findings: This resulted in the specification of the procedure for dietary supplements' marketing in Poland, the required documents and key aspects. The conducted studies and findings demonstrate that the marketing of supplements in Poland is not demanding.
Originality/value: The applicant must file the notification document to the Main Sanitary Inspectorate (MSI). Due to the above, this paper specifies the opportunities and dangers of adverse events deriving from the relevant regulations, especially for consumers. Hence, the paper encourages to continue the discussion on fundamental issues taken up in this elaboration at the international level.

Keywords: Supplement Dietary, Procedure for the Introduction, Regulations, Poland.

Category of the paper: Research paper.

1. Introduction

The market of supplements is characterised by unusual receptiveness, while globally demonstrating a continuous growing development trend – shown in Fig. 1 (Binns et al., 2018; Hys, 2018).

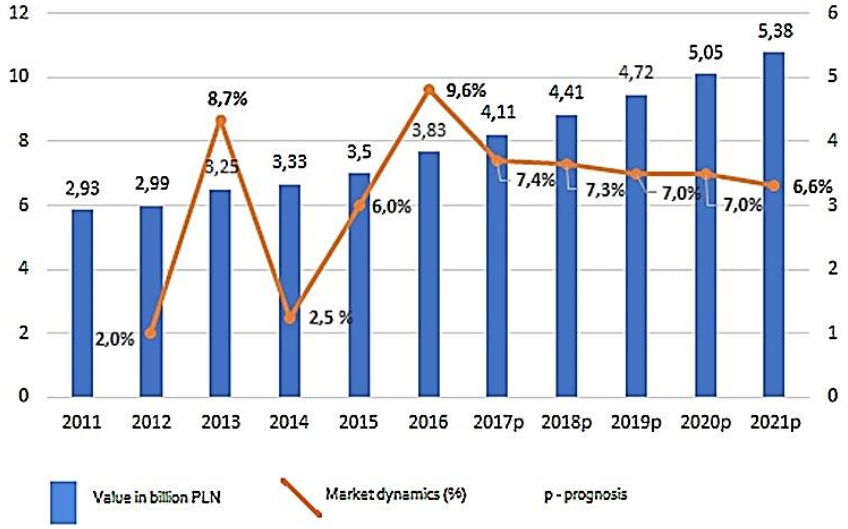

Figure 1. Dietary supplements market in Poland: values (in billions PLN) and dynamics (%), 2011-2020.

Source: Makowska, Jasiński, 2019.

Depending on interest groups articulated by the dietary supplement market's stakeholders (Hys, 2020; Hys, Koziarska, 2020, 2021), it seems important to take up the topic of identifying marketing procedures (Dickinson et al., 2015; Petroczi et al., 2011). This shall enable specifying certain relevant opportunities and restrictions for entrepreneurs (Brewster, Goldsmith, 2007). The term "dietary supplement" refers to a broad category of consumables whose primary function is to enhance the nutritional value of a person's regular diet by providing a more potent form of one or more nutrients (...) (Polish Journal of Laws; Dz.U. 2006, no. 171, item 1225, Article 3.3, paragraph 39). Dietary supplements were hence explicitly categorised as food. The institution that deals with providing scientific advice and notification on existing and emerging dangers related to the food chain in the European Union is the European Food Safety Authority – EFSA (European Food Safety Authority. Food Supplements).

In Poland, on the other hand, the institution that deals with supervising activities on public health, deriving from the citizens' use of dietary supplements, among others, is the Main Sanitary Inspectorate – MSI (Basic Information – Main Sanitary Inspectorate). In general, the EU's food law covers a series of complementary regulations, directives, executive acts and decisions issued by the European Commission (EC). It is necessary to mention, among others, the regulations on:

- specific product types (including dietary supplements, new food, GMO, additives, flavours, permissible contamination levels, trade standards),
- food information methods (e.g. labelling rules, food and health declarations),
- methods of conducting activity in the food sector (e.g. legal acts that regulate the requirements on hygiene, product identification, including the supply chain),
- risk management (e.g. official food controls or the RASFF system – Rapid Alert System for Food and Feed).

The review of the regulations on substances added to food, including dietary supplements, was developed by an international team of scientists (Magnuson et al., 2013; Tsokeva et al., 2016). The broad review presents a specification of the aforementioned regulations with reference to specific countries, such as: Argentina, Australia, Brazil, Canada, China, European Union, Japan, Mexico, New Zealand and the United States. The conducted analysis provides an image of the issue's multidimensionality and complexity. In addition, it features reference to institutions that are recognised counselling bodies and to the role they have in maintaining food safety (Chaloupkova et al., 2020; Vo Van Regnault et al., 2022). These include the following: Codex Alimentarius Commission (CAC) (WHO, International food standards, Codex Alimentarius, 2017) and the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

The issue of EU regulations on the safety of food, including dietary supplements, is continued in the international scientific discourse (Brewster, Goldsmith, 2007; Dwyer et al., 2018). By reviewing the EU regulations on dietary supplements, Pereira et al. (Pereira et al., 2017) specified the main food regulations (Fig. 2). The Directive 2002/46/EC (Directive 2002/46/EC) was the foundations of European law on food, including dietary supplements (Morrow, 2008). It can be assumed that the directive's adoption commenced the processes of deliberate food supplement management in all countries in the community (Skeie et al., 2009; Lim, Kirikoshi, 2008; Vissers, 1998).

According to the directive's entries, the legislation on dietary supplements' regulation is intended, among others, to facilitate the free movement of products in EU markets and provide consumers with access to products that pose no threat to their health or life (Justa Neves, Caldas, 2015; Directive 2002/46/EC). These products must be fitted with adequate labelling. In addition, the key regulations on dietary supplements include, among others, the following (Evans-Brown et al., 2019; Giunta et al., 2010; Pereira et al., 2017):

- Regulation (EC) No. 1924/2006 on nutrition and health claims on food.
- Directive 2000/13/EC, an EU statute that harmonises regulations among member states concerning food packaging and marketing.
- Labelling of goods in regards to their nutritional value (Directive 90/496/EEC).
- Directive 2006/37/EC of the European Parliament and of the Council of the European Union (Directive 2006/37/EC) - revising Annex II to Directive 2002/46/EC of the European Parliament and of the Council with respect to the inclusion of certain chemicals.

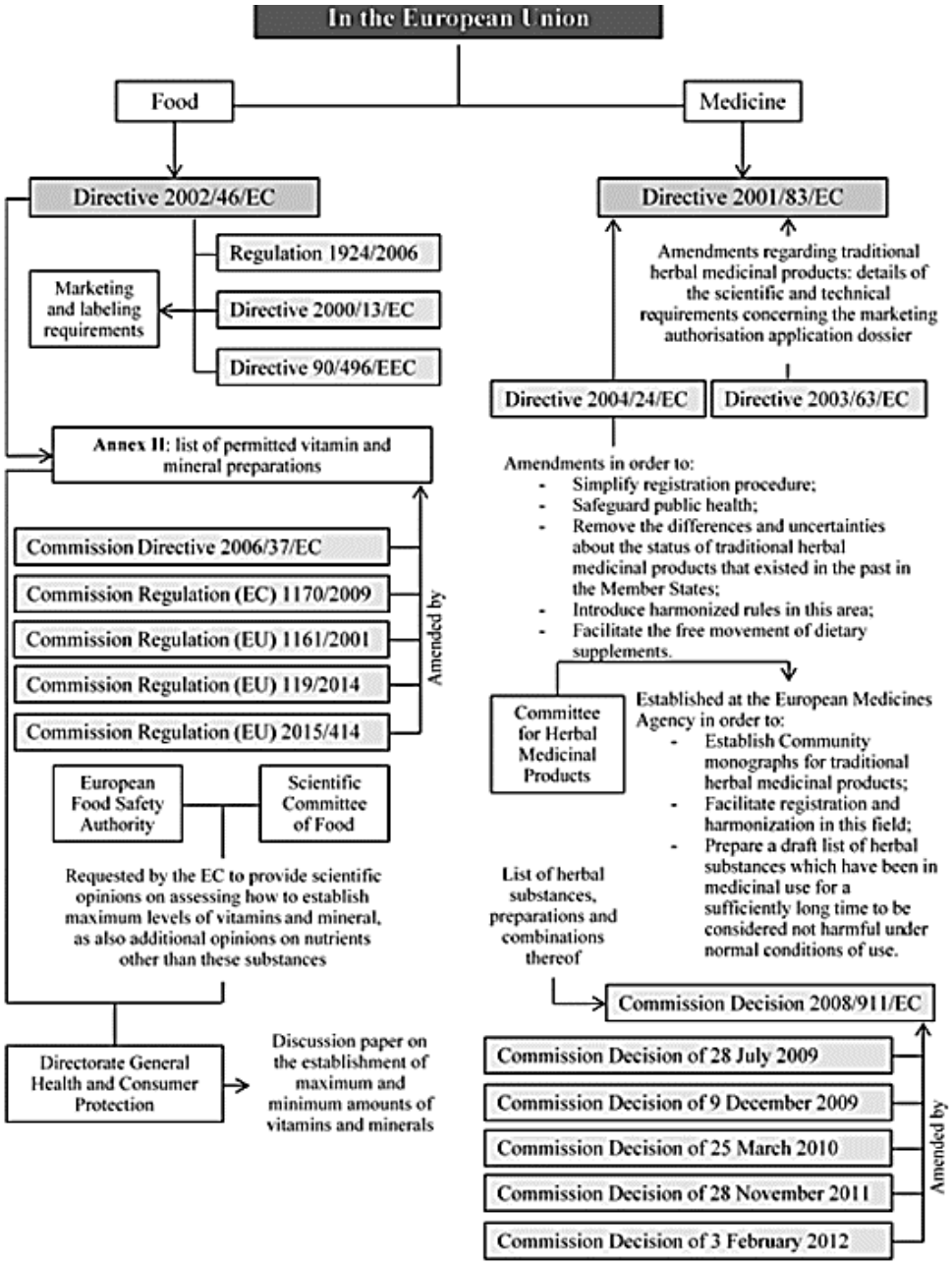

Figure 2. Overview of the legislation on dietary supplements in UE.

Source: Pereira et al., 2017.

- Regulation (EC) No 1170/2009 of the European Commission (Directive 2002/46/EC of the European Parliament and of the Council and Regulation (EC) No 1925/2006 of the European Parliament and of the Council as regards the lists of vitamin and mineral additives and their forms in foods and food supplements.
- Regulation (EU) No 1161/2011 of the European Parliament and of the Council amending Regulation (EC) No 1925/2006 of the European Parliament and of the Council and Commission Regulation (EC) No 953/2009 of the European Parliament and of the Council with respect to the lists of mineral substances that may be added to foods.

- Regulation (EU) No 119/2014 of the European Parliament and of the Council amending Directive (EC) No 1925/2006 of the European Parliament and of the Council with respect to chromium-enriched yeast used in the production of dietary supplements and chromium (III) lactate tri-hydrate added to foods.
- Directive 2002/46/EC of the European Parliament and of the Council as regards (6S) was amended by Regulation (EU) 2015/414 of the European Commission. Glucosamine salt of 5-methyltetrahydrofolate, a nutrient additive.

The paper is focused on the requirements applying to the marketing of dietary supplements in Poland (for public trading). Thereby, it attempts to refer to the guidelines regulating the dietary supplements' marketing in Poland. It is based on the current regulations from the point of view of enterprises that deal in the marketing of the aforementioned products.

2. Materials and methods

The aim of the paper is to present the current rules of law and the required documentation on the marketing of dietary supplements in the Republic of Poland, with consideration of the relevant EU regulations. The review of literature analysis methodology is shown in Figure 3.

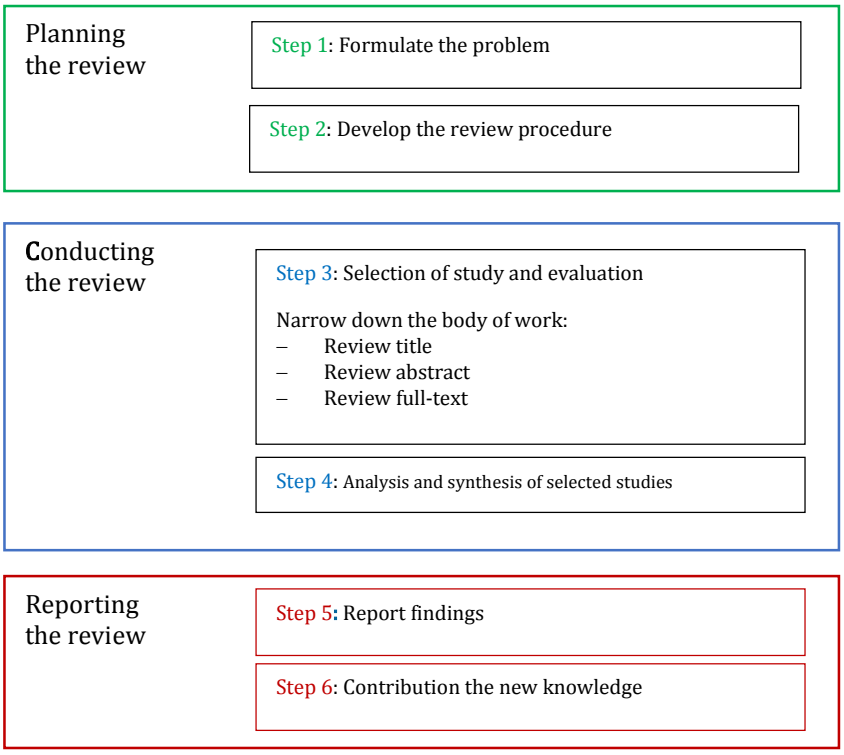

Figure 3. Review of literature analysis methodology.

The theses put forward by the authors is as follows: the current system for food safety, including dietary supplements, requires elaboration to adapt it to the current market conditions.

The paper features an analysis of literature concerning the current national and UE legislation as well as subject literature. The research was intended to present the current law on the dietary supplements' marketing based on the Polish example. It is especially intended to identify and specify the procedure and required documentation for the marketing of or the intent to market dietary supplements in the Republic of Poland. The performed research activities utilised the method of incomplete induction and document comparisons.

3. Results and discussions

3.1. Regulations on Dietary Supplements in Poland

Regardless of EU regulations, each member state is able to introduce their own detailed and complementary regulations, procedures and special requirements that are not regulated by EU law. This also applies to the system of notification on the dietary supplements' marketing in Poland. In the EU, the institution that supervises the safety of food products is the European Food Safety Authority (EFSA). In Poland, by contrast, this role was assigned to the Main Sanitary Inspectorate (MSI). The requirements on the safety of food and nutrition, including dietary supplements, are regulated in Poland with an act (Polish Journal of Laws; Dz.U. 2006, no. 171, item 1225) and the Regulation of the Minister of Health on the composition and labelling of dietary supplements (Polish Journal of Laws; Dz.U. of 2018, item 1951). These documents constitute the framework for the detailed national legislation, taking into account the requirements of the Directive of the European Parliament and of the Council, necessary to ensure food and nutritional safety (Directive 2002/46/EC) as well as the European Commission Regulation on additives that can be added to food (EC) no. 1170/2009 (Regulation (EC) No 1170/2009).

The Act on **food and nutritional** safety includes general conditions that must be met. These especially concern the additional substances and flavours, contaminants, pesticide residuals, food irradiation conditions, organoleptic features and activities that must be undertaken on all food production or trade stages to ensure the protection of human health and life (Act of 25 August 2006). Therefore, dietary supplements are admitted for trading in Poland by the Chief Sanitary Inspector (CSI). According to the act, in order to market or report the intent to market a dietary supplement, it is necessary to file a relevant notification to the CSI and present the packaging design (Act of 25 August 2006).

3.2. Marketing of Dietary Supplements in Poland

The path specifying the procedure for marketing a dietary supplement in Poland, including the legislation acts, institutions and required documents is presented in Figure 4.

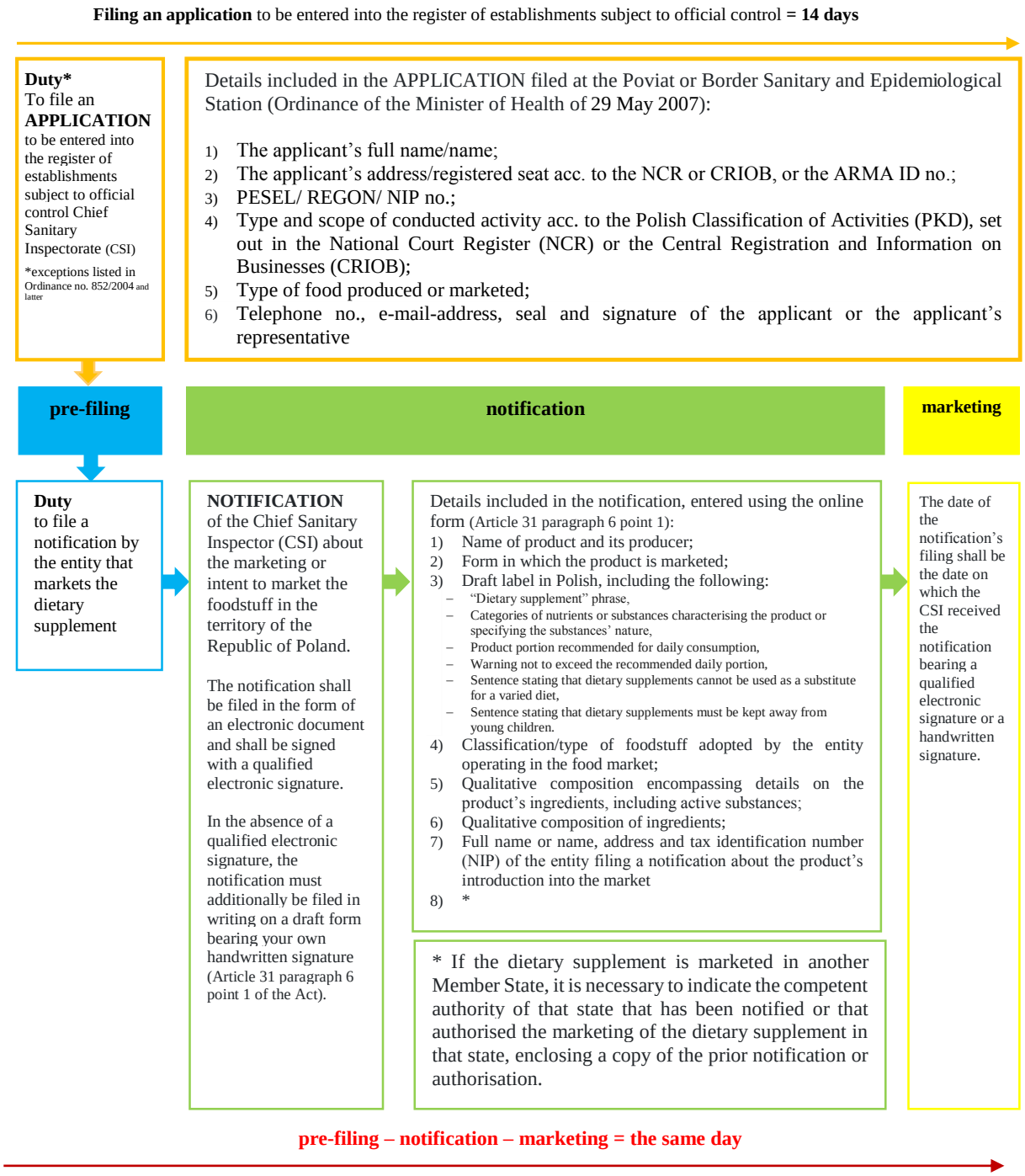

Figure 4. Procedure for the marketing of/intent to market a dietary supplement in Poland.

Due to the fact that the legal acts were presented in paragraph 3.1, this part of the paper will be focused on the notification form and its contents. The draft CSI notification form on products marketed in Poland was established in the Regulation of the Minister of Health (Polish Journal of Laws; Dz.U. 2019, item 2499).

The form is named "Notification about the marketing/intent to market in the Republic of Poland" (Appendix no. 1 to the Regulation of the Minister of Health of 21 December 2019). Firstly, the applicant is obliged to specify the identification details of the business entity that files the notification to the CSI. The identification details must especially include the full name of the person or the name and address of the entity filing the notification of the marketing of or intent to market a foodstuff, and its tax identification number (NIP). Then, the form includes an information clause specifying the legal entry that regulates the issue in Poland (Act of 25 August 2006).

Next, it is necessary to provide the CSI with information about the foodstuff's trade name, classification (type) and form. In terms of the foodstuff's *type*, the legislator proposes to use one of the foodstuff types mentioned in the adopted classification, i.e. dietary supplement, infant formula, follow-on formula, foodstuff replacing every-day diet, weight control foodstuff, enriched food, special medical purpose food. The definitions and distinction of particular categories was presented in relevant legal entries and discussed in scientific works (Polish Journal of Laws; Dz.U. 2019, item 2499; Appendix no. 1 to the Regulation of the Minister of Health of 21 December 2019; Food for Special Medical Purposes, 2017/C 401/01; Regulation (EU) No 609/2013; Directives 96/8/EC, 1999/21/EC, 2006/125/EC and 2006/141/EC, Directive 2009/39/EC).

In terms of the foodstuff's *form*, the legislator requires the applicant to specify (Appendix no. 1 to the Regulation of the Minister of Health of 21 December 2019) the ingredient's name, content (quantity per 100 g quantity per 100ml), quantity in a daily portion as well as additional information. Additional information is a category of information concerning ingredient features that ensure their explicit identification. It is important for plant products to specify the following data (Appendix no. 1 to the Regulation of the Minister of Health of 21 December 2019): Latin species name, plant part, plant ingredient form, concentration, ingredients with a physiological effect. On the other hand, in terms of mineral components and vitamins, it is necessary to specify the chemical form and origin of the components, while for other ingredients it is necessary to specify the information specific to the given ingredient type (chemical form, bacteria strain, origin) (Appendix no. 1 to the Regulation of the Minister of Health of 21 December 2019).

Furthermore, the applicant must specify the producer's personal details or name and address. If the given foodstuff was already marketed in other EU member state(s) and if it is required to provide notification about this fact, the notification must include the name of the state body notified or that permitted the marketing of the foodstuff in their state.

The regulation also requires providing appendices to the notification, especially 1) draft labelling in Polish and 2) copy of notification filed or permit obtained in another EU member state. The draft labelling should include the necessary information that enable the evaluation of the adopted foodstuff classification (Regulation (EU) No 1169/2011).

The notification can be delivered to the CSI in two ways: in a traditional paper copy form via any certified mail institution or in an electronic form (the so-called e-notification) with a digital signature. The detailed recommendations and stages of procedure are specified in the so-called user station instructions for the Electronic Notifications System (ENS) available on the CSI's website (User instructions in the workplace Electronic Notification System (ESP).

Aside from formal requirements, it must be noted that filing a dietary supplement notification at the CSI does not require paying any official fees. On one hand, this complies with the Directive's entries (Directive 2002/46/EC) as it makes it possible for any entity that meets the statutory conditions and ensures free access to these products to consumers to market dietary supplements. On the other hand, it is possible to state that there are no barriers to enter the market, thereby leading to market pathologies evidenced by official food control reports (e.g. the RASFF system, Supreme Audit Office's report). It can be noted that the marketing of dietary supplements in Poland features no quality control (RASFF – food and feed safety alert; Annual Reports of the Supreme Audit Office, 2017).

It is also not required to present the results of substance stability testing (Bojarowicz et al., 2012; Bojarowicz & Dźwigulska, 2012a, 2012b). Furthermore, dietary supplements are not tested in terms of possible interactions with medicine or other food substances, are not subject to pharmaceutical supervision control and are not monitored in terms of adverse effects. As result of the conducted inspections, the Supreme Audit Office also pointed to numerous violations in this scope (SAO's Report, 2017).

Moreover, in the case of dietary supplements, the legislator did not introduce the obligation to enclose a factsheet and only included entries on the information that must be placed on the packaging. The applicant is obliged to provide the following information on the packaging (Polish Journal of Laws; Dz. U. of 2018, item 1951): the "dietary supplement" phrase; category of nutrients or substances characterising the product or disclosing the substances' nature; product portion recommended for daily consumption; warning not to exceed the daily portion; sentence stating that dietary supplements cannot be used as a substitute for a varied diet; sentence stating that dietary supplements must be kept away from young children.

Therefore, the entries required on the packaging of dietary supplements are placed only for information, or even symbolic, purposes. From the consumer's viewpoint, the information placed on packaging does not provide useful information and the legislator's relevant liberal entries can enable incorrect or even criminal activities for dishonest applicants. On the other hand, in terms of factsheets that could be required for dietary supplements, two approaches are used in practice: there are none or are minimalistic. This means that factsheets contain limited information or information repeated from the packaging on indications, dosage, warning that

the preparations must not be used during pregnancy and breast feeding as well as preparations available for purchase. They are missing, as in the case of medicinal products, such information as: dosage, administration method and route, administration frequency, treatment duration, symptoms and procedure in case of over dosage, procedure if a dose is omitted, risk of withdrawal syndrome, specification of adverse effects, expiration date, specification of special storage conditions, specification of changes indicating deterioration of the product's quality, weight, volume or number of dosage units, the responsible entity's name and address, name and address of the producer or importer at which the series is released (…) (Polish Journal of Laws; Dz.U. no. 39, item 321; Polish Journal of Laws; Dz.U. no. 84, item 551). A comparison between a dietary supplement's leaflet and a medicinal product's leaflet is justified as in their publications, scientists raise the issue that consumers equate these two products and treat them as symbiotic (Angell, Kassirer, 1998; Dodge et al., 2011).

In addition, the published results of food safety inspections conducted by various institutes point to irregularities, including falsification of dietary supplements. In Poland, the CSI's website publishes warnings about hazardous products and decisions on the withdrawal of a particular dietary supplement from the market (if the supplement does not meet the requirements) (SAO's Report, 2017). Nevertheless, researchers specify the most common errors, including (Annual Report, The EU Agri-Food Fraud Network and the Administrative Assistance and Cooperation System): labelling, substitution of a declared ingredient (with a different one or with lower quality), lower "active" substance content than declared in the labelling as well as unauthorised substances content, irregularities related to documentation (including missing, falsified, forged documents), use of unlawful processing and intellectual property violations.

The specified irregularities provide further critical issues to the discussion and it is fundamental to implement an efficient system to monitor the correctness of marketed dietary supplements. Due to the above, the authors suggest to take regulatory action and solve the issue of preventing, according to the rules of law, the marketing of dietary supplements that are ineffective and may be hazardous to the consumers' health and life.

4. Conclusion

The observed rapid technical progress and development of production devices prevent regulations and legislations (both national and EU) from keeping up with regulating the dietary supplements market and the safety system requirements, especially for consumers and their interests. It must be noted that the adoption of the Directive 2002/46/EC (Directive 2002/46/EC) commenced the processes of deliberate food supplement management in all countries in the community. Nevertheless, these processes are insufficient and require further action (Sir Macara, 2002).

- This refers, among others, to liberal regulations on the provided consumer information, terminology inaccuracies, easy marketing of dietary supplements, no fees, etc. It is possible to notice that in this situation the barrier to enter the dietary supplements market is small, making it easy for pathologies (including food falsification) to occur. For consumers, it can cause bad decisions, financial losses and health disorders in extreme cases.
- In summary, it is possible to state that the specified procedure for marketing of dietary supplements in the Republic of Poland is reprehensibly liberal (undemanding). The notification form is not complicated. The applicant pays no fees related to the notification. There are also no regulations on factsheet contents.
- All of the above activities are only administrative in nature and in terms of numerous identified irregularities they should engage the legislator to define further non-liberal regulations that would prevent the occurrence of pathologies in the market. It is suggested to implement a systemic, community-wide support for food safety monitoring (control) institutions.
- It is important to resolve the following dilemmas: is the supervision system sensitive to irregularities in the current food safety system and whether it can eliminate any deviations and pathologies related to dietary supplements to in order to prevent endangering consumer health?

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Author contributions

All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by [Hys Katarzyna], [Dominika Matuszek], [Krzysztof Olejnik] and [Karol Bierczyński]. The first draft of the manuscript was written by [Katarzyna Hys] and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

Conceptualization: [Hys Katarzyna]; Methodology: [Hys Katarzyna], [Dominika Matuszek], [Krzysztof Olejnik] and [Karol Bierczyński]; Formal analysis and investigation: [Hys Katarzyna]; Writing - original draft preparation: [Hys Katarzyna]; Review and editing:

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References

1. Act of 25 August 2006 on food and nutritional safety (Polish Journal of Laws; Dz.U. 2006, no. 171, item 1225, Article 3.3, paragraph 39).
2. Angell, M., Kassirer, J.P. (1998). Alternative medicine—the risks of untested and unregulated remedies. *N. Engl. J. Med., vol. 339,* 839-841.
3. Annual Report, The EU Agri-Food Fraud Network and the Administrative Assistance and Cooperation System (2020). Available: https://ec.europa.eu/food/system/files/2021-09/ff_ffn_annual-eport_2020_1.pdf
4. Annual Reports of the Supreme Audit Office (2017). Available: https://www.nik.gov.pl/en/nik-audits/annual-reports
5. Appendix no. 1 to the Regulation of the Minister of Health of 21 December 2019 (item 2499).
6. Basic Information – Main Sanitary Inspectorate. Available: www.gov.pl
7. Binns, C.W., Lee, M.K., Lee, A.H. (2018). Problems and Prospects: Public Health Regulation of Dietary Supplements. *Annual Review of Public Health, vol. 39,* 403-20, doi:10.1146/annurev-publhealth-040617-013638. PMCID:29272167
8. Bojarowicz, H., Dźwigulska, P. (2012). Suplementy diety. Część I. Suplementy diety a leki – porównanie wymagań prawnych (Dietary supplements. Part I. Dietary supplements and drugs – comparison of legal requirements). *Hygeia Public Health, vol. 47(4),* 427-432.
9. Bojarowicz, H., Dźwigulska, P. (2012). Suplementy diety. Część II. Wybrane składniki suplementów diety oraz ich przeznaczenie (Dietary supplements. Part II. Selected components of dietary supplements and their application). *Hygeia Public Health, vol. 47(4),* 433-441.
10. Bojarowicz, H., Dźwigulska, P. (2012). Suplementy diety. Część III. Interakcje suplementów diety z lekami (Dietary supplements. Part III. Interaction between dietary supplements and drugs). *Hygeia Public Health, vol. 47(4),* 442-447.
11. Brewster, N.A.T., Goldsmith, P.D. (2007). Legal systems, institutional environment, and food safety. *Agric. Econ., vol. 36,* 23-38.
12. Chaloupkova, P., Petrtyl, M., Verner, V., Kokoska, L. (2020). Dietary supplements versus functional foods: Consumers' attitudes to their consumption. *British Food Journal, vol. 122(12),* 3853-3868, doi: 10.1108/BFJ-10-2019-0767.

13. Commission Directive 2006/37/EC of 30 March 2006 amending Annex II to Directive 2002/46/EC of the European Parliament and of the Council as regards the inclusion of certain substances.
14. Commission Directives 96/8/EC, 1999/21/EC, 2006/125/EC and 2006/141/EC, Directive 2009/39/EC of the European Parliament and of the Council and Commission Regulations (EC) No 41/2009 and (EC) No 953/2009 (OJ L 181, 29.6.2013, p. 35).
15. Commission Regulation (EC) No 1170/2009 of 30 November 2009 as regards the lists of vitamin and minerals and their forms that can be added to foods, including food supplements.
16. Commission Regulation (EC) No 953/2009 of 13 October 2009 on substances that may be added for specific nutritional purposes in foods for particular nutritional uses.
17. Commission Regulation (EU) 2015/414 of 12 March 2015 as regards (6S)-5-methyltetrahydrofolic acid, glucosamine salt used in the manufacture of food supplements.
18. Commission Regulation (EU) No 1161/2011 of 14 November 2011 as regards the lists of mineral substances that can be added to foods.
19. Commission Regulation (EU) No 119/2014 of 7 February 2014 as regards chromium enriched yeast used for the manufacture of food supplements and chromium(III) lactate tri-hydrate added to foods.
20. Council Directive of 24 September 1990 on nutrition labelling for foodstuffs (90/496/EEC).
21. da Justa Neves, D.B., Caldas, E.D. (2015). Dietary supplements: International legal framework and adulteration profiles, and characteristics of products on the Brazilian clandestine market. *Regulatory Toxicology and Pharmacology*, *vol. 73*, 93-104, http://dx.doi.org/10.1016/j.yrtph.2015.06.013
22. Dickinson, A., Blatman, J., El-Dash, N., Franco, J.C. (2018). Consumer usage and reasons for using dietary supplement: report of series of surveys. *J. Am. Coll. Nutr.*, *vol. 33(2)*, 176-182.
23. Directive 2000/13/EC of the European Parliament and of the Council of 20 March 2000 on the approximation of the laws of the Member States relating to the labelling, presentation and advertising of foodstuffs.
24. Directive 2002/46/EC of the European Parliament and of the Council of 10 June 2002 on the approximation of the laws of the Member States relating to food supplements.
25. Dodge, T., Litt, D., Kaufman, A. (2011). Influence of the dietary supplement health and education act on consumer beliefs about the safety and effectiveness of dietary supplements. *J. Health Commun.*, *vol. 16*, 230-244, doi:10.1080/10810730.2010.529493
26. Dwyer, J.T., Coates, P.M., Smith, M.J. (2018). Dietary Supplements: Regulatory Challenges and Research Resources. *Nutrients, 10(1),* 41, doi: 10.3390/nu10010041. PMID: 29300341; PMCID: PMC5793269.
27. European Food Safety Authority. *Food Supplements*. Available: www.efsa.europa.eu/en/topics/topic/foodsupplement

28. Evans-Brown, M., Sedefov, R. (2018). Responding to new psychoactive substances in the European Union: Early warning, risk assessment, and control measures. *Handb Exp Pharmacol, 252,* 3-49, doi:10.1007/164_2018_160
29. Giunta, R., Basile, G., Tibuzzi, A. (2010). Legislation on Nutraceuticals and Food Supplements: A Comparison between Regulations in USA and EU. In: M.T. Giardi, G. Rea, B. Berra (eds.), *Bio-Farms for Nutraceuticals*. *Advances in Experimental Medicine and Biology, vol. 698.* Boston, MA: Springer, https://doi.org/10.1007/978-1-4419-7347-4_24
30. Hys, K., Koziarska, A. (2021). Supplementary Product Forms: Analysis of Polish Market Trends. *European Research Studies Journal, vol. 24, iss. 4B,* 982-996, doi:10.35808/ersj/2825.
31. Hys, K., Koziarska, A. (2020). Supply Analysis of Supplementary Products in Poland. *European Research Studies Journal, vol. 23, special iss. 1,* 549-571, doi:10.35808/ersj/1777.
32. Hys, K. (2018). Healthcare products and food supplements in Poland – a comparison. *MATEC Web Conf., vol. 183, no. 01006.* R. Ulewicz, B. Hadzima (Eds.), https://doi.org/10.1051/matecconf/201818301006.
33. Hys, K. (2020). Identification of the reasons why individual consumers purchase dietary supplements. In: W. Sroka (ed.), *Perspectives on Consumer Behaviour. Theoretical Aspects and Practical Applications* (pp. 193-209). Contributions to Management Science, Springer.
34. Information from European Union Institutions, Bodies, Offices And Agencies European Commission Notice on the classification of Food for Special Medical Purposes (2017/C401/01).
35. Khan, S.U., Khan, M.U., Riaz, H., Valavoor, S., Zhao, D., Vaughan, L., Okunrintemi, V., Bin Riaz, I., Shahzeb Khan, M., Kaluski, E., Murad, M.H., Blaha, M.J., Guallar, E., Michos, E.D. (2019). Effects of Nutritional Supplements and Dietary Interventions on Cardiovascular Outcomes. *Annals of Internal Medicine, vol. 171(3),* 190, doi:10.7326/M19-0341.
36. Lim, C.W., Kirikoshi, T. (2008). Understanding the effects of pharmaceutical promotion: a neural network approach guided by genetic algorithm-partial least squares. *Health Care Manage. Sci., 11,* 359-372 https://doi.org/10.1007/s10729-008-9053-z
37. Lisiński, M. (2016). Procedury naukowe indukcji zupełnej i niezupełnej w metodologii nauk o zarządzaniu. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie, no. 6(954).*
38. Magnuson, B., Munro, I., Abbot, P., Baldwin, N., Lopez-Garcia, R., Ly K., McGirr, L., Roberts A., Socolovsky S. (2013). Review of the regulation and safety assessment of food substances in various countries and jurisdictions. *Food Additives & Contaminants: Part A, vol. 30(7),* 1147-1220, doi: 10.1080/19440049.2013.795293

39. Makowska, M., Jasiński, Ł. (2019). A discussion of the unresolved 2016/17 plans for regulating the Polish dietary supplements market. *Health Policy, vol. 123, iss. 6,* 544-549, doi.org/10.1016/j.healthpol.2019.04.001
40. Morrow, J.D. (2008). Why the United States Still Needs Improved Dietary Supplement Regulation and Oversight. *Clinical Pharmacology & Therapeutics, vol. 83, no. 3,* 391, doi:10.1038/sj.clpt.6100500
41. Pereira, C., Barros, L., Ferreira, I.C.F.R. (2017). Dietary Supplements: Foods, Medicines, or Both? A Controversial Designation with Unspecific Legislation. *Current Pharmaceutical Design, vol. 23(19),* 2722-2730, doi: https://doi.org/10.2174/ 138161282366170117122801
42. Petroczi, A., Taylor, G., Naughton, D.P. (2011). Mission impossible? Regulatory and enforcement issues to ensure safety of dietary supplements. *Food Chem. Toxicol., vol. 49,* 393-402.
43. *RASFF – food and feed safety alerts*. Available: https:// food.ec.europa.eu/safety/rasff-food-and-feed-safetyalerts_en
44. Regulation (EC) No 1924/2006 of the European Parliament and of the Council of 20 December 2006 on nutrition and health claims made on food.
45. Regulation (EC) No 1925/2006 of the European Parliament and of the Council of 20 December 2006 on the addition of vitamins and minerals and of certain other substances to food.
46. Regulation (EU) No 1169/2011 of the European Parliament and of the Council of 25 October 2011 on the provision of food information to consumers.
47. Regulation of the Minister of Health of 20 February 2009 on the requirements for labelling of medical product packaging and leaflet contents (Polish Journal of Laws; Dz.U. no. 39, item 321).
48. Regulation of the Minister of Health of 21 December 2019 amending the Regulation on the draft notification form on products marketed in the Republic of Poland, registry of products covered by the notification and the list of national scientific bodies with jurisdiction to issue opinions. Polish Journal of Laws; Dz.U. 2019, item 2499).
49. Regulation of the Minister of Health of 26 April 2010 on leaflet legibility testing (Polish Journal of Laws; Dz.U. no. 84, item 551).
50. Regulation of the Minister of Health of 9 October 2007 on the composition and labelling of dietary supplements (Polish Journal of Laws; Dz.U. of 2018, item 1951).
51. *SAO's Report* (2017). Available: https://www.nik.gov.pl/
52. Sir Macara, A. (2002). Managing for Health: Why Health Care? *Health Care Management Science, 5,* 239-242.
53. Skeie, G., Braaten, T., Hjartaker, A., Lentjes, M. (2009). Use of dietary supplements in the European Prospective Investigation into Cancer and Nutrition calibration study. *Eur. J. Clin. Nutr., vol. 63,* 226-238.

54. Tsokeva, Zh., Sokolova, K., Ganeva, M. (2016). Dietary supplements: issues related to their legislation and safety monitoring. *Pharmacia, vol. 63, no. 3*.
55. *User instructions in the workplace Electronic Notification System (ESP).* Available: https://powiadomienia.gis.gov.pl/esp/manuals/instrukcje%20stanowiskowe%20-%20pracownik%20przedsiebiorstwa.pdf
56. Van Regnault, G.Vo, Costa, M.C., Adanić Pajić, A., Bico, A.P., Bischofova, S., Blaznik, U., Menniti-Ippolito, F., Pilegaard, K., Rodrigues, C., Margaritis, I. (2021). The need for European harmonization of Nutrivigilance in a public health perspective: a comprehensive review. *Critical Reviews in Food Science and Nutrition*, doi: 10.1080/10408398.2021.1926904
57. Vissers, J.M. (1998). Health care management modelling: a process perspective. *Health Care Management Science, 1,* 77-85, https://doi.org/10.1023/A: 1019042518494
58. WHO (World Health Organ.) (2017). *International food standards (Codex Alimentarius).* Geneva. Available: http://www.who.int/foodsafety/areas_work/food-standard/en

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ECONOMIC CRISES – CAUSES, EFFECTS AND WAYS TO OVERCOME

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Purpose: The aim of the research undertaken in the article is to review the greatest crises of modern times, starting from 1997, when the Asian crisis broke out, to the last global crisis, which was the pandemic crisis. In particular, the causes, effects and ways of overcoming crises were analyzed.
Design/methodology/approach: The article consists of literature studies, which review publications on the greatest crises that have affected the economy in recent years. The research allowed us to determine the scale of subsequent economic crises occurring in global economies in recent years.
Findings: During the research, an attempt was made to identify the causes, effects and ways of overcoming crises
Research limitations/implications: Based on the research conducted, implications for the future can be identified. They may concern stimulating selected elements of the economic environment in such a way that it would effectively translate into positive effects for the economy.
Practical implications: The practical implications of the obtained results may concern the further use by decision-makers of appropriate instruments, which, introduced in times of crises, brought positive effects for the economy. Using them in post-crisis conditions, or building similar tools on their basis, may bring the desired economic effect. Examples include monetary or fiscal policy instruments.
Social implications: What will be the impact on society of this research? How will it influence public attitudes? How will it influence (corporate) social responsibility or environmental issues? How could it inform public or industry policy? How might it affect quality of life? Not all papers will have social implications.
Originality/value: The article compares the crisis conditions that occurred during recent major economic crises. The value of such research is the ability to stimulate positive economic effects by using the same or modified tools that were used during the crisis.

Keywords: pandemic crisis, Asian crisis, Russian crisis, financial crisis, economy.

Category of the paper: Research paper.

1. Introduction

The pandemic crisis is one of the last major crises that the modern economy has had to face in recent years. In 1997, the Asian crisis broke out, followed by the Russian crisis in 1998 and the global financial crisis in 2008. Each of these crises has had significant effects on the global economy, in particular causing serious economic consequences. Taking into account these circumstances accompanying the greatest crises, the purpose of the research undertaken in the article was determined. The aim of the research is to review the greatest crises of modern times, starting from 1997, when the Asian crisis broke out, to the last global crisis, which was the pandemic crisis. In particular, the causes, effects and ways of overcoming crises were analyzed.

The article is based on literature studies, which included a review of publications on the greatest crises that have affected the economy in recent years. The research allowed us to determine the scale of subsequent economic crises that have appeared in recent years in world economies, determine their causes, effects and indicate ways of combating them.

2. The concept of crisis

In today's times, characterized by high uncertainty, business activity is associated with constant risk. In such conditions, crises are no longer perceived as states of emergency, but are an inherent feature of the modern economy.

The word crisis is one of the most frequently used concepts nowadays (Barton, 1993). It comes from the Greek "krino" and means a turning point, a breakthrough, a decisive moment, a qualitative change in a system or in a system (Dictionary of foreign words, 1980). The word "crisis" in English expands the meaning of this concept to include such features as suddenness, traumatic nature and subjective consequences of trauma in the form of negative experiences. Generally speaking, a crisis can be defined as a sudden or growing event, threatening human life, health, property and the environment, countering which requires the involvement of forces and resources that sometimes exceed local capabilities (Kitler, Wiśniewski, Prońko, 2000). A similar definition is provided by Otwinowski: a crisis is the culminating phase of a growing threat situation, arising as a result of unexpected circumstances. In this phase, the dominant role is played by the fact of a real or perceived loss of control over the developing situation and the lack of a concept for controlling it (Otwinowski, Crisis and crisis situation, 2010). According to Kopaliński's dictionary, a crisis is a moment, a period of breakthrough, crisis, decisive turn, a period of economic collapse (Kopaliński, 1968).

Crises most often have several causes, with one predominating, which is the basis for the crisis and at the same time may be a turning point towards improving or worsening the situation. The crisis intensifies as existing problems worsen or new ones emerge. This situation is most often accompanied by general destabilization and the so-called domino effect. Moreover, Clarke states that a crisis is the result not only of the danger itself (threat to a basic value), but above all of the circumstances in which it occurred. Most likely, in other circumstances, the same threat would not mean that we or our organization would be in crisis. There are many different categories of crises. We may be dealing with a social, economic, economic, ecological, political, military crisis, etc. (Goldstein, Razin, 2015.). Regardless of the type of crisis, certain common features of this type of situation can be identified. First of all, in each case we are faced with limited decision-making time. There is also an element of surprise here - we cannot fully predict what the consequences of the decisions made or the solutions used will be. In a crisis situation, managers work under strong time and environmental pressure. In addition, other typical features of crises can be indicated, including (Conference Materials, 1998):

- surprise,
- information deficit,
- delayed reactions,
- events are becoming more and more dangerous,
- loss of control, real or perceived,
- threat to interests,
- increase in mental tension,
- meticulous external control (media, public opinion),
- the formation of the mentality of the besieged,
- panic,
- interruption of normal decision-making processes.

Every crisis is a challenge to society's sense of normality, tradition, values and security. In recent years, we have experienced several significant economic crises that have had repercussions on the global economy. The first of them was the Asian crisis that broke out in 1997 and the Russian crisis that followed it in 1998. Ten years later - in 2008, the global financial crisis occurred. However, in 2020, a pandemic crisis broke out.

3. Asian crisis

The 1997 Asian crisis was an economic phenomenon that affected many countries in East and Southeast Asia, such as Thailand, Indonesia, Malaysia, the Philippines and South Korea. It began with the devaluation of the Thai baht in June 1997. This triggered speculative

transactions in other currencies in the region, linked to the US dollar (World Bank, 1998). As a result, currency rates fell by over 50%, and the value of assets of enterprises from the above countries listed on stock exchanges decreased sharply (Alba, Bhattacharya, Claessens, Hernandez, 1998). However, the causes of this crisis were more complex and varied depending on the country. The phenomena that are also the factors driving the Asian crisis include: (Pisany, 2020):

- excessive debt in foreign currencies that became increasingly difficult to repay as domestic currencies weakened,
- trade imbalance, consisting of excessive imports and insufficient exports, which resulted in a current account deficit,
- weakness of the banking system and financial supervision, which allowed abuses, corruption and inefficient allocation of capital,
- rigid currency systems that maintained artificially high exchange rates and limited the flexibility of monetary policy,
- too fast economic growth, which led to overheating of the economy and the creation of a speculative bubble.

The Asian crisis led to the bankruptcy of many enterprises and banks, increased unemployment and poverty, and a decline in GDP and economic confidence. The crisis also had negative effects on the global economy, especially Japan, the United States and Europe (Chang, 2017). The 1997 Asian crisis was an important lesson for the region and the world, demonstrating the need for better risk management, greater transparency and international cooperation. The crisis also resulted in a change in the economic development model in Asia, which became more sustainable, diversified and based on domestic demand. Most countries affected by the crisis turned to the International Monetary Fund (IMF), which provided them with loans in exchange for introducing strict adjustment programs. These programs included increasing interest rates, cutting public spending, privatization and liberalizing markets. Thanks to such aid, many countries managed to rebuild and achieve high economic growth in the following years.

4. Russian crisis

Immediately after the Asian crisis, in 1998, there was a Russian crisis. It was an economic phenomenon that affected Russia and other countries after the Asian crisis. The crisis began with Russia's failure to repay its foreign debt in August 1998, which resulted in the devaluation of the ruble, the collapse of the securities and banking markets, increased inflation and poverty, as well as a political crisis (Melich, 2000). The causes of this crisis also include:

- excessive debt in foreign currencies, which became increasingly difficult to repay as the domestic currency weakened,
- trade imbalance of excessive imports and insufficient exports, which resulted in a current account deficit,
- weakness of the banking system and financial supervision, which allowed abuses, corruption and inefficient allocation of capital,
- rigid currency systems that maintained artificially high exchange rates and limited the flexibility of monetary policy,
- too fast economic growth, which led to overheating of the economy and the creation of a speculative bubble (Domańska, 2017).

In order to contain the crisis, Russia turned to the International Monetary Fund (IMF), which granted it loans in exchange for introducing strict adjustment programs. These programs included increasing interest rates, cutting public spending, privatization and liberalizing markets. However, some critics believed that these programs deepened the recession and increased social inequality.

The Russian crisis of 1998 was an important lesson for Russia and the world, demonstrating the need for better risk management, greater transparency and international cooperation. The crisis also resulted in a change in the model of economic development in Russia, which became more sustainable, diversified and based on domestic demand. Most economic sectors managed to recover and achieve high economic growth in the following years.

5. Global financial crisis

The 2008 global financial crisis was a worldwide collapse in financial and banking markets that began with the subprime mortgage crisis in the United States. However, the causes of the crisis were much more complex and varied depending on the country and sector. The most important causes of this crisis include (Czekaj, 2010):

- excessive debt in foreign currencies that became increasingly difficult to repay as domestic currencies weakened,
- trade imbalance, consisting of excessive imports and insufficient exports, which resulted in a current account deficit,
- weakness of the banking system and financial supervision, which allowed abuses, corruption and inefficient allocation of capital,
- rigid currency systems that maintained artificially high exchange rates and limited the flexibility of monetary policy,

- too fast economic growth, which led to overheating of the economy and the creation of a speculative bubble,
- widespread use of securitization and credit derivatives to distribute risk and increase financial leverage,
- a significant share in market transactions of an alternative banking system exempt from supervision (shadow banking system).

The 2008 financial crisis had serious consequences for the global economy, including:

- decline in GDP, increase in unemployment and poverty in many countries,
- collapse or takeover of many banks and other financial institutions,
- loss of savings and trust by many investors and consumers.

The countries that suffered the most from the financial crisis include: the United States, European Union countries (including Greece, Spain, Portugal, Ireland, Italy), Iceland, Great Britain, China, Japan, and India. However, the impact of the financial crisis was felt around the world, and its effects lasted for many years after the crisis broke out (Nawrot, 2009).

In order to overcome the crisis, the intervention of governments and central banks was necessary, thanks to which the financial system was saved and economic growth was initiated. A fundamental step taken by many countries was to introduce regulatory and supervisory reforms to prevent similar crises in the future. Regulatory rules have been strengthened and regulators have begun to closely monitor banks and other financial institutions. Capital and liquidity requirements have been increased and the level of investment risk has been reduced. Many countries have also strengthened their deposit protection systems to prevent bank customers from losing their savings. In addition, to reduce the risks associated with excessive debt levels, many countries have taken steps to reduce budget deficits and increase control over spending.

Thanks to the above actions, positive effects were achieved. One of them was that many countries introduced more stringent regulations regulating the financial sector in order to prevent similar crises in the future (Glucksmann, 2008). Moreover, the financial crisis increased people's awareness of the risks associated with investments and other financial aspects, which allowed for better risk management. The crisis also caused an increase in interest in finance and prompted many people to deepen their knowledge in this field. As a result of the financial crisis, many companies began to look for new ways to survive, which led to increased innovation in many sectors of the economy (Wague, 2009).

6. Pandemic crisis

The pandemic crisis that occurred in 2020-2022 consisted of the occurrence and spread of the infectious disease COVID-19, caused by the new coronavirus SARS-CoV-2. This crisis has had serious consequences for people's health and lives, as well as for the economy, society and politics. In Poland, over 6.5 million cases of infections and over 119,000 deaths due to COVID-19 have been recorded. The most cases and deaths occurred in November 2020 and April 2021 (Central Statistical Office, 2023).

To prevent the spread of the virus, the government has introduced many restrictions and sanitary recommendations, such as wearing masks, maintaining social distance, limiting contacts, closing schools, universities, restaurants, cinemas, theaters, gyms, shopping malls, hairdressing salons, banning gatherings, and restricting movement. on, introduction of quarantine and isolation for infected and suspected infected people, etc. (Economy after pandemic..., 2023).

To counteract the negative effects of the crisis on the economy and society, governments of individual countries implemented appropriate assistance measures. The Polish government adopted several assistance packages, such as the anti-crisis shield, financial shield, sectoral shield, and reconstruction fund (Ścieżki fiskalne po kryzysie, 2023). The total value of these measures amounted to over 400 billion Polish zlotys. Assistance included, among others, tax exemptions and incentives for investment in research, development, and innovation, wage subsidies, unemployment benefits, grants for entrepreneurs, rent subsidies, support for healthcare, education, culture, sports, tourism, agriculture, etc. The fiscal policy pursued by the government.

Directed support for the economy has brought many positive effects. In the case of Poland, the crisis became one of the sources of economic innovation. Assistance packages created conditions for seeking new solutions and adapting to the changing reality. This applies particularly to innovations in e-services, telemedicine, e-commerce, e-education, e-administration, e-culture, e-sports, e-entertainment, e-tourism, and e-work (Kamiński, 2021).

7. Conclusion

Modern times are characterized by great uncertainty, lack of complete information and constant risk. In such conditions, crisis ceases to be an exceptional state, but becomes a permanent feature of the modern world.

The article reviews the conditions in which the greatest economic crises in recent years occurred. As a result of the analysis, the causes and effects of these crises were detailed and what actions were taken to combat the crisis were indicated. Included are the 1997 Asian crisis, the 1998 Russian crisis, the 2008 global financial crisis and the pandemic crisis. It was indicated that many actions taken to combat the crisis brought far-reaching economic effects. In addition to eliminating the crisis, some of the instruments used had a positive impact on the revival of the economy, reduction of financial risk, increase in the level of innovation of the economy, etc. Thanks to this, the perception of the crisis situation has changed only in terms of a threat, but we perceive it as a causative factor of new production, service and organizational solutions. The value of such research is the ability to stimulate further positive impact on the economy by using the same or modified tools that were used in the analyzed crises.

Based on the research conducted, implications for the future can be identified. They may concern stimulating selected elements of the economic environment in such a way that this would effectively translate into improving the economic parameters of the economy. The practical implications of the obtained results may concern the further use by decision-makers of appropriate instruments, which, introduced during the crisis, resulted in an increase in production, an increase in the innovativeness of the economy, and a reduction in risk. Applying them in post-crisis conditions, or building similar tools on their basis, may bring the desired effect in the economy. Examples include monetary or fiscal policy instruments.

References

1. Alba, P., Bhattacharya, A., Claessens, S., Hernandez, L. (1998). *Volatility and Contagion in a Financially-Integrated World: Lessons from East Asia's Recent Experience*. PAFTAD 24 Conference Asia Pacific Financial Liberalization and Reform, Chiang.
2. Bank Światowy (1998). *Asia: The Road to Recovery.* Washington.
3. Barton, R.M. (1993). *Crisis Management*. Oxford, p. 12.
4. Chang, C.-Y. (2017). *Capital Flows, Financial Markets and Banking Crises.* London.
5. Czekaj, J. (2010). Wpływ światowego kryzysu gospodarczego na polską gospodarkę. In: G. Kołodko (ed.), *Globalizacja, kryzys i co dalej?* Warszawa: Poltext.
6. Domańska, M. (2017). *Kryzys w Rosji. Degradacja modelu zarządzania gospodarką*. OSW Ośrodek Studiów Wschodnich im. Marka Karpia.
7. Główny Urząd Statystyczny (2023). https://stat.gov.pl/covid/
8. Glucksmann, A. (2008). Koniec życia w mydlanej bańce. *Dziennik – Europa, 4-5.10.2008*.
9. Goldstein, I., Razin, A. (2015). Three branches of theories of financial crises. *Foundations and Trends in Finance, no. 10*.

10. *Gospodarka po pandemii. 5 negatywnych i 5 pozytywnych wskaźników* (2023). https://businessinsider.com.pl/finanse/makroekonomia/gospodarka-po-pandemii-5-negatywnych-i-5-pozytywnych-wskaznikow/35ts97v
11. Kitler, W., Wiśniewski, B., Prońko, J. (2000). *Wybrane problemy zarządzania kryzysowego w państwie.* Warszawa, p. 43.
12. Kopaliński, W. (1968). *Słownik wyrazów obcych i zwrotów obcojęzycznych*. Warszawa, p. 417.
13. Materiały konferencyjne (1998). *Administracja wobec sytuacji kryzysowych*. *Zarządzanie sytuacjami kryzysowymi*. Krajowa Szkoła Administracji Publicznej, p. 4.
14. Melich, A. (2000). Rosyjski kryzys finansowy 1998 r. Przyczyny i skutki. *Prace Naukowe Akademii Ekonomicznej w Katowicach*.
15. Nawrot, W. (2009). *Globalny kryzys finansowy XXI wieku. Przyczyny, przebieg, skutki, prognozy*. Warszawa: CeDeWu.
16. Otwinowski, W. (2010). Kryzys i sytuacja kryzysowa. *Przegląd Naukowo-Metodyczny. Edukacja dla Bezpieczeństwa, no. 2,* pp. 83-89.
17. Pisany, P. (2020). Lekcje płynące z historii gospodarczej — kryzys azjatycki z 1997 roku a aktualna potrzeba rozwoju źródeł finansowania w walucie krajowej od rezydentów. *Prace Prawnicze, Administratywistyczne i Ekonomiczne, no. 33*.
18. *Słownik wyrazów obcych* (1980). Warszawa, p. 404.
19. Wague, M. (2009). *Międzynarodowe kryzysy gospodarcze i ich konsekwencje*. *Ekonomika i organizacja gospodarki*. Warszawa: Wyd. SGGW.

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REVIEW OF METHODS FOR MEASURING THE EFFECTIVENESS OF NON-PROFIT ORGANIZATIONS

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Purpose: The aim of the research undertaken in the article is to try to find an answer to the question whether, despite the fact that non-profit organizations are not intended to be commercially profitable, it is possible to assess the effectiveness of their activities.
Design/methodology/approach: The article consists of a literature study that reviews publications on methods for measuring the effectiveness of non-profit organizations. For the literature analysis, publications relating directly or indirectly to the topic of operation of non-profit organizations and measuring their effectiveness were used. The literature on this topic is not extensive, compared to publications dealing with the issue of measuring efficiency in commercial enterprises. In addition to the analysis of individual methods of measuring the effectiveness of non-profit organizations indicated in the literature, a comparison of the strengths and weaknesses of each of the proposed solutions was made.
Findings: During the research, it was found that there are methods of measuring effectiveness, which differ significantly from traditional methods used to evaluate business activities, and can be used in the evaluation of non-profit organizations.
Research limitations/implications: Based on the research conducted, implications for the future can be identified. They may concern the use of selected methods to assess the effectiveness of selected non-profit organizations.
Practical implications: Practical implications of the obtained results may concern the use of the presented methods of assessing effectiveness by managers and supervisors of non-profit organizations.
Social implications: The use of the methods presented in the article for assessing the economic efficiency of non-profit organizations will allow potential donors to direct support to organizations that use the accumulated capital most effectively. However, it does not have to be efficiency measured in financial terms.
Originality/value: The article indicates what methods of assessing effectiveness can be used in the case of non-profit organizations. The value of such research is the ability to evaluate the activities of non-profit organizations without having to take into account financial aspects.

Keywords: performance assessment, non-profit organizations.

Category of the paper: Research paper.

1. Introduction

Non-profit organizations belong to the so-called the "third sector" in the socio-economic system of democratic countries with a free market economy. The first sector is usually public administration. The second sector consists of commercial enterprises. The third sector includes other organizations, both state, private and local government, which include foundations, associations, political parties and trade unions. Third sector entities are very diverse, but their common feature is that they do not operate for profit, and their activities are intended to serve the social good (Szymoniczek, 2014). Therefore, these types of organizations are called non-profit or non-governmental organizations (Blicharz, 2012). The history of such organizations dates back to antiquity. Originally, it manifested itself as sharing between the rich and the poor or supporting the so-called patrons of the development of certain areas of life, e.g. art, science, literature. Such activity was described in the past as philanthropic activity (Bogacz-Wotanowska, 2016). Some of the oldest non-profit organizations in Poland, still operating today, are the Polish Red Cross and the Polish Scouting Association.

Each socio-economic sector performs specific functions in society. Non-profit organizations also perform many functions, making them essential for the good and efficient functioning of the entire country. The most important functions of non-governmental organizations include (Szymkiewicz et al., 1998):

- representing social interests, recognizing society's needs and finding ways to best meet them,
- influencing the activities of entities from the other two sectors: public and private entrepreneurs,
- finding unmet needs and taking initiative where the public sector often remains helpless and the private sector is not motivated to act in the form of the promise of profit,
- stimulating innovative changes in socio-economic life.

Non-profit organizations, despite the basic assumption that they are not profit-oriented organizations, must have a source of financing for their activities. They often consume many resources of various types, including financial resources. Financing non-profit organizations is a very complex topic. In Poland, there are many sources of obtaining funds by non-profit organizations, but some of them remain a source only theoretically, because in practice they are basically unused. Financing sources can be divided into three main groups:

- self-financing – financing activities from membership fees or own business activity. However, in the case of running a paid business activity, there is a requirement to balance the revenues and costs of a given activity (Adamiak et al., 2015),

- funds from the private sector - most often taking the form of cash donations, donations in kind, collections or sponsorship (Schimanek, 2015), although it is also possible to obtain debt financing in the form of loans, bank credits, etc.
- funds from the public sector - related to entrusting the performance of all or part of specific public tasks, investment subsidies, civic budget, granting loans (Kurleto, 2008).

2. Specificity of effectiveness in non-profit organizations

Efficiency is a broad concept that is defined and understood differently in science and economic practice. This may not be a problem in everyday life, but in scientific discourse it is important to clearly understand this concept. The PWN electronic dictionary states that effective means: giving good results, efficient or significant, real (Słownik Języka Polskiego, 2023). Efficiency can be defined as the ratio between the value of expenditure incurred and the value of results obtained (Majowska, 2012).

Efficiency can be assessed in various contexts, but from the point of view of the topic at hand, it is important to justify the need to examine effectiveness in specific entities, such as non-profit organizations. Efficiency in the non-profit sector is measured primarily by the goal (Dyczkowski, 2016):

- determining whether the costs incurred were absolutely necessary and whether they could not have been lower and whether they were justified in relation to the result,
- confirming the credibility of the organization's activities in the eyes of potential donors,
- improving the organization's operations,
- consolidating a positive image and trust among stakeholders,
- proving that the organization's mission is implemented appropriately, competing with other entities.

Measuring the effectiveness of non-profit organizations should meet the basic conditions defined by M. Hudson, such as (Hudson, 1997):

- should contain objective indicators indicating the real change that has occurred thanks to the organization's activities, for example the number of people trained in a given issue,
- should enable comparison of costs and results of individual activities, to realistically assess whether the funds have been appropriately allocated,
- should measure the quality of implemented activities or services so that it can be improved.

3. Social Return on Investment (SROI)

One of the methods for assessing the effectiveness of non-profit organizations, recommended in the literature on the subject (Juraszek-Kopacz, Tyrowicz, 2008) is Social Return on Investment (SROI). This indicator is a variation of the Return of Investment (ROI) indicator used to measure efficiency in commercial enterprises. The SROI indicator is calculated as the quotient of the total value of the project (i.e. the current economic value of the project plus its current social value) and the value of expenditure incurred on the project:

SROI = value of the project / value of expenditure incurred on the project

where:

venture value = current economic value of the venture + current social value

SROI estimation begins with determining the economic value of a given project. For this purpose, the costs of the project itself should be excluded from the total organizational costs. However, the costs of the project include part of the organization's fixed costs. If the project is extended over a period of several years, appropriate forecasting methods should be used. The economic value of the project is calculated for each year of its duration as a result of the following action:

economic value of the project = net profit + depreciation (loss of value of resources, if any) - investments - loans and repayable grants

The results obtained in this way should still be subjected to the discounting process (Juraszek-Kopacz, Tyrowicz, 2008).

In the process of calculating social value, there is a need to determine the following four factors:

- size of the target group,
- savings achieved per person from the target group,
- increase in tax revenues per person from the target group,
- the amount of costs incurred for the target group (care, training, etc.).

Determining the number of beneficiaries is simple if the organization conducts activities aimed at a clearly defined target group, for example, it runs a shelter for the homeless. Then we know exactly how many people benefited from such help. When conducting other activities, e.g. social campaigns, their possible impact should be assessed. The savings achieved and the increase in tax revenues are also easiest to estimate when it comes to organizations undertaking specific activities, for example activating the unemployed. For many others, this is subject to high error. Social costs, which also need to be estimated, include costs that cannot be reported in accounting. They are related to the following three phenomena:

- crowding effect - thanks to external support, a non-governmental organization can offer products so attractive that it becomes a competition for commercial companies ("pushing" them out of the market), which may consequently lead to their bankruptcy or decisions about layoffs,
- the effect of pointless cost - it means supporting activities that would also be carried out without external support, because, for example, they are attractive to commercial enterprises,
- substitution effect - changing existing solutions to others related to receiving financial support, for example employing disabled people instead of able-bodied people in order to reduce the costs of social security contributions (Wasiela, 2013).

The above-mentioned phenomena mean that projects that may seem effective from the point of view of the organization may not be so on the scale of society (Moroń, Klimowicz, 2016). When estimating the value of savings, you must always take into account possible alternatives.

The assessed economic and social value is compared with the amount of expenditure allocated for the task, obtaining the social rate of return. The result shows how much profit each monetary unit invested in the project brings to society.

4. Measures of organizational success

Another group of specific performance measures that can be used in the case of non-profit organizations are measures of organizational success. They use opinions about the organization expressed by its audience, other organizations or society more generally. According to the assumptions of these assessment methods, success can be said when an organization (Krzelowska, 2008):

- can raise funds,
- has a recognizable name,
- has many volunteers motivated to act,
- maintains good relations with many media,
- has a large number of "customers",
- is able to obtain funds from the European Union,
- conducts transparent activities,
- has social trust,
- carries out the mission in an effective way,
- increases the number of its branches.

The use of this measure of the effectiveness of non-profit organizations requires conducting surveys or interviews among the organization's environment, including its direct stakeholders.

5. Participatory action research (PAR)

Participatory action research (PAR) is a method aimed at solving practical social problems in a scientific way while involving in this process everyone affected by a given problem (Ćwiklicki, 2014). It can be carried out in three ways: by establishing tripartite committees in which employees, management board and other stakeholder groups are represented, through research conferences or dedicated workshops (Chrostowski, 2011). First of all, in the PAR method, a diagnosis of the organization should be carried out. A properly prepared questionnaire can be used for this purpose. Already at this stage, all interested parties, both researchers and respondents, should be involved in its construction. The tool created in this way describes a certain ideal of the organization in key areas such as: finances, transparency, identification of members with the organization, or trust in leaders. People involved in the study assess how much their organization deviates from or meets a given pattern. On this basis, a report is created which shows what the entity has the biggest problems with and what areas it copes with best. The study should be repeated after a certain period to check whether the changes introduced are heading in the desired direction (Kafel, 2016).

6. Prove it!

"Prove it!" is a method created by the New Economics Foundation to better understand the scale of an organization's impact. This measure is intended primarily for organizations conducting small or medium-sized projects whose main goal is change in local society introduced by its members (New Economics Foundation, 2023). An important feature of the "Prove it!" method is the involvement of all participants in creating indicators for measuring the effects of the project, by means of which the change caused by the implementation of the project will be measured. The indicators are included in the project measurement survey, the results of which allow us to assess whether the assumed goals have been achieved and to what extent. This is especially true of goals related to social and human capital, i.e. changes in the relationships between community members, changes in self-assessment of their capabilities and perception of their own quality of life (Juraszek-Kopacz, Tyrowicz, 2008).

7. "U^2" method – prove and improve

"U2" - Prove and Improve is a method consisting of several basic stages. First, the organization's mission and goals are reviewed. Goals should result from the mission and directly bring you closer to achieving it. An entity may set too many goals and there is a risk that its activities will be dispersed and the implementation of individual activities will not be directly related with the implementation of the mission, which is to be the primary value. After carefully defining the goals, the organization determines the stakeholders, beneficiaries and target group of its activities. Beneficiaries are the direct recipients of activities, they may overlap with the target group, which is the recipients of activities intended by the organization. And stakeholders are the broadest group. These are the people whom the project affects, both positively and negatively, even unintentionally. Determining these groups introduces the organization to creating an impact map at four levels: beneficiaries, local community, external relations and systemic change. Then, a list of indicators is created that will constitute the basis for demonstrating the change caused by the project. The final stage is to present the research results.

8. Conclusion

The selected methods for assessing the effectiveness of non-profit organizations presented above are only a proposal that can be expanded or narrowed according to the needs of the evaluators. Many other methods can be found in the literature on the subject. This proves that despite the fact that non-profit organizations are not intended to be commercially profitable, it is possible to assess the effectiveness of their activities. Unfortunately, observation of business practice shows that most third sector entities do not use them. There are several possible reasons for this situation. Conducting research exceeds the organization's capabilities, primarily in terms of:

- time - most of the organization's activists are volunteers who devote their free time to it and do not have the opportunity to spend additional hours conducting analyzes and collecting the necessary materials,
- financial - the financial resources of the third sector are limited, which is why organizations do not decide to outsource efficiency assessment to external entities,
- substantive requirements - the presented methods are difficult to perform correctly for people who do not have related education, complicated scientific descriptions do not encourage efforts, to try out the proposed tools.

Another factor that may influence non-profit organizations lack of analysis of their own achievements is the lack of pressure from the external environment to present such results. Social entities need social legitimacy, including social trust, to function regardless of the effectiveness and rationality of their activities (Majowska, 2012). However, such an assessment seems to be increasingly expected, both by aid beneficiaries and donors. It would likely contribute to both donors making more rational choices and organizations being able to improve their structure and operations. The review of methods for assessing the effectiveness of non-profit organizations presented in this article constitutes only exploratory research in the field of the discussed issues. Detailed examination of this topic still requires many scientific studies and sharing of experiences by organization members among themselves. This requires greater interest in the scientific world in non-profit organizations and their impact on society and the economy. Further studies and creation of solutions are necessary that will concern general aspects of the functioning of non-profit organizations. Particularly important are attempts to create a unified solution that allows assessing the effectiveness of both the organizations themselves and external entities that, for example, want to provide material support to non-profit organizations. Another possibility is to develop a training program for members of non-profit organizations, which would allow for a quick and understandable introduction to the use of efficiency measurement methods. The popularization of such knowledge would contribute to improving the quality of operation of many non-profit organizations and increase their self-awareness.

References

1. Adamiak, P., Charycka, B., Gumkowska, M. (2015). *Polskie organizacje pozarządowe.* Warszawa, p. 16.
2. Blicharz, J. (2012). *Administracja publiczna i społeczeństwo obywatelskie w państwie prawa.* Wrocław, p. 15.
3. Bogacz-Wotanowska, E. (2016). Istota i podstawowe zasady funkcjonowania organizacji pozarządowych. In: E. Bogacz-Wotanowska, S. Wrona (eds.), *Zarządzanie organizacjami pozarządowymi* (p. 13). Kraków.
4. Chrostowski, A., Kostera, M. (2011). Etnografia jako narzędzie diagnostyczne w procesie doradztwa naukowego. *Problemy zarządzania, nr 2*, Warszawa, pp. 33-34.
5. Ćwiklicki, M. (2014). Granice stosowania action research w naukach o zarządzaniu. In: M.J. Szymankiewicz, P. Kuźbik (eds.), *Zarządzanie organizacją z perspektywy metodologicznej. Wybrane zagadnienia* (pp. 133-134). Łódź.

6. Dyczkowski, T. (2016). Analiza dokonań OPP, prezentowanych w ich sprawozdaniach rocznych z wykorzystaniem metody drążenia tekstu. *Studia ekonomiczne. Zeszyty naukowe Uniwersytetu Ekonomicznego w Katowicach, nr 274*, Katowice, p. 58.
7. Hudson, M. (1997). *Bez zysków i strat. Sztuka kierowania organizacjami sektora pozarządowego*. Warszawa, p. 112.
8. Juraszek-Kopacz, B., Tyrowicz, J. (2008). *Zmierzyć niemierzalne, czyli o pomiarze oddziaływania społecznego*. Warszawa, p. 17.
9. Kafel, T. (2016). Zastosowanie metody participatory action research w diagnozowaniu organizacji pozarządowych. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie, nr 7*. Kraków, pp. 32-37.
10. Krzelowska, M. (2008). Sukces organizacji pożytku publicznego w świetle badań. *Trzeci sektor, nr 13*. Warszawa, pp. 68-75.
11. Kurleto, M.H. (2008). *Organizacje pozarządowe w działalności pożytku publicznego*. Warszawa, s. 93-94.
12. Majowska, M. (2012). W kierunku maksymalizacji efektywności organizacji - perspektywa uniwersalistyczna, sytuacyjna i instytucjonalna. *Prace naukowe Uniwersytetu Ekonomicznego we Wrocławiu, nr 262*. Wrocław, p. 222, 228.
13. Moroń, D., Klimowicz, M. (2016). Zastosowanie stopy społecznego zwrotu z inwestycji (SROI) jako wskaźnika mierzenia efektywności projektów społecznych. *Wrocławskie Studia Politologiczne, nr 21*. Wrocław, p. 78.
14. New Economics Foundation (2023). https://www.nefconsulting.com/our-services/evaluation-impact-assessment/prove-and-improve-toolkits/prove-it/, 17.11.2023.
15. Schimanek, T. (2015). Finansowanie organizacji pozarządowych w Polsce. Diagnoza. In: *System finansowania organizacji pozarządowych w Polsce*. Kraków.
16. Słownik Języka Polskiego (2023). https://sjp.pwn.pl/
17. Szymkiewicz, A., Plaskoń, J., Tabaczyńska, A. (1998). *Porządnie poza rządem*. Warszawa, p. 148.
18. Wasiela, W. (2013). Wartość dodana i potrzeby społeczne - związek skazany na porażkę? *Choice, nr 7*. Łódź, p. 20.

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INDUSTRY 4.0 SOLUTIONS AND COMPANY PERFORMANCE: EMPIRICAL EVIDENCE FROM MULTIPLE CASE STUDY OF AUTOMOTIVE INDUSTRY

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Purpose: Recent geopolitical, economic, and social changes worldwide directly impact the operations of manufacturing enterprises. This paper aims to highlight the potential outcomes achieved through the implementation of modern technological solutions within the scope of Industry 4.0 in organizations operating in the manufacturing sector. The presented results are part of wider research (Michna et al., 2021).
Design/methodology/approach: The research methods consist of a comprehensive literature review of the subject under study and the results of empirical research conducted in 2023 based on multiple case study in production companies in Poland.
Findings: The study presents the effects achieved by companies after implementing Industry 4.0 solutions, such as: production cost reduction, increase in profits, productivity and production efficiency and improvements in working conditions.
Research limitations/implications: The study was conducted in two selected manufacturing plants operating in the Polish market, with the limitation being the sample selection and the subjective assessment of the study participants.
Practical implications: The research results provide an overview of potential and achieved effects and changes in the functioning of the enterprise following the implementation of Industry 4.0 technologies. An additional categorization into effects achieved in socio-economic, environmental areas, and overall corporate governance allows for situating the organization's performance in light of recent legislative changes related to the Fit for 55 packages (Fit for 55, 2021).
Originality/value: The study can assist practitioners and specialists in Industry 4.0 in analyzing the potential effects of implementing new technological solutions and aid in planning future activities within the organization.

Keywords: Industry 4.0, Results, Performance, Production.

Category of the paper: Empirical research results.

1. Introduction

The last decade of research on the phenomenon of Industry 4.0 provides extensive information on various aspects of the implementation of modern solutions. From the types of technologies and new solutions (Berman, 2012; Chaudhuri et al., 2024; Frank et al., 2019; Lukoki et al., 2020; Manavalan, Jayakrishna, 2019; Oettmeier, Hofmann, 2017), through areas related to driving forces and barriers during implementation (Arnold et al., 2018; Michna, Kruszewska, 2021, 2022a; Müller, 2019; Neto et al., 2020; Stentoft et al., 2019; Türkeş et al., 2019; Vuksanović Herceg et al., 2020; Yilmaz et al., 2022), to changes in the competency model of employees (Beke et al., 2020; Hernandez-de-Menendez et al., 2020; Kannan, Garad, 2020; Michna, Kruszewska, 2021, 2022b, 2022b; Poszytek, 2021) and the functioning of enterprises (Basana et al., 2024; Calış Duman, Akdemir, 2021; Dalenogare et al., 2018; Dev et al., 2020; Kamble et al., 2020; Wang, Hou, 2024). Base of (Dombrowski, Wagner, 2014) "the technologies of the future production will cause far-reaching changes for the socio-technical production system". In today's reality, numerous economic, political, and social changes directly impact the operations of businesses. The results achieved by the organization reflect the direction of its development. Not only do financial aspects, such as turnover, profit, or asset size, play a crucial role, but the significance of all non-financial aspects of the company's functioning is also increasing. The CSRD directive (Corporate Sustainability Reporting Directive (EU) 2022/2464, 2022) introduced at the end of 2023 places reporting on sustainable development on par with financial reporting for businesses. The financial results of a company, along with aspects such as their impact on stakeholders (including customers, suppliers, employees, local communities), satisfaction, competence development, equality, environmental impact (including water, air, and ecosystems), and compliance with fundamental rights throughout the company's value chain, are among the many disclosures that will require organizations to provide accurate and comprehensive presentations in official annual reports in the coming years. All these elements are grouped into three categories known as ESG - Environmental, Social, and Governance aspects.

How does the implementation of Industry 4.0 solutions impact the organization's performance? In the literature on the subject, we can find numerous case studies and literature reviews regarding the effects brought about by the implementation of new technological solutions. The integration of advanced technologies is revolutionizing the landscape of production companies, ushering in a new wave of efficiency, flexibility, and competitiveness (Bal, Erkan, 2019; Caiado et al., 2022; Peukert et al., 2015; Soniewicki, Paliszkiewicz, 2019). Automation and smart technologies streamline production processes, minimizing downtime, reducing errors, and enhancing overall operational efficiency (Barbie et al., 2020; Chong et al., 2018; Dahmani et al., 2021; Hirsch-Kreinsen, 2014; Pfeiffer, 2016; Quan Chong et al., 2018). Collection and analysis of real-time data, empowering decision-makers with valuable insights for informed and timely decision-making (Chaudhuri et al., 2024; Lin et al., 2018). Smart

supply chain management ensures better coordination, reducing lead times, optimizing inventory, and enhancing overall supply chain resilience (Caiado et al., 2022; Veile et al., 2020). The implementation of IoT devices and sensors allows companies to predict and prevent equipment failures, minimizing disruptions and costly downtime (Manavalan, Jayakrishna, 2019). With advanced technologies, production can be tailored to meet individual customer needs, fostering greater customer satisfaction and loyalty. Through the adoption of smart manufacturing practices, companies can optimize resource utilization, minimize waste, and achieve cost savings across various aspects of production. Automation and advanced analytics contribute to improved quality control, ensuring that products meet or exceed stringent quality standards. The integration of humans and machines in the production process leads to more collaborative and safer work environments, with employees focusing on higher-value tasks (Adem et al., 2020; Dutta et al., 2021; Leso et al., 2018; Vrchota et al., 2019). Industry 4.0 positions production companies on a global stage, enhancing their competitiveness by leveraging cutting-edge technologies to meet market demands efficiently. In conclusion, the implementation of Industry 4.0 marks a paradigm shift for production companies, unlocking a multitude of benefits that propel them into a future of smarter, more efficient, and sustainable manufacturing. As technology continues to evolve, embracing Industry 4.0 seems to be not just a choice but also a strategic imperative for companies aspiring to thrive in the modern industrial landscape (Barton, 2021; Culot et al., 2020; Erol et al., 2016; Motyl et al., 2017; Veile et al., 2020).

2. Methods

Empirical data were obtained from two companies operating in the manufacturing industry. One of the companies is located in the Podkarpackie Voivodeship, while the other is in the Wielkopolskie Voivodeship in Poland. Both companies produce, among other things, elements and components used in the automotive sector. The criteria for selecting companies for the multiple case study were: the manufacturing sector - both organizations represent the manufacturing industry and produce rubber parts; the aspect of Industry 4.0 - the organizations are actively involved in the implementation of Industry 4.0 solutions; and the size of the company - both belong to large organizations, following the guidelines of the current accounting law. Qualitative research in the form of case studies was conducted from November to December 2023. In each of the organizations, a review of available documentation published on the websites of both companies was carried out, including certificates of implemented management systems, descriptions of organizational activities, and specifications of manufactured products. Additionally, the study also focused on the implemented work principles and the organizational structure of the company. The study involved individuals working at the managerial level, including the organization's president, directors,

and department managers representing organizational units such as product development, quality, production, and environmental protection. For the purposes of this publication, we selected results obtained from studying leaders managing similar areas. Specifically, in the first company, the surveyed individual manages the occupational health and safety and environmental aspects, while in the second organization, participant manage the quality and environmental areas. During the interviews, notes were taken, which were subsequently compiled in a research journal.

Table 1.
Factors - effects of implementing Industry 4.0 solutions

	Factors		Source
Governance	Reduction cost of	production	1. Ghobakhloo et al., 2022
		product development	
		inventory	
		scrap & rework	2. Müller, 2019
		purchasing base materials	
		energy	
		waste disposal	
	Increase of	profit	3. Neto et al., 2020
		customer satisfaction	
		speed of delivery	
		responsiveness	4. Kagermann et al., 2013
		flexibility of supply	
		product range offerings	
		the level of sales	
		market share	5. Arnold et al., 2016
		productivity	
		production efficiency	
		production flexibility	6. Stock, Seliger, 2016
	Improving	reliability of supply	
		order fulfillment capabilities	
		the quality of products and services	
		access to data	7. Müller et al., 2018
Social	Improving in	working conditions	
		worker safety	
		employee health	8. Sarkis, Zhu, 2017
		labor relations	
		employee morale	
		employee qualifications	9. Herrmann et al., 2014
		employee engagement	
		work pressure	
Environment	Improving in Increase of	the environmental situation of the organization	
		efficiency in the use of resources	10. Stock, Seliger, 2016
		sustainable development	
	Reduction of	solid waste	
		liquid waste	
		greenhouse gas emissions	11. Michna, Kruszewska, 2020, 2021
		wasted electricity	
		the use of hazardous/harmful/toxic materials	
		environmental impact	

Source: Own work.

This study focuses on one element of the conducted research, namely, on the effects obtained after the implementation of selected Industry 4.0 solutions in the surveyed companies. The study participants were asked to assess the extent to which the implementation of Industry 4.0 solutions influenced various factors, which are listed in the table below. A five-point Likert scale was used for evaluation, where: 1 indicated that the implementation had no impact on the factor, 2 - had a slight impact, 3 - had a moderate impact, 4 - had a relatively significant impact, and 5 - had a very significant impact. All factors potentially affected by the implementation of Industry 4.0 solutions were selected from previous literature reviews and classified according to the ESG framework (factors related to the environment, social factors, and factors related to corporate governance) similarly as "Triple Bottom Line" proposed by (Kiel et al., 2017).

3. Results

The first of the surveyed companies is one of the largest Polish manufacturers of rubber pneumatic springs for trucks and buses. Additionally, it provides services in vulcanization and the repair of conveyor belts, as well as rubber coating of drums. The company has a certified management system for quality in accordance with ISO 9001:2015 and IATF 16949:2016, as well as an environmental management system in line with ISO 14001:2015. The organization has been operating in the market for over 30 years and boasts a wide range of products, having reached approximately 6000 customers with its offerings. In the study, this organization was represented by a managing leader responsible for the area of environment and occupational health & safety management. As part of new technologies, the organization primarily employs automation of material flows in the warehouse area. It implements IoT in many locations, focusing at the moment on sensing areas related to excessive resource consumption but also on automatically acquiring data regarding resource utilization, machine settings, and production processes. The company also has terminals in the production area that facilitate daily work for employees, enabling control and settings of machines. Based on direct information from the survey participant: *Our company is heavily investing in sensors to significantly relieve and automate data from production lines. This is a substantial topic, and work on it is still ongoing. We started to work on utilizing large datasets and analytics, but it's progressing gradually. We use mobile technologies and have terminals at workstations.*

The second organization is a global supplier of rubber products, rubber-metal products, and rubber products combined with other materials. It offers a wide range of products for the household appliances, agriculture, construction, and automotive industries. It has been supplying its products for over 90 years. This company also holds certified quality, environmental, and occupational health and safety management systems according to ISO9001 and IATF16949, ISO14001 and ISO45001. This organization was represented by a quality and environment manger. Industry 4.0 solutions are implemented in this organization in areas such as: human resources management, procurement, production, production planning, and the department of technology and new product development. These changes relate to production processes, materials, logistics, as well as the product itself. In recent years, the organization has implemented automated documentation flows primarily related to the circulation of personnel, financial, and logistic documents. In the production hall, some processes have been automated, replacing human labor with robots or automatic loading. Employees have been reassigned to other tasks. *We have automatic loading of elements during the injection molding process. We are implementing robots, for example, on the deburring line. Just a few years ago, people worked there, and now we have an automated line, and everyone considers it standard. In the glue application process, we use robots. For me, Industry 4.0 is a broader project.*

During the design of injection molds, simulations are used to optimize material flows during the injection molding process. Words of research participants: *We conduct injection molding simulations for molds. We check hot runners, which, during mold design, allow material recovery - optimization of material consumption.* Company working on technologies such as RFID (Radio-Frequency Identification) and NFC (Near Field Communication) to be employed in their products. The plant's ambition is to implement Manufacturing Execution Systems (MES) and have all machines operate in a network, although the organization acknowledges significant challenges in this regard, mainly due to limitations in the current machinery park. Based on direct information from the survey participant: *Now, we are implementing an advanced planning module – the production plan is supposed to retrieve customer orders and all data from the System. Another example is an automatic monitoring system for maintenance. This is already implemented. Employees no longer have to manage this manually*.

In summary both participants represent the same organizational area within the company and have similar responsibilities within their scope of duties. Additionally, both companies are large enterprises operating in the same industry and offer products made from the same raw material. Therefore, the primary method applied for this research was comparative analysis. All tables and charts below contain the survey results for both participants, where C1 represents data from the employee of the first company, C2 for the participant from the second company and the average value for both surveyed cases.

Table 2.
Results for governance factors - effects of implementing Industry 4.0 solutions

	Factors		C1	C2	Medium
Governance	Reduction cost of	production	4	5	4,5
		product development	3	2	2,5
		inventory	4	2	3
		scrap & rework	3	3	3
		Purchasing base materials	3	2	2,5
		energy	3	4	3,5
		waste disposal	2	3	2,5
	Increase of	profit	4	5	4,5
		customer satisfaction	4	3	3,5
		speed of delivery	4	3	3,5
		responsiveness	4	4	4
		flexibility of supply	4	3	3,5
		product range offerings	4	2	3
		the level of sales	3	4	3,5
		market share	4	3	3,5
		productivity	4	5	4,5
		production efficiency	4	5	4,5
		production flexibility	4	3	3,5
	Improving	reliability of supply	4	3	3,5
		order fulfillment capabilities	4	3	3,5
		the quality of products and services	4	4	4
		access to data	4	4	4
		reliability of supply	4	3	3,5
		order fulfillment capabilities	4	3	3,5

Source: Own work.

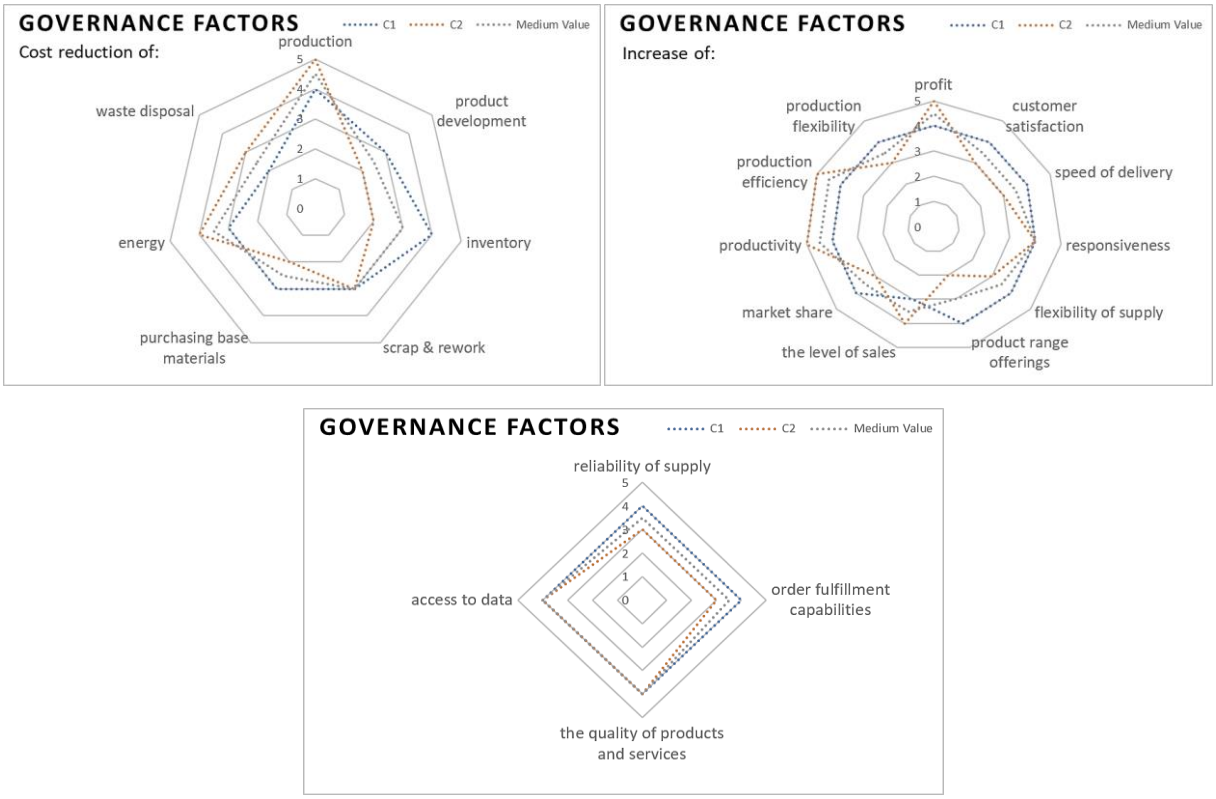

Figure 1. Results for the governance factor group.

Source: Own work.

In the governance factors group, both participants indicate that the implementation of Industry 4.0 solutions had the greatest impact in terms of reducing production costs, increasing the organization's profit, productivity, and efficiency. It also influenced greater access to data and the improvement of the quality of products and services provided by these organizations.

The first participant also highlighted the effect of reducing inventory costs and increasing the range of product offering, while for the second participant these elements were not important.

Table 3.
Results for social factors - effects of implementing Industry 4.0 solutions

	Factors		C1	C2	Medium
Social	Improvement of	working conditions	5	4	4,5
		worker safety	4	4	4
		employee health	3	4	3,5
		labor relations	3	3	3
		employee morale	3	2	2,5
		employee qualifications	4	4	4
		employee engagement	3	3	3
		work pressure	3	3	3

Source: Own work.

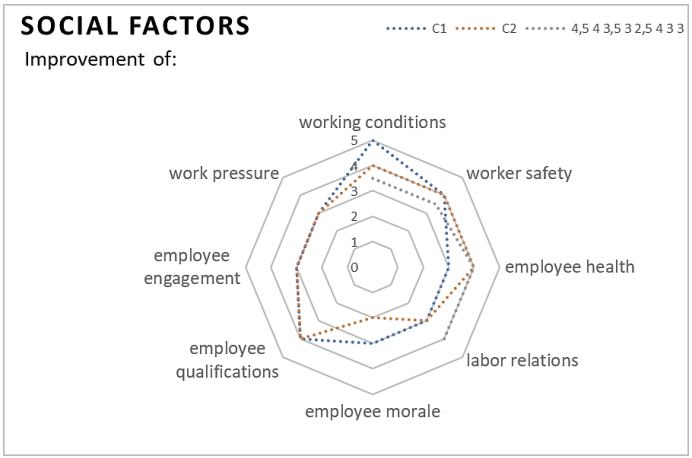

Figure 2. Results for the social factor group.

Source: Own work.

Also, regarding social factors, participants agree that the implementation of Industry 4.0 solutions has contributed to improving working conditions in their organizations. Improvement in safety and an increase in employees' qualifications were also highlighted as significant aspects. The least significant appears to be the impact on boosting employee morale. A participant from the second organization considered this factor to have had only a slight impact.

Table 4.
Results for social factors - effects of implementing Industry 4.0 solutions

	Factor		C1	C2	Medium
Environment	Improvement of	the environmental situation	4	3	3,5
		efficiency in the use of resources	4	4	4
		sustainable development	3	3	3
		solid waste	4	4	4
		liquid waste	4	2	3
		greenhouse gas emissions	2	3	2,5
		wasted electricity	4	4	4
		the use of hazardous/harmful/toxic materials	2	3	2,5
		environmental impact	3	3	3

Source: Own work.

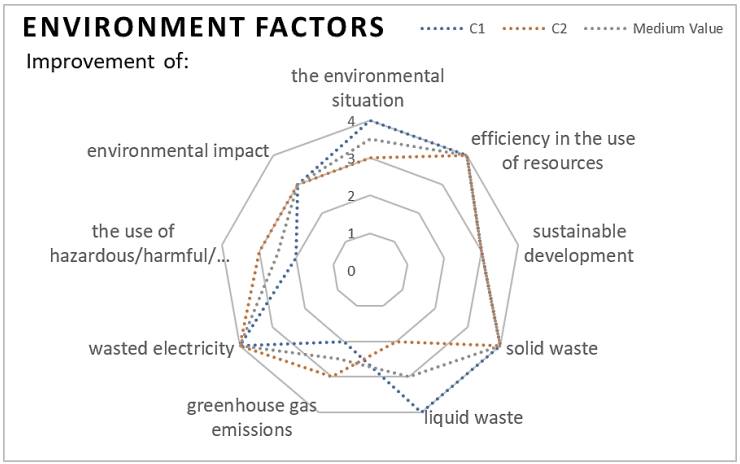

Figure 3. Results for the environment factor group.

Source: Own work.

In the case of environmental factors, participants indicate that the achieved effects primarily concern improvements in managing and reducing the amount of solid waste, wasted electricity, and generally, in better utilization of available resources.

Considering all the elements from each of the presented groups of factors - managerial, social, or environmental - according to the surveyed participants, Industry 4.0 solutions have the greatest impact in their organizations on reducing production costs, increasing profits, productivity, production efficiency, and improving working conditions. To a lesser extent, they contribute to reducing the costs of developing new products, purchasing basic materials, or lowering waste costs. From a social and environmental perspective, Industry 4.0 solutions in their organizations also did not influence the increase in morale among employees, the reduction of the use of hazardous substances, and did not significantly impact the reduction of greenhouse gas emissions. Table 5 gather exemplary responses obtained during the study. The collected information mainly pertains to the results achieved within the organization.

Table 5.
Information related to results obtained after the implementation of Industry 4.0 solutions

Group	Sentences from company C1	Sentences from company C2
Speed & Efficiency	*The implemented solutions have, for example, allowed us to pack and send more parcels in the logistics area than before. There are no longer such mistakes, and overall, we have accelerated work processes and increased warehouse efficiency.*	*In our industry, there is constant pressure on prices, and as a result, on what we call 'efficiency'.* *For it to be cost-effective, the process must be highly efficient, and this is the reason for the majority of innovations in the plant.* *Everyone in the company talks about this automation, but we encounter the fact that automated processes must pay off, and they must pay off quickly.*
Availability & accuracy of data	*Above the packing stations, we installed cameras, and just this fact, along with informing the customer that we have a complete visual record of what has been packed and how it was packed, reduced our complaints by 90%.*	*What results have been achieved? Above all, data accuracy has increased. In the machining processes, data is read, and there is no possibility of scanners making mistakes. In the production and logistic areas data is collected, and we use a barcode system.*
Independency	*For example, when we want to find out how much energy a specific area consumes, we no longer want to come in on weekends or remember to take manual readings. We are moving in this direction to be independent of people.*	*We have never done it in a way that when we implement automation, we lay off people – we always transfer them to a new project.* *No one has been let go due to improvements. Sometimes, certain inspections are too complicated, and a human presence is still necessary.*
Integration	*Last year, we introduced a project to save energy in the compressed air installation, and we had to do it manually, coming in on weekends. We no longer want to come in on weekends, so we are pressing the executives to automate this, so that the data is simply read automatically.*	*A shift to a job involving process control instead of performing processes - time savings for all of us.* *I have access to data.* *Previously, someone had to grapple with Excel; now we have everything integrated.*
Employees	*The biggest challenge is always the mindset among all people, convincing them. Also, the costs of sensors and certain improvements are high. I think these two things are the most significant.* *Often, we hear "why do we need this? What's the point?" Sometimes, we want to push away certain things that, in the end, we will have to accept. It's good that we have a sizable leadership group that enforces these changes.*	*Production employees still feel the threat (replacement by robots). Managers see the benefits. If the work is simpler, robots would be better. Production workers are afraid, and they also resist, but based on our experiences, the resistance is now less.*

Source: Own work.

4. Summary and conclusion

The main goal of this article was to present the effects that organizations achieve after implementing new technologies understood as Industry 4.0 technologies. The presented results include the subjective assessment of employees based on their experience and observations over the past years. As a research method, a multiple case study was adopted, along with an analysis of available documentation and a comparative analysis of responses to the question:

On a scale from 1 to 5, please assess to what extent the implementation of Industry 4.0 solutions has affected specific factors. The information obtained from interviews with study participants and the result on a 5-point Likert scale in response to the posed question confirms analyses available in the literature (Bal, Erkan, 2019; Mogos et al., 2019), indicating that the implementation of modern technologies not only impacts the reduction of production costs but also directly contributes to the increase in profits achieved by the organization. The words of one of the study participants: *…there is no other way; either a person quickly understands it, or they are out of business,* unequivocally indicate that the awareness of the necessity for changes, seeking more efficient solutions, increasing productivity, and thereby enhancing production and sales capabilities is the direction in which organizations are heading. Another important aspect highlighted by the study participants is the socio-psychological aspect related to personnel. The resistance of employees and their fears of being replaced by robots are evident in both surveyed organizations. Undoubtedly, this is one of the factors on which the implementation of Industry 4.0 has a direct impact. One of the participants stated: *There must be a satisfactory balance between a socio-psychological approach - people must have jobs. Automation and robotization, Industry 4.0 – it doesn't cure everything. There is a need for sharp-minded people.* The implementation of industry solutions in the surveyed organizations did not have a significant impact on the cost reduction of developing new products or purchasing basic materials, nor did it result in emission reduction.

This research was not free from limitations. The presented results are limited to two specific cases, two specific companies operating in polish manufacturing sector and are subjective opinions of employees working in specific conditions and occupying higher-level management positions. Moreover, it is recommended to investigate the presented subject on a wider range of organizations and at various levels of positions within the organization.

References

1. Adem, A., Çakit, E., Dağdeviren, M. (2020). Occupational health and safety risk assessment in the domain of Industry 4.0. *Applied Sciences, 2*(5), 977.
2. Arnold, C., Kiel, D., Voigt, K.-I. (2016). How the industrial internet of things changes business models in different manufacturing industries. *International Journal of Innovation Management, 20*(08).
3. Arnold, C., Veile, J.W., Voigt, K.-I. (2018). What drives Industry 4.0 adoption? An examination of technological, organizational and environmental determinants. *IAMOT 2018 Conference Proceedings*, 1-19.
4. Bal, H.Ç., Erkan, Ç. (2019). Industry 4.0 and Competitiveness. *Procedia Computer Science, 158,* 625-631.

5. Barbie, A., Hasselbring, W., Pech, N., Sommer, S., Flogel, S., Wenzhofer, F. (2020). *Prototyping Autonomous Robotic Networks on Different Layers of RAMI 4.0 with Digital Twins. IEEE International Conference on Multisensor Fusion and Integration for Intelligent Systems (MFI)*, 1-6.
6. Barton, C.J. (2021). The Fourth Industrial Revolution Will Not Bring the Future We Want. *IEEE Technology and Society Magazine*, *40*(3), 31-33.
7. Basana, S.R., Malelak, M.I., Suprapto, W., Siagian, H., Tarigan, Z.J.H. (2024). The impact of SCM integration on business performance through information sharing, quality integration and innovation system. *Uncertain Supply Chain Management*, *12*(1), 435-448.
8. Beke, E., Horvath, R., Takacs-Gyorgy, K. (2020). Industry 4.0 and Current Competencies. *Our Economy*, *66*(4), 63-70.
9. Berman, B. (2012). 3-D printing: The new industrial revolution. *Business Horizons*, *55*(2), 155-162.
10. Caiado, R., Scavarda, L., Azevedo, B., Nascimento, D.L., Quelhas, O. (2022). Challenges and Benefits of Sustainable Industry 4.0 for Operations and Supply Chain Management—A Framework Headed toward the 2030 Agenda. *Sustainability*, *14*, 1-26.
11. Calış Duman, M., & Akdemir, B. (2021). A study to determine the effects of Industry 4.0 technology components on organizational performance. *Technological Forecasting and Social Change*, *167*, 120615.
12. Chaudhuri, R., Chatterjee, S., Mariani, M.M., Wamba, S.F. (2024). Assessing the influence of emerging technologies on organizational data driven culture and innovation capabilities: A sustainability performance perspective. *Technological Forecasting and Social Change*, *200*, 123165.
13. Chong, Z.Q., Low, C.Y., Mohammad, U., Rahman, R.A., Shaari, M.S.B. (2018). Conception of Logistics Management System for Smart Factory. *International Journal of Engineering & Technology*, *7*, 126-131.
14. Culot, G., Orzes, G., Sartor, M., Nassimbeni, G. (2020). The future of manufacturing: A Delphi-based scenario analysis on Industry 4.0. *Technological Forecasting and Social Change*, *157*, 120092.
15. Dahmani, N., Benhida, K., Belhadi, A., Kamble, S., Elfezazi, S., Jauhar, S.K. (2021). Smart circular product design strategies towards eco-effective production systems: A lean eco-design industry 4.0 framework. *Journal of Cleaner Production*, *320*, 128847.
16. Dalenogare, L.S., Benitez, G.B., Ayala, N.F., Frank, A.G. (2018). The expected contribution of Industry 4.0 technologies for industrial performance. *International Journal of Production Economics*, *204*, 383-394.
17. Dev, N.K., Shankar, R., Qaiser, F.H. (2020). Industry 4.0 and circular economy: Operational excellence for sustainable reverse supply chain performance. *Resources, Conservation and Recycling*, *153*, 104583.

18. Dombrowski, U., Wagner, T. (2014). Mental Strain as Field of Action in the 4th Industrial Revolution. *Procedia CIRP, 17*, 100-105.
19. Dutta, G., Kumar, R., Sindhwani, R., Singh, R.Kr. (2021). Digitalization priorities of quality control processes for SMEs: A conceptual study in perspective of Industry 4.0 adoption. *Journal of Intelligent Manufacturing*, *32*(6), 1679-1698.
20. Erol, S., Jäger, A., Hold, P., Ott, K., Sihn, W. (2016). Tangible Industry 4.0: A Scenario-Based Approach to Learning for the Future of Production. *Procedia CIRP*, *54*, 13-18.
21. Fit for 55: Delivering the EU's 2030 Climate Target on the way to climate neutrality, COM(2021) 550, European Commission (2021). https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52021DC0550
22. Corporate sustainability reporting directive (EU) 2022/2464, EP, CONSIL, 322 OJ L (2022). http://data.europa.eu/eli/dir/2022/2464/oj/eng
23. Frank, A.G., Dalenogare, L.S., Ayala, N.F. (2019). Industry 4.0 technologies: Implementation patterns in manufacturing companies. *International Journal of Production Economics*, *210*, 15-26.
24. Ghobakhloo, M., Iranmanesh, M., Vilkas, M., Grybauskas, A., Amran, A. (2022). Drivers and barriers of Industry 4.0 technology adoption among manufacturing SMEs: A systematic review and transformation roadmap. *Journal of Manufacturing Technology Management*.
25. Hernandez-de-Menendez, M., Morales-Menendez, R., Escobar, C.A., McGovern, M. (2020). Competencies for Industry 4.0. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *14*(4), 1511-1524.
26. Herrmann, C., Schmidt, C., Kurle, D., Blume, S., Thiede, S. (2014). Sustainability in manufacturing and factories of the future. *International Journal of Precision Engineering and Manufacturing-Green Technology*, *1*(4), 283-292.
27. Hirsch-Kreinsen, H. (2014). *Smart production systems: A new type of industrial process innovation*, 1-21.
28. Kagermann, H., Wahlster, W., Helbig, J. (2013). *Recommendations for implementing the strategic initiative INDUSTRIE 4.0 Final report of the Industrie 4.0 Working Group*. https://ia801901.us.archive.org/35/items/FinalReportRecommendationOnStrategicInitiativeIndustrie4.0/Final%20Report_%20Recommendation%20on%20strategic%20initiative%20Industrie_4.0.pdf
29. Kamble, S.S., Gunasekaran, A., Ghadge, A., Raut, R. (2020). A performance measurement system for industry 4.0 enabled smart manufacturing system in SMMEs - A review and empirical investigation. *International Journal of Production Economics*, *229*, 107853.
30. Kannan, S., Garad, A. (2020). Competencies of quality professionals in the era of industry 4.0: A case study of electronics manufacturer from Malaysia. *International Journal of Quality & Reliability Management*, https://doi.org/10.1108/IJQRM-04-2019-0124
31. Kiel, D., Müller, J., Arnold, C., Voigt, K.-I. (2017). *Sustainable Industrial Value Creation: Benefits and Challenges of Industry 4.0*. 1-21.

32. Leso, V., Fontana, L., Iavicoli, I. (2018). The occupational health and safety dimension of Industry 4.0. *La Medicina Del Lavoro*, *109*(5), 327-338.
33. Lin, D., Lee, C.K., Lau, H.C.W., Yang, Y. (2018). Strategic response to Industry 4.0: An empirical investigation on the Chinese automotive industry. *Industrial Management and Data Systems*, 589-605.
34. Lukoki, V., Varela, L., Machado, J. (2020). *Simulation of Vertical and Horizontal Integration of Cyber-Physical Systems.* 7th International Conference on Control, Decision and Information Technologies (CoDIT), 282-287.
35. Manavalan, E., Jayakrishna, K. (2019, January). A review of Internet of Things (IoT) embedded sustainable supply chain for industry 4.0 requirements. *Computers & Industrial Engineering*, *127*, 925-953.
36. Michna, A., Kmieciak, R., Kruszewska, J. (2021). *Industry 4.0 Implementation in automotive sector: Driving forces, barriers and competencies. Pilot empirical study.* Proceedings of the 38th International Business Information Management Association (IBMIA), pp. 9444-9450.
37. Michna, A., Kruszewska, J. (2020). *Industry 4.0 solution implementation factors: Driving forces, barriers and chances. Planned research of SME.* Proceedings of the 36th International Business Information Management Association (IBMIA), pp. 13924-13927.
38. Michna, A., Kruszewska, J. (2021). *Driving Forces, Barriers and Competencies in Industry 4.0 Implementation.* Proceedings of the 37th International Business Information Management Association (IBMIA), pp. 11112-11117.
39. Michna, A., Kruszewska, J. (2022a). *Dimensions of the Industry 4.0 implementation in manufacturing industry: Literature review.* Proceedings of the 40th International Business Information Management Association Conference (IBIMA), pp. 9444-9450.
40. Michna, A., Kruszewska, J. (2022b). Study on key competences for the implementation of Industry 4.0 solutions. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie*, *161*.
41. Mogos, M.F., Eleftheriadis, R.J., Myklebust, O. (2019). Enablers and inhibitors of Industry 4.0: Results from a survey of industrial companies in Norway. *Procedia CIRP*, *81*, 624-629.
42. Motyl, B., Baronio, G., Uberti, S., Speranza, D., Filippi, S. (2017). How will Change the Future Engineers' Skills in the Industry 4.0 Framework? A Questionnaire Survey. *Procedia Manufacturing*, *11*, 1501-1509.
43. Müller, J.M. (2019). Assessing the barriers to Industry 4.0 implementation from a workers' perspective. *IFAC-PapersOnLine*, *52*(13), 2189-2194.
44. Müller, J.M., Kiel, D., Voigt, K.-I. (2018). What Drives the Implementation of Industry 4.0? The Role of Opportunities and Challenges in the Context of Sustainability. *Sustainability*, *10*(1), 1-24.

45. Neto, A.A., Deschamps, F., da Silva, E.R., de Lima, E.P. (2020). Digital twins in manufacturing: An assessment of drivers, enablers and barriers to implementation. *Procedia CIRP*, *93*, 210-215.
46. Oettmeier, K., Hofmann, E. (2017). Additive manufacturing technology adoption: An empirical analysis of general and supply chain-related determinants. *Journal of Business Economics*, *87*(1), 97-124.
47. Peukert, B., Benecke, S., Clavell, J., Neugebauer, S., Nissen, N.F., Uhlmann, E., Lang, K.-D., Finkbeiner, M. (2015). Addressing Sustainability and Flexibility in Manufacturing Via Smart Modular Machine Tool Frames to Support Sustainable Value Creation. *Procedia CIRP*, *29*, 514-519.
48. Pfeiffer, S. (2016). Robots, Industry 4.0 and Humans, or Why Assembly Work Is More than Routine Work. *Societies*, *6*(2), 16.
49. Poszytek, P. (2021). The Landscape of Scientific Discussions on the Competencies 4.0 Concept in the Context of the 4th Industrial Revolution—A Bibliometric Review. *Sustainability*, *13*(12), 6709.
50. Quan Chong, Z., Yee Low, C., Mohammad, U., Abd Rahman, R., Bahari Shaari, M.S. (2018). Conception of Logistics Management System for Smart Factory. *International Journal of Engineering & Technology*, *7*(4.27), 126.
51. Sarkis, J., Zhu, Q. (2017). Environmental Sustainability and Production: Taking the Road Less Traveled. *International Journal of Production Research*.
52. Soniewicki, M., Paliszkiewicz, J. (2019). The Importance of Knowledge Management Processes for the Creation of Competitive Advantage by Companies of Varying Size. *Entrepreneurial Business and Economics Review*, *7*(3), 43-63.
53. Stentoft, J., Jensen, K.W., Philipsen, K., Haug, A. (2019). *Drivers and Barriers for Industry 4.0 Readiness and Practice: A SME Perspective with Empirical Evidence*, 5155-5164.
54. Stock, T., Seliger, G. (2016). Opportunities of Sustainable Manufacturing in Industry 4.0. *Procedia CIRP*, *40*, 536-541.
55. Türkeș, M., Oncioiu, I., Aslam, H., Marin-Pantelescu, A., Topor, D., Căpușneanu, S. (2019). Drivers and Barriers in Using Industry 4.0: A Perspective of SMEs in Romania. *Processes*, *7*(3), 1-20.
56. Veile, J.W., Schmidt, M.-C., Müller, J.M., Voigt, K.-I. (2020). Relationship follows technology! How Industry 4.0 reshapes future buyer-supplier relationships. *Journal of Manufacturing Technology Management*, *32*(6), 1245-1266.
57. Vrchota, J., Mařiková, M., Řehoř, P., Rolínek, L., Toušek, R. (2019). Human Resources Readiness for Industry 4.0. *Journal of Open Innovation: Technology, Market, and Complexity*, *6*(1), 3.
58. Vuksanović Herceg, I., Kuč, V., Mijušković, V.M., Herceg, T. (2020). Challenges and Driving Forces for Industry 4.0 Implementation. *Sustainability*, *12*(4208), 1-22.

59. Wang, L., Hou, S. (2024). The impact of digital transformation and earnings management on ESG performance: Evidence from Chinese listed enterprises. *Scientific Reports*, *14*(1). Scopus.
60. Yilmaz, A., Dora, M., Hezarkhani, B., Kumar, M. (2022). Lean and industry 4.0: Mapping determinants and barriers from a social, environmental, and operational perspective. *Technological Forecasting and Social Change*, *175*, 121320.

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ORGANIZATIONAL KNOWLEDGE: DEFINITIONS, TAXONOMIES, AND METAPHORS IN A DIGITAL TRANSFORMATION ENVIRONMENT

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Purpose: In the era of digital transformation, organizational knowledge becomes even more important than before in building the competitive advantage of enterprises (Malerba et al., 2020; Santorno et al., 2018; Chen et al., 2023). Digital transformation forces companies to rethink knowledge resources to meet current requirements.
Design/methodology/approach: The research methods consist of a comprehensive and systematic domestic and foreign literature review of organizational knowledge definitions, taxonomies, and metaphors in a digital transformation environment.
Findings: The development of companies in a dynamic, competitive business environment with digital transformation is altering the way knowledge is perceived within organizations and requires a new approach to understanding knowledge assets and their formation.
Research limitations/implications: The research should continue on the relationship between digital transformation and knowledge processes in the organization (acquisition, generation, storage, sharing, and transfer).
Practical implications: The research results prove that an adequate understanding of organizational knowledge, its taxonomy, and the right choice of metaphors guide efforts on knowledge creation in organizations in a digital transformation environment.
Originality/value: The research contributes to organizational knowledge management and sheds light on how knowledge metaphor analysis contributes to diagnosing situations and finding solutions that contribute to an organization's potential.

Keywords: Systematic literature review, organizational knowledge, knowledge definitions, knowledge taxonomies, metaphorical analysis.

Category of the paper: Literature review, general review.

1. Introduction

According to the knowledge-based theory of the company, knowledge is strategically the company's most important resource, and the essential role of the company is to integrate the

expertise of employees into products and services (Grant, 1996; Hughes et al., 2022; Pereira et al., 2021; Chen et al., 2023). Thus, a company can be seen as a knowledge-integrating organization (Michna, 2017, p. 10). The fundamental assumption of this theory is that knowledge is the critical input enabling the production process and that it is the primary source of value for the enterprise. Among the mechanisms that integrate specialized knowledge are: rules and directives, procedures, sequentiality, group problem solving, and digital technology.

2. Knowledge Definitions and Knowledge Taxonomies

When discussing the concept of knowledge, it is important to distinguish between such related concepts as data, information, knowledge, and wisdom (Liew, 2013; Chaffey et al., 2005, p. 223; Hussain, 2021; Jakubik, 2022). Data are discrete, objective facts, e.g. numbers, symbols, and images, without context or interpretation. They are source-based, not processed, and it is impossible to draw conclusions and take action from them. Yet they are the material from which information is created. Information is data that has been given meaning, interpreted and placed in a certain context (Jemielniak, 2012, p. 39). Knowledge, on the other hand, is a combination of data and information to which expert opinions, skills, and experience are added. The result is a valuable resource that can be used in decision-making (Chaffey, 2005; Khan, 2023; Jakubik, 2023).

Davenport and Prusak (2000, p. 5) define knowledge as a fluid mixture of experience, values, contextual information, and expert conclusions that provides a framework for evaluating and absorbing new experiences and information. Argote (2013) observes that knowledge is the result of learning, while it manifests itself as a cognitive change or as a change in behavior. It can also be understood as the totality of knowledge and skills possessed by an individual. Knowledge and ignorance co-exist (Shankar, 2014, p. 65).

Table 1.
Distinctions between data, information, knowledge and wisdom

Level	Definition	Learning process	Outcome
Data	Raw facts	Accumulating truths	Memorization (data bank)
Information	Meaningful, useful data	Giving form and functionality	Comprehension (information bank)
Knowledge	Clear understanding of information	Analysis and synthesis	Understanding (knowledge bank)
Wisdom	Using knowledge to establish and achieve goals	Discerning judgments and taking appropriate action	Better living/success (wisdom bank)

Source: Bierly, Kessler, Christensen, 2000, 595-618.

Knowledge can be seen by differentiating it with data and with information or as state of mind, object, process, and access to information or ability. Different perceptions of knowledge have various implications for knowledge management (Table 2).

Table 2.
Knowledge Definitions and Their Implications

Definition of Knowledge		**Implications for Knowledge Management (KM)**	**Implications for Knowledge Management Systems (KMS)**
Knowledge vis a vis Data and Information	Data is facts, raw numbers Information is processed/interpreted data Knowledge is personalized information	KM focuses on exposing individuals to potentially useful information and facilitating assimilation of information	KMS will not appear radically different from existing IS, but will be extended toward helping in user assimilation of information
State of Mind	Knowledge is the state of knowing and understanding	KM focuses on exposing individuals to potentially useful information and facilitating assimilation of information	Impossible to mechanize state of knowing. Role of IT to provide sources of knowledge rather than knowledge itself.
Object	Knowledge are objects to be stored and manipulated	Key KM issue is building and managing knowledge stocks	Role of IT involves gathering, codifying, and storing knowledge
Process	Knowledge is a process of applying expertise	KM focus is on knowledge flows and the process of creation, sharing, and distributing knowledge	Role of IT to provide link among sources of knowledge to create wider breadth and depth of knowledge flows
Access to Information	Knowledge is a condition of access to information	KM focus is organized access to and retrieval of knowledge content	Role of IT to provide effective search and retrieval mechanisms for locating relevant information
Capability	Knowledge is the potential to influence action	KM is about building core competencies and understanding strategic know-how	Role of IT is to enhance intellectual capital by supporting development of individual and organizational competencies

Source: Alavi, Leidner, 2001, pp. 107-136.

Nonaka and Takeuchi (Nonaka, 1997, pp. 14-37; Nonaka et al., 2000, p. 275) presented the concept of knowledge conversion, which deals with the interaction between tacit knowledge into explicit knowledge. This dynamic and interactive model of knowledge creation is anchored in the assumption that organizational knowledge is created through interactions between tacit and explicit knowledge in both ontological and epistemological dimensions (Vidic, 2022). In the ontological dimension, knowledge is created by members of the organization, as it cannot produce knowledge without creative individuals, which it supports by providing the best possible conditions conducive to knowledge creation (Michna, 2017, pp. 26-28).

On the epistemological dimension, the division identified by Polanyi (1966, p. 4), who distinguished tacit and explicit knowledge in the philosophical sciences, was taken as a starting point. Tacit knowledge is objective, related to theory and concerns past experiences "there and then" (extra-contextuality). In practice, the concept of tacit knowledge is the basis of the theory of knowledge creation in organizations. Tacit knowledge is inarticulate,

subjective, contextual, linked to senses, dexterity, physical experiences and intuition, and is created "here and now", in a given context (Insch et al., 2008; Nonaka et al., 2000, pp. 5-34). Tacit knowledge includes both cognitive and technical elements. Cognitive tacit knowledge refers to ingrained schemas, beliefs, and mental models that are taken for granted. Technical tacit knowledge is related to personal abilities or specific know-how.

The creation of organizational knowledge is a spiraling, iterative process, crossing departmental as well as organizational boundaries (Nonaka et al., 2000, pp. 84-95; Nonaka, 1998, pp. 40-54; Nishihara, 2021). The process starts at the individual level and is carried higher and higher by broadening the scope of interaction, and includes the following modes of knowledge conversion: Socialization - Externalization - Combination - Internalization. Socialization is the conversion of tacit knowledge into tacit knowledge through shared experience (master and pupil) set in a specific context. Through observation, imitation, exercise and co-learning, there is a sharing of experience and an adaptation of thinking to that of others, which would be impossible to achieve through conversation alone. Open meetings can be helpful, building mutual trust within the team. Externalization is the transposition of tacit knowledge into explicit knowledge through a creative cognitive process using metaphors, analogies, patterns, hypotheses, and mental models. The great usefulness of metaphors in the externalization of knowledge stems from the possibility of better understanding new phenomena and developing novel concepts by referring to phenomena whose structures and features are already familiar. Combination is the conversion of explicit knowledge into explicit knowledge. This process occurs within structured knowledge by categorizing, selecting or unifying information. It primarily involves combining different components of explicit knowledge (for example, knowledge just formulated by a team of employees is combined with pre-existing knowledge contained in an existing database), which can lead to the creation of new knowledge within an organization. Internalization is the transformation of explicit knowledge into tacit knowledge through verbalization and various types of documentation. The purpose of this process is to provide knowledge to employees by sharing and disseminating the experiences of others.

In the concept discussed above, it is clearly indicated that tacit and explicit knowledge do not exist in a "pure" form. All knowledge is rooted in tacit knowledge, and even the "most" explicit knowledge contains some tacit elements. Tacit knowledge and explicit knowledge are not opposites, but constitute a continuum and interact with each other in a continuous spiral. Transfer of tacit knowledge plays an important role to achieve the knowledge recontextualization (Tran, 2022).

Nonaka et al. (2014) also presented the concept of knowledge triad relationships comprising tacit knowledge, explicit knowledge and fronesis – practical knowledge. Aristotle explains fronesis (*phronesis*, Gr.) as practical wisdom or prudence (Steyl, 2020; Darnell et al., 2022; Massingham, 2019). This practical knowledge includes valuation (optimal evaluation of the "here and now"), through which the context is interpreted, the essence of the issue is grasped,

and meaning-making beyond the context takes place. Fronesis is linked to leadership capacity and innovations (Hylving, 2020), as well as should be spread across all organizational levels.

Knowledge is a very broad concept and different types of knowledge (Michna, 2017, p. 9) are distinguished by various criteria (Table 3).

Table 3.
Knowledge Taxonomies and Examples

Knowledge Types	Definitions	Examples
Tacit Cognitive Tacit: Technical Tacit:	Knowledge is rooted in actions, experience, and involvement in specific context Mental Models Know-how applicable to specific work	Best means of dealing with specific customer
Explicit	Articulated, generalized knowledge	Knowledge of major customers in a region
Individual	Created by and inherent in the individual	Insights gained from completed project
Social	Created by and inherent in collective actions of a group	Norms for inter-group communication
Conscious	Explicit knowledge of an individual	Syntax of a programming language
Automatic	Individual's tacit, subconscious knowledge	Riding a bike
Objectified	Codified knowledge of a social system	An operating manual
Collective	Tacit knowledge of a social system	Organization culture
Declarative	Know-about	What drug is appropriate for an illness
Procedural	Know-how	How to administer a particular drug
Causal	Know-why	Understanding how the drug works
Conditional	Know-when	Understanding when to prescribe the drug
Relational	Know-with	Understanding how the drug interacts with other drugs
Pragmatic	Useful knowledge for an organization	Best practices, business frameworks, project experiences, engineering drawings, market reports

Source: Alavi, Leidner, 2001, pp. 107-136.

One can also separate out the knowledge that exists in routines – systemic, socio-political, and strategic. Each of these types of knowledge has its own dimensions (Table 4).

Table 4.
Organizational Knowledge Types and Dimensions

Knowledge Types	Definitions	Examples
Systemic	Know-how Documented systems, processes, practices and policies	Unspoken rules and meanings associated with the policies, processes etc.
Socio-Political	Organization charts, roles and responsibilities Who does what where Formal decision process i.e. governance structure	How to get things done i.e. influence networks, coalitions etc. Who's powerful and who isn't Values, norms and behaviors
Strategic	Documented context including annual reports, industry prospectus etc.	Interpretations of the 'official word' Competitive and industry position and perceptions of stakeholders Core competencies Status and role in industry, society and community

Source: Evans, Easterby-Smith, 2001, 135-154.

Different types of knowledge require different sources of knowledge acquisition (Kmieciak et al., 2016; Czerwińska-Lubszczyk, 2014; Kmieciak et al., 2018). Fletcher and Harris (2012) distinguish four sources of new knowledge acquisition by companies, divided into external and internal: direct experience, indirect experience, internal information, and external information seeking.

3. Knowledge Metaphors and Knowledge Characteristics

The most important part of the knowledge creation process occurs when tacit knowledge is transformed into explicit knowledge. Tacit knowledge cannot be expressed explicitly, so in order to establish a dialogue, organizational members often use metaphors, analogies, and different types of narratives as means of expression (Venkitachalam et al., 2012).

In the literature, one can find metaphors that represent the very concept of knowledge as water, love (Andriessen, 2008) or energy (Brătianu et al., 2008). The latter metaphor is based on both quantum and classical physics. Namely, if, in the context of Newton's principles of dynamics, knowledge is metaphorically understood as mechanical energy, it can come in two forms. Tacit knowledge is described as potential energy, while explicit knowledge is described as kinetic energy. In this context, the externalization of knowledge can be presented as the conversion of potential energy into kinetic energy. A broader metaphor of viewing all knowledge conversion processes as thermodynamic principles is also presented (Brătianu, 2011). Appropriate metaphors enable a better understanding of the concept of knowledge and guide efforts regarding knowledge creation in an organization (Table 5). Although it is worth noting that metaphors have some limitations, for example in converting tacit knowledge into explicit knowledge, there is no strict and unambiguous quantitative relationship between knowledge forms, unlike the laws of physics.

Table 5.
Different metaphors and models for knowledge, how it spreads and its relationship with practice

Discipline/tradition (with examples of key scholars)	**Metaphor or shorthand description for knowledge**	**Metaphor or description for spread and distribution of knowledge**	**Implied link between knowledge and practice**
Perspectives consistent with 'knowledge translation'			
Clinical science	Research discoveries (laboratory science)	T1 knowledge transmission	*In vitro* discoveries are tested *in vivo* to generate clinical applications
Clinical epidemiology/ evidence-based medicine	Research evidence (e.g. clinical practice guidelines)	T2 knowledge dissemination/translation	'Evidence-based practice/policy' = implementation of clinical research evidence

Cont. table 5.

Perspectives inconsistent with 'knowledge translation'			
Philosophy (Polanyi)	Personal knowledge, embodied knowledge, tacit knowledge	Acquiring a way of engaging with the world	Knowledge is embodied, inseparable from the knower and contiguous with practice
Nichomachean ethics (Aristotle) and narrative medicine (Montgomery)	Practical reason	Accumulation of experience under the supervision of wise and good teachers, reflection on practice, often transmitted as 'stories'	*Praxis* is the ability to make wise, practical, ethical judgments ('what best to do in this case')
Philosophy (Wittgenstein) and ethnomethodology (Garfinkel)	'Language games': the unwritten rules that members of a social group follow as they go about their everyday practices	Learning a set of rules (not by codification but by recognizing 'family resemblances' between different situations and contexts of action and acting them out)	Knowledge is a set of dispositions that people acquire and promulgate within a community, and which confer the ability to speak and act appropriately in a social situation
Cultural sociology (Bourdieu)	Cultural capital, 'knowing how' rather than 'knowing that'	Cultural and social [re]production through people's interactions	Knowledge is the socially acquired capacity or tendency of a person to act appropriately in given circumstances
Organizational sociology (Brown and Duguid; Weick, Brown and Duguid)	Individual: 'sticky' knowledge (cannot easily be passed on), 'knowing the ropes'. Collective: shared representations, institutional logics, routines	Accumulation of experience, reflection on practice, informal storytelling ('office gossip'), following routines	Knowledge is the ability to exercise judgment within a particular field of practice. It involves (a) the ability to draw distinctions and (b) connection with a collectively generated and shared domain of practice
Communities of practice (Lave and Wenger)	Knowledge as socially shared practices, linked to membership and identity	Apprenticeship, social learning, legitimate peripheral participation (learning by 'lurking' in the community of practice)	Knowledge is contiguous with practice
Management studies/resource-based view of the firm (Nonaka)	Knowledge (especially tacit knowledge) is a commodity or resource to be managed and thus a key contributor to profitability	The 'knowledge creation cycle' (socialization, externalization e.g. through storytelling, combination with other knowledge and internalization)	Knowledge in an organization takes many forms, one of which is embodied in practice
Interdisciplinary perspective on healthcare (Davies)	Diverse: research evidence plus tacit knowledge plus local knowledge, linked in a messy way	Knowledge interaction ('messy engagement of multiple players with diverse sources of knowledge') and knowledge intermediation ('managed processes by which knowledge interaction can be promoted')	Dynamically linked in a somewhat messy (but ultimately productive) way
Engaged scholarship (Van de Ven)	What emerges when researchers and practitioners collaborate to address a practical problem	Co-production	Knowledge emerges from collaborative practice

Cont. table 5.

Eclectic synthesis of all the above (Gabbay and le May)	Mindlines (individually embodied, collectively reinforced, largely tacit guidelines)	The knowledge of research evidence is transformed and internalized through interaction with patients, reflection on practice, and exchange of stories with trusted colleagues (communities of practice)	Knowledge, practice and context are inseparable. An individual's mindline is one person's mental embodiment of their 'knowledge-in-practice-in-context', mediated through collective mindlines, so that they become 'contextually adroit'

Source: Greenhalgh, Wieringa, 2011, 501-509.

The selection of a certain metaphor in an organization guides the process of finding solutions to improve knowledge management (Table 6).

Table 6.
Results of the knowledge as water metaphor

Diagnosis	**Solutions**
Knowledge does not flow	Build canals
Separate source of knowledge	Flush out and freshen knowledge
Knowledge is not channeled	Tap knowledge from people leaving
No dispersion of knowledge	Create knowledge map
Hydrocephalus: people keeping knowledge to themselves	Managers as knowledge channels Knowledge management

Source: Andriessen, 2008, 5-12.

Distinctive characteristics of knowledge that have key implications for management and use for value creation are pointed out. Namely, it points to (Grant, 1996; Kang et al., 2010; Michna et al., 2020, p. 71; Jasimuddin, 2019; Bayona et al., 2020):

- it is embedded in the minds of employees,
- inexhaustible, knowledge is not diminished in the process of exploitation and transfer,
- transferability, with explicit knowledge being transferable through communication and tacit knowledge through application,
- viscosity, which makes it difficult to transfer,
- aggregability, which is the ability of the recipient to add new knowledge to existing knowledge,
- utility, which refers to the ability of the owner of the resource to obtain a return equal to the value created by the resource,
- domain specificity,
- indispensability,
- self-supply, knowledge that is shared by employees does not lose its value,
- spontaneity,
- simultaneity,
- non-linearity.

4. Conclusion

Foreign as well as domestic literature on knowledge, its taxonomy and metaphors is remarkably extensive. The creation and use of knowledge in the era of digital transformation requires a redefinition of organizational knowledge resources and a better understanding of its characteristics through the use of appropriate metaphors. It is also a challenge for companies to constantly seek information on technological developments, even if they are not currently relevant to the market in which the company operates, but may be in the future. Implementing digital transformation requires identifying those technologies (Saariko et al., 2020) that can be incorporated into internal processes as well as business offerings. The dynamic fractal organization (Nonaka et al., 2013) or the hypertext structure (Tariq, 2022; Michna, 2017, pp. 30-31), which is an open system whose knowledge interacts with customers, suppliers, and the rest of the environment, can help with this. Process learning, otherwise known as deutero learning, is also becoming increasingly important and takes place when organizations learn how to understand learning through single (adaptive) as well as double loop (reconstructive) learning (Dörner et al., 2021, p. 69). This type of learning is also referred to as meta-learning and is discontinuous, cognitive, and conscious (Visser, 2007). Its main goal is to increase the ability to learn and the object of learning is the learning itself.

References

1. Alavi, M., Leidner, D.E. (2001). Knowledge management and knowledge management systems: Conceptual foundations and research issues. *MIS Quarterly, Vol. 25(1),* pp. 107-136.
2. Andriessen, D.G. (2008). Stuff or love? How metaphors direct our efforts to manage knowledge in organisations. *Knowledge Management Research & Practice*, *6*(1), 5-12.
3. Antunes, H.D.J.G., Pinheiro, P.G. (2020). Linking knowledge management, organizational learning and memory. *Journal of Innovation & Knowledge*, *5*(2), 140-149.
4. Argote, L. (2013). *Organizational Learning: Creating, Retaining and Transferring Knowledge.* US: Springer.
5. Bayona, J.A., Caballer, A., Peiró, J.M. (2020). The relationship between knowledge characteristics' fit and job satisfaction and job performance: The mediating role of work engagement. *Sustainability*, *12*(6), 2336.
6. Bierly, III, P.E., Kessler, E.H., Christensen, E.W. (2000). Organizational learning, knowledge and wisdom. *Journal of organizational change management, 13(6),* 595-618.

7. Bolisani, E., Bratianu, C., Bolisani, E., Bratianu, C. (2018). The elusive definition of knowledge. *Emergent knowledge strategies: Strategic thinking in knowledge management*, 1-22.
8. Bratianu, C., Andriessen, D. (2008). *Knowledge as energy: A metaphorical analysis.* Proceedings of the 9th European Conference on Knowledge Management. Harorimana, D., Watkins, D. (eds.). Southampton Solent University, UK, 4-5 September, 2008, pp. 75-82.
9. Bratianu, C., Bejinaru, R. (2020). Knowledge dynamics: a thermodynamics approach. *Kybernetes, 49*(1), 6-21.
10. Bratianu, C., Vătămănescu, E.M., Anagnoste, S., Dominici, G. (2020). Untangling knowledge fields and knowledge dynamics within the decision-making process. *Management Decision*, *59*(2), 306-323.
11. Chen, A., Lin, Y., Mariani, M., Shou, Y., Zhang, Y. (2023). Entrepreneurial growth in digital business ecosystems: An integrated framework blending the knowledge-based view of the firm and business ecosystems. *The Journal of Technology Transfer*, *48*(5), 1628-1653.
12. Chaffey, D., Wood, S. (2005). *Business Information Management. Improving Performance Using Information Systems*. Harlow: Prentice Hall/Financial Times.
13. Czerwińska-Lubszczyk, A., Michna, A. (2014). Relacje pomiędzy sieciami współpracy a funkcjonowaniem MŚP w dotychczasowych badaniach empirycznych. *Prace Naukowe Uniwersytetu Ekonomicznego we Wrocławiu*, *359*.
14. Davenport, T.H., Prusak, L. (2000). *Working knowledge. How organizations manage what they know*. Massachusetts: Harvard Business School Press, Boston.
15. Darnell, C., Fowers, B.J., Kristjánsson, K. (2022). A multifunction approach to assessing Aristotelian phronesis (practical wisdom). *Personality and individual differences*, *196*, 111684.
16. Dörner, O., Rundel, S. (2021). Organizational learning and digital transformation: A theoretical framework. *Digital Transformation of Learning Organizations*, 61-75.
17. Evans, N., Easterby-Smith, M. (2001). Three types of organizational knowledge: implications for the tacit-explicit and knowledge creation debates. *Organizational Learning and Knowledge Management: New Directions*, 135-154
18. Fletcher, M., Harris, S. (2012). Knowledge acquisition for the internationalization of the smaller firm: content and sources. *International Business Review, Vol. 21(4),* pp. 631-647.
19. Grant, R.M. (1996). Towards a knowledge-based theory of the firm. *Strategic Management Journal*, *Vol. 17*, pp. 109-122.
20. Greenhalgh, T., Wieringa, S. (2011). Is it time to drop the 'knowledge translation'metaphor? A critical literature review. *Journal of the Royal Society of Medicine, 104(12),* 501-509.

21. Hughes, M., Hughes, P., Hodgkinson, I., Chang, Y.Y., Chang, C.Y. (2022). Knowledge-based theory, entrepreneurial orientation, stakeholder engagement, and firm performance. *Strategic Entrepreneurship Journal*, *16*(3), 633-665.
22. Hussain, M., Satti, F.A., Ali, S.I., Hussain, J., Ali, T., Kim, H.S., ..., Lee, S. (2021). Intelligent knowledge consolidation: from data to wisdom. *Knowledge-Based Systems*, *234*, 107578.
23. Hylving, L., Koutsikouri, D. (2020). *Exploring phronesis in digital innovation*. 28th European Conference on Information Systems (ECIS), June 15-17, 2020.
24. Jakubik, M. (2023). Evolution of Knowledge Management Towards Wisdom Management. *Journal of Information & Knowledge Management*, *2350051*.
25. Jakubik, M., Müürsepp, P. (2022). From knowledge to wisdom: will wisdom management replace knowledge management? *European Journal of Management and Business Economics*, *31*(3), 367-389.
26. Jasimuddin, S.M., Li, J., Perdikis, N. (2019). An empirical study of the role of knowledge characteristics and tools on knowledge transfer in China-based multinationals. *Journal of Global Information Management (JGIM)*, *27*(1), 165-195.
27. Insch, G.S., McIntyre, N., Dawley, D. (2008). Tacit knowledge: A refinement and empirical test of the academic tacit knowledge scale. *The Journal Of Psychology*, *142(6)*, 561-580
28. Jemielniak, D. (2012). Zarządzanie wiedzą. Podstawowe pojęcia. In: D. Jemielniak, A.K. Koźmiński (eds.), *Zarządzanie wiedzą*. Warszawa: Wolters Kluwer.
29. Kang, J., Rhee, M., Kang, K.H. (2010). Revisiting knowledge transfer: Effects of knowledge characteristics on organizational effort for knowledge transfer. *Expert Systems with Applications*, *37*(12), 8155-8160.
30. Khan, S., Shaheen, M. (2023). Od eksploracji danych do eksploracji mądrości. *Journal of Information Science*, *49*(4), 952-975.
31. Kmieciak, R., Michna, A. (2016). Orientacja międzynarodowa Mikro, Małych i Średnich Przedsiębiorstw – bariery, ograniczenia i perspektywy. *Zeszyty Naukowe. Organizacja i Zarządzanie, 97*. Politechnika Śląska, 411-425.
32. Kmieciak, R., Michna, A., Felden, C. (2018). A Comparison of Information Technology Capability, Employee Empowerment and Innovativeness in German and Polish Firms. *Journal of East European Management Studies*, *23*(4), 642-672.
33. Liew, A. (2013). DIKIW: Data, Information, Knowledge, Intelligence, Wisdom and their Interrelationships. *Business Management Dynamics, Vol. 2(10),* pp. 49-62.
34. Malerba, F., McKelvey, M. (2020). Knowledge-intensive innovative entrepreneurship integrating Schumpeter, evolutionary economics, and innovation systems. *Small Business Economics*, *54*, 503-522.
35. Massingham, P. (2019). An Aristotelian interpretation of practical wisdom: the case of retirees. *Palgrave Communications*, *5*(1), 1-13.

36. Michna, A. (2017). *Orientacja na zarządzanie wiedzą w kontekście innowacyjności małych i średnich przedsiębiorstw*. Wydawnictwo Politechniki Śląskiej.
37. Michna, A., Brzostek, K., Kmieciak, R. (2020). *Zarządzanie wiedzą małego i średniego przedsiębiorstwa w warunkach orientacji rynkowej - zależności, modele i uwarunkowania organizacyjne*. Wydawnictwo Politechniki Śląskiej.
38. Nishihara, A. (2021). Revisiting Nonaka's Organizational Knowledge Creation Theory for during and after the COVID-19 Pandemic. *Kindai Management Review, 9.* The Institute for Creative Management and Innovation, Kinki University, 63-74.
39. Nonaka, I. (1994). A dynamic theory of organizational knowledge creation. *Organization Science, Vol. 5(1).*
40. Nonaka, I., Kodama, M., Hirose, A., Kohlbacher, F. (2014). Dynamic fractal organizations for promoting knowledge-based transformation–A new paradigm for organizational theory. *European Management Journal*, *32*(1), 137-146.
41. Nonaka, I., Konno, N. (1998). The concept of Ba: Building a foundation for knowledge creation. *California Management Review, Vol. 40(3),* pp. 40-54.
42. Nonaka, I., Takeuchi, H. (2000). *Kreowanie wiedzy w organizacji*. Warszawa: Poltex.
43. Nonaka, I., Toyama, R., Konno, N. (2000). SECI, Ba, and Leadership: A unified model of dynamic knowledge creation. *Long Range Planning, Vol. 33(1).*
44. Pereira, V., Bamel, U. (2021). Extending the resource and knowledge based view: A critical analysis into its theoretical evolution and future research directions. *Journal of Business Research, 132,* 557-570.
45. Ode, E., Ayavoo, R. (2020). The mediating role of knowledge application in the relationship between knowledge management practices and firm innovation. *Journal of Innovation & Knowledge, 5(3),* 210-218.
46. Saarikko, T., Westergren, U.H., Blomquist, T. (2020). Digital transformation: Five recommendations for the digitally conscious firm. *Business Horizons, 63*(6), 825-839.
47. Santoro, G., Vrontis, D., Thrassou, A., Dezi, L. (2018). The Internet of Things: Building a knowledge management system for open innovation and knowledge management capacity. *Technological Forecasting And Social Change, 136,* 347-354.
48. Shankar, S.S.R. (2014). *Patanjali Yoga Sutras, Vol. 1.* Arktos.
49. Steyl, S. (2020). Aristotelian practical wisdom in business ethics: Two neglected components. *Journal of Business Ethics, 163*(3), 417-428.
50. Tariq, E., Alshurideh, M., Akour, I., Al-Hawary, S. (2022). The effect of digital marketing capabilities on organizational ambidexterity of the information technology sector. *International Journal of Data and Network Science, 6*(2), 401-408.
51. Tran, Y., Nguyen, N., Fletcher, M. (2022). The Mediating Role of Tacit Knowledgel in Knolwedge Recontexualisation by Returnee Entrepreneurs. *Academy of Management Proceedings, No. 1,* p. 17926. Briarcliff Manor, NY: Academy of Management.

52. Venkitachalam, K., Busch, P. (2012). Tacit knowledge: review and possible research directions. *Journal of Knowledge Management, Vol. 16(2),* pp. 357-372.
53. Vidic, F. (2022). Knowledge asset as competitive resource. *SocioEconomic Challenges*, *6*(4), 8-20.
54. Visser, M. (2007). Deutero-learning in organizations: a review and a reformulation. *Academy of Management Review, Vol. 32, No. 2,* pp. 659-667.

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MINING DUST AS A HEALTH THREAT TO EMPLOYEES OF EXTRACTION DEPARTMENTS OF COAL MINES

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Purpose: The presented article is empirical in nature and deals with the issue of human resource management in the mining work environment in the face of health risks for workers exposed to the harmful effects of coal mine dust at the workplace. Its purpose is to draw the attention of the management of coal mines in Poland to the growing problem of the increase in the incidence of pneumoconiosis among miners and the obligations that fall on the employer and management in connection with the need to fulfill the provisions of Article 207 of the Labour Code (Labour Code) and the changing European legislation (Directive of the European Parliament and of the Council (EU) 2017/2398 of December 12, 2017). The article presents the results of a health study of miners employed in the mining divisions of mine X exposed to the risk of harmful dusts and SiO_2 chemicals contained in mine dust. The impetus for the study in question was the increasing incidence of occupational diseases among workers in Polish coal mines in recent years, among which new cases of pneumoconiosis predominated. In 2022, pneumoconiosis of miners accounted for 92.1% of all diagnosable occupational diseases in the PKD's economic activity section B - mining and quarrying. The second factor prompting the research topic was the amendment of the regulation on chemicals, their mixtures, agents or technological processes with carcinogenic or mutagenic effects in the work environment introduced on January 24, 2020, including crystalline silica - the respirable fraction formed during work - among the agents with carcinogenic or mutagenic effects.
Design/methodology/approach: A study of the assessment of the prevailing dust hazard and the frequency of respiratory lesions among workers in the mining departments of mine X exposed to the harmful effects of mine dust as a by-product of the manufacturing process was carried out using the following methods: individual dosimetry, infrared spectrometry, directional interview, diagnostic tests and spirometry.
Findings: The results made it possible to identify the workplaces with the highest exposure to harmful effects of coal dust and to recognize the effects of this action in the form of respiratory lesions in 28.6% of the miners of mine X examined, who had not previously reported health complaints.
Research limitations/implications: Health examinations of coal mine workers are a sensitive issue and one that is reluctantly raised by mine management, union organizations and the workers themselves. The inadequacy of Polish legislation, which, in the event of the diagnosis of symptoms of an occupational disease, guarantees an employee to keep his or her previous salary as a result of transfer to another job for only 6 months (Article 230 of the Labor Code), causes employees to hide their health status until they are eligible for retirement and are reluctant to undergo earlier diagnostic examinations. The condition for making the data

available for the purposes of the above article was to guarantee the complete anonymity of the subjects and the workplace, which is in line with the policy of the Silesian University of Technology, which guarantees the anonymity of the data obtained in circular letters addressed to the Mining Companies.
Practical implications: Recognized new cases of pneumoconiosis incidence among surveyed employees of mining divisions indicated the necessity of changing the current approach of employers and managers to the issue of measuring harmful factors at workplaces and the necessity of expanding preventive examinations of miners to include capillary blood gasometry, peripheral blood morphology, low-dose high-resolution computed tomography allowing scrinig of lung cancer. The proper approach of mine management and health and safety services to miners' health issues should improve the financial condition of mining companies and mines by reducing the occupational morbidity of the protection of employees, who are the pillar of the company's efficiency.
Social implications: A review of the literature and the results obtained show that the problem of the incidence of pneumoconiosis among coal mine miners not only in Poland is again a growing social problem, resulting in an increase in occupational morbidity rates and incurred social costs related to the loss of physical ability to perform work by miners and the need for their treatment. On the other hand, the consequences of long-term exposure of workers to harmful factors leads to occupational diseases, the consequence of which is often a change of job and loss of part of the workers' wages, so it would be advisable to consider public consultations in this area in order to develop new legal regulations to increase worker protection.
Originality/value: The article is directed to the management of coal mines and health and safety services. It presents the results of environmental measurements and diagnostic tests of miners carried out in real time, to which access is difficult. In addition, the article presents solutions for early diagnosis of respiratory health disorders and better management of human resources and protection of miners' health as a superior value.

Keywords: mine, mining division, pneumoconiosis, mine dust, occupational disease, diagnostic testing, spirometry.

Category of the paper: Research paper.

1. Introduction

Pneumoconiosis is one of the most commonly diagnosed occupational diseases caused by harmful agents found in the workplace. In 2022, in terms of the frequency of newly diagnosed occupational diseases, pneumoconiosis ranked second, right after infectious and parasitic diseases, among which COVID-19 was by far the most prevalent, with 1,053 cases. According to data from the IMP in Lodz (Swiatkowska, Hanke, 2023), in 2022 the number of diagnosed occupational pneumoconiosis in Poland amounted to 466 cases (17.6% of total occupational pathologies), of which coal miners' pneumoconiosis accounted for 254 cases (54.5% in this group). For years, it has been among the most commonly diagnosed pneumoconiosis of occupational etiology next to asbestosis and silicosis. Due to the specific nature of employment in a particular industry and exposure to mine dust (stone and coal dust), coal workers'

pneumoconiosis is more common in men (99.6% of cases) than in women (0.4%). By virtue of the number of people working in conditions of exposure to fibrosing dust, 19215 out of a total of 22802 (Akusztol et al., 2022), pneumoconiosis is the most commonly diagnosed occupational disease in the socio-economic sector that includes mining and quarrying (Section B), where 351 cases of pneumoconiosis were found in 2022. Equally determinant risks in the mining and quarrying sector are carcinogenic dusts containing the respirable fraction of crystalline silica SiO_2 that cause lung cancer. Of the 19834 people exposed to carcinogenic dusts in 2022, as many as 11 out of 47 such cases in the mining industry were diagnosed in Poland. And since the inclusion of crystalline silica as a carcinogen in 2022, there have already been 42 such cases. Analysis of cases of pneumoconiosis by age groups shows that the number of decisions issued declaring an occupational disease in the form of pneumoconiosis increases with the age of the worker. In the case of the PKD section of mining and quarrying, more than 92.3% of the established cases of pneumoconiosis are diagnosed in workers who are already retired, and most often in the advanced stage of this disease that bodes poorly for the health future of former miners.

What is worrying, therefore, is not only the continued increase in the number of cases of pneumoconiosis among miners, but the fact of late diagnosis of these conditions, especially since they are often chronic diseases that significantly affect health, and can take years to develop. Therefore, early detection of disease symptoms and prompt initiation of treatment have the greatest impact today on the course of the disease and its possible consequences. Too late recognition of the patient's ailment carries very serious and irreversible consequences not only for the miner himself, but also for his family and society as a whole. Therefore, such an important element in the fight against miner's pneumoconiosis, lung and bronchial cancers caused by exposure to mine dust (stone and coal dust) is that employers and managers take appropriate preventive measures to limit the occurrence of dust in the workplace and cover employees at risk of fibrosing dust with medical prophylaxis appropriate to the risk. This is particularly important, especially in mines and coal mining plants, where most technological processes are still based on the physical labor of miners.

Human resource management in coal mines should therefore view "people as a valuable source of the company's success and treat them as a fixed asset, which should be provided with the best and safe working conditions and opportunities for the full development of their abilities" (Koziol, Piechnik-Kurdziel, Kopeć, 2000). In turn, labor efficiency depends not only on the numerical state of the workforce, but at the same time on its qualitative state, i.e. on the characteristics of its composition, i.e. the structure of employment according to certain criteria, as a rule, interdependent, as well as aspects of work safety and health of employees, who are the pillars of the company's efficiency (Figure 1).

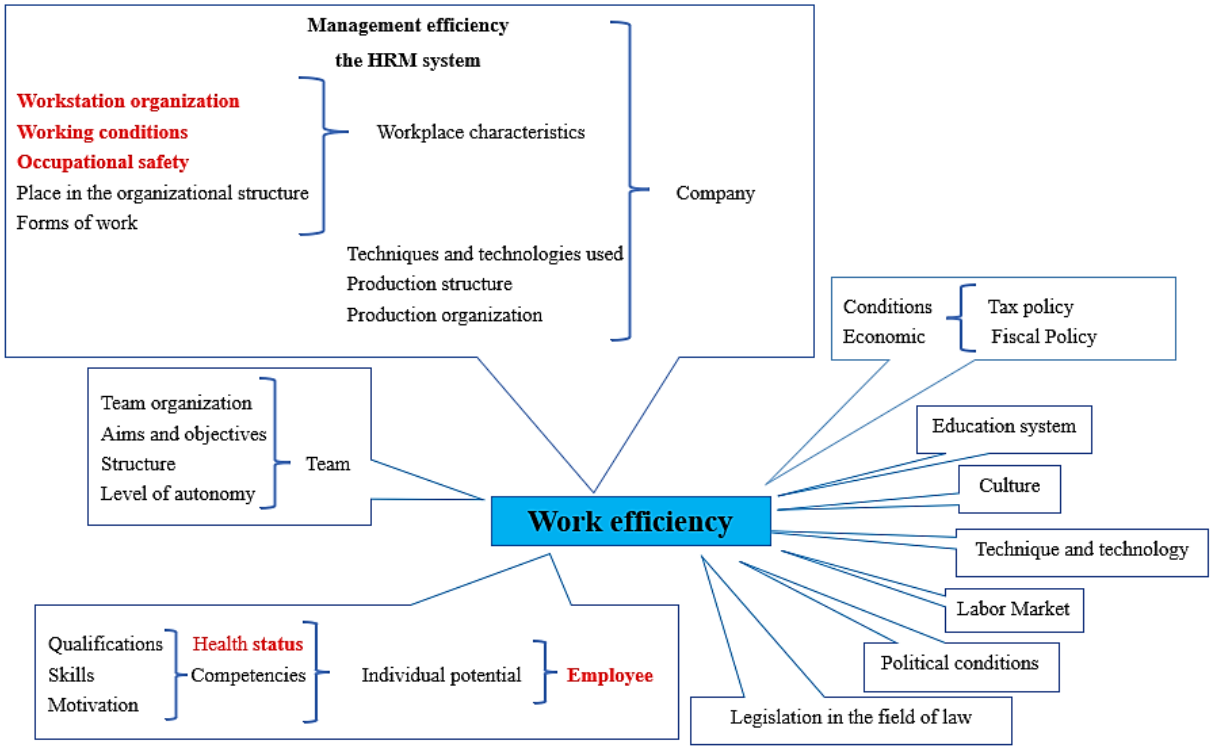

Figure 1: Determinants of labor efficiency.

Source: own compilation based on Mocek, 2021, pp. 118-135.

The purpose of the study, in the first place, was: to assess the actual state of the risk of fibrous and carcinogenic dusts in the mine workings of the mining divisions of the X mine located in Ruda Śląska in light of the amended 2020 legal regulations regarding the counting of the respirable fraction of free crystalline silica to carcinogenic dusts, and to assess the actual state of health of active coal mine miners. In the second place, to remind employers of their obligations under the provisions of Chapter X of the Labor Code, which states, among other things, that the employer is obliged to:

a) be responsible for the state of health and safety at the workplace,
b) protect the health and lives of employees by ensuring safe and sanitary working conditions,
c) conduct tests and measurements of factors harmful to health in the work environment,
d) assess and document the occupational risks associated with the work and apply the necessary preventive measures to reduce the risk,
e) Inform employees about the occupational risks associated with their work and the principles of protection from hazards,
f) respond to the needs for ensuring occupational health and safety and adjust the measures taken to improve the existing level of protection of the health and life of workers, taking into account the changing conditions of work performance.

2. Literature review and hypothesis development

Despite the many international efforts and actions taken (López-Campos, Soler-Cataluña, Miravitlles, 2020; Blackley, Halldin, Laney, 2018; Blackley et al., 2016). to reduce coal mine workers' exposure to harmful dusts generated in the mining process (Blackley et al., 2016; Weissman, 2022; Liu, T., Liu, S.H., 2020) still tens of thousands of miners worldwide are exposed to their harmful effects (Laney, Weissman, 2014; Perret et al., 2017, Perret et al., 2020). The result of this exposure is pneumoconiosis, which is common among miners (Cohen et al., 2022; Barber, Fishwick, 2016), with acute-fibrosis and chronic-failure (Han et al., 2018; Antao et al., 2005; Almberg et al., 2018), which for years have been the subject of research and scientific publications by many researchers from Columbia (Rey et al., 2015), the Czech Republic (Tomášková et al., 2017), Poland (Brodny, Tutak, 2018), Asia (Perret et al., 2017), Australia (Zosky et al., 2016), the United States of America (Hall et al., 2019) and other industrialized countries of the world. In all of these countries, recent years have seen a renewed increase in the incidence of pneumoconiosis especially of the silicosis type manifested in its most severe form associated with rapid massive fibrosis of lung tissue. Studies in Asia and the United States indicate that the incidence among miners has more than doubled since the end of the 20th century (Shi et al., 2020; Suarthana et al., 2011). The main reason for the increase in morbidity among miners today is believed to be improvements in mining equipment and raw material processing technologies that have enabled the cost-effective recovery of thin coal seams. The mining of thin seams also entails the extraction of large amounts of surrounding rock layers excavated with the coal, which may contain crystalline silica. Studies conducted by various researchers show that in some mines the rock layers occupy more than 50% of the total volume of extraction carried out from thin seams which generates almost twice as much respirable dust compared to the coal seam itself (Cohen et al., 2016; Sarver, Keles, Afrouz, 2021; Johann-Essex et al., 2017; Trechera et al., 2022).

In order to reduce this danger, various technical solutions are being introduced in the mine workings of coal mines to reduce the amount of dust produced or to deprive it of its volatile properties. Among the most effective technical solutions are:

- Dust collection devices (Xu, Wang, 2021; Kuczera, Ptaszynski, 2019).
- Sprinkler systems mounted on the heads of mining machines (Balaga et al., 2016; Lutynski, 2020).
- Hydration of the rock mass (Chao et al., 2022; Liao et al.).
- Water curtains installed in mine workings (Balaga, 2019; Peng et al., 2022).
- Ventilation systems (Balaga et al., 2015; Ji et al., 2016).

Considering the above, it should be stated that taking care of the health and life of employees is one of the basic duties of the employer resulting directly from the Labor Code Act (ISAP, 2018) and other international (EUR-Lex, 2017; EUR-Lex, 1989) and industry

regulations. This means that for the **respirable fraction of crystalline silica generated during coal mining,** all obligations related to carcinogens under the regulation (ISAP, 2020; ISAP, 2021 i.e.):

- Include silica in the register of work whose performance makes it necessary to be in contact with chemicals, their mixtures, agents or technological processes with carcinogenic or mutagenic effects.
- Include workers exposed to silica in the register of workers exposed to chemicals, their mixtures, agents or technological processes with carcinogenic or mutagenic effects.
- Conduct periodic training of employees taking into account the topics contained in paragraph §9 item. 2 of the Ordinance (ISAP,1997), as well as appropriate preventive examinations.
- Every year, by January 15, send information in this regard to the relevant state provincial sanitary inspector and the relevant district labor inspector.
- Regularly conduct occupational risk assessments of workers exposed to crystalline silica, the respirable fraction generated during work, and other fibrous dust.

3. Research Methodology

Volume Assessment of health risks for employees of selected mining divisions of Mine X due to long-term exposure to mine dust (coal-dust) was carried out by employees of the Department of Safety Engineering of the Silesian University of Technology in cooperation with employees of the Central Laboratory for Work Environment Research "Stanisław Bielaszka" in Jastrzebie Zdroj and physicians in the field of pulmonology. As part of the research conducted in accordance with the regulations in force in Poland (ISAP, 1997; ISAP, 2011; ISAP, 2018a), were carried out:

1. Measurement of dust concentrations of inhalable and respirable fractions at the workplace.
2. Measurement of chemical concentrations at workplaces.
3. Preventive diagnostic testing of the respiratory system of employees of selected mining divisions.

Workplace sampling was used to determine the concentration of inhalable and respirable fraction dust at the workplace based on:

- PN-Z-04008-7:2002 "Protection of clean air - Sampling - "Principles of air sampling in the working environment and interpretation of results".
- PN-G-04035:2002+Az1:2005 "Protection of air purity in underground mines. Measurement of air dust concentration and determination of free crystalline silica content in dust".

For sampling of harmful substances (dust), the method of individual dosimetry was used using individual pumps that allow sampling of air in the worker's breathing zone continuously for a period at least equal to 75% of the duration of the work shift.

Studies of the respirable and inhalable fraction of dust were based on standards:

- PN-91/Z-04030.06 "Determination of respirable dust at workplaces by the filter-weight method",
- PN-91/Z-04030.05 "Determination of total dust at workplaces by the filter-weight method".

The basis for determining the concentration of crystalline silica was infrared spectrometry (Maciejewska, 2012):

Prior to the survey, a site visit was made and information was collected on:

- The location and naming of the workstation.
- The type and course of technological processes.
- types of machinery and equipment and activities performed.
- harmful factors characteristic of the technological processes in question.
- the duration of exposure to harmful health factors (exposure time).

Apparatus

Individual aspirators of SKC's type 224-44MTX were used for air sampling at workstations, which are subject to checking each time before and after measurement with a rotameter of type ROS-06 with factory number 079902, which has a calibration certificate issued by OUM in Poznan accredited at PCA (No. AP 085) - Figure 2.

The doughnuts used for the measurements were dried to a constant mass in a desiccator, after which they were weighed on a RADWAG AS60/220.R2 balance with serial number 508222, which has a certificate of legalization and calibration issued by "TOPS" S.C. Mass Measurement Laboratory accredited by PCA (No. AP 093).

Each siphon was assigned appropriate holders (inhalable fraction) and cyclones (respirable fraction).

Figure 2. Type 224-44 MTX individual aspirators used in environmental studies.

Source: own study.

In order to determine the concentration of chemicals at workplaces, tests and measurements were carried out at workplaces based on: PN-Z-04008-7:2002 and PN-Z-04008-7: 2002r/Azl December 2004. "Principles of air sampling in the work environment and interpretation of results".

Based on the determined concentration values in the dust and/or chemical samples, the average concentration by weight was determined formula (1) and (2) and the exposure rates W_E were calculated for the entire work shift formula (3):

- for samples taken by individual dosimetry based on formula (1):

$$C_w = \frac{C_1 \cdot t_1 + C_2 \cdot t_2 + C_3 \cdot t_3 + \cdots + C_n \cdot t_n}{t_1 + t_2 + t_3 + \cdots + t_n} \quad (1)$$

where:

C_1, C_2, ..., Cn - concentrations obtained from the determination of individual samples [mg/m^3],

t_i - time of taking individual samples [min],

n - the number of samples.

- for samples taken by the stationary method based on formula (2) and (3):

$$\bar{X}_{gw} = \frac{\bar{X}_{g1} \cdot t_1 + \bar{X}_{g2} \cdot t_2 + \bar{X}_{g3} \cdot t_3 + \bar{X}_{gk} \cdot t_k}{t_1 + t_2 + t_3 + \cdots + t_k} \quad (2)$$

where:

X_{g1}, X_{g2} ..., X_{gk} - concentrations obtained from the determination of individual samples [mg/m^3],

t_{123}, ..., t_k - duration of individual measurement periods in minutes,

k - the number of measurement periods,

$$W_E = C_W \cdot \frac{T_e}{T_o}, \text{ or } W_E = \bar{X}_{gw} \cdot \frac{T_e}{T_o} \quad (3)$$

where:

C_W $X_{,gw}$ - weighted average concentration of a specific type of dust/chemical, expressed in [mg/m^3],

T_e - time of exposure during the working shift, expressed in minutes,

T_o - reference time for 8-hour working time, or 480 minutes,

W_E - exposure indicator,

Working conditions are considered safe if the calculated exposure index did not exceed the NDS for the substance, and the exposure index W_N is less than or equal to 1 formula (4).

$$W_N = \frac{W_E}{NDS} \leq 1 \quad (4)$$

where:

W_N - exposure-indicator,

W_E - exposure index for total or respirable dust or chemical substance, expressed in [mg/m^3],

NDS - the maximum permissible concentration for total or respirable dust or chemical substance, expressed in [mg/m^3].

For sampling of harmful substances (chemical agents), the method of individual dosimetry was used using individual pumps that allow sampling of air in the breathing zone of the worker continuously for a period at least equal to 75% of the duration of the work shift

Apparatus

SKC's type 224-44 MTX individual aspirators were used to collect air samples for testing the concentration of chemicals at workstations, which are subject to checking each time before and after measurement with a type ROS-06 rotameter with serial number 079901, which has a calibration certificate issued by OUM in Poznan accredited at PCA (no. AP 084).

The doughnuts used for the measurements were dried to a constant mass in a desiccator, after which they were weighed on an AS60/220.R2 balance from RAD W AG, factory number 508222, which has a certificate of legalization and calibration issued by "TOPS" S.C. Mass Measurement Laboratory accredited by PCA (No. AP 093).

Chemical analysis was performed on the following equipment:

- Crystalline silica: FT-IR Spectrum TWO spectrophotometer from Perkin Elmer Factory No. 97389 - calibration certificate for polystyrene film issued by the General Office of Measures - infrared absorption spectrophotometry method.

Preventive diagnostic examinations of employees of selected mining divisions of mine X were carried out based on the miner's interview, physical examination and spirometry.

4. Results and Discussion

The most important organizational structure of any deep coal mine is the Mining Branches, whose primary task is to exploit (mine) the accessed coal seam or deposit between two parallel galleries (Figure 3). The roadways transport the material necessary for the production process (subwall roadway) and collect the worked coal from the longwall (headwall roadway). The basic equipment of a longwall is a mechanized casing, which protects the crew from uncontrolled rock fall, a scraper conveyor, which transports the processed coal, and a longwall shearer, whose task is to mine the coal body. The length of longwalls ranges from 60 to 250 meters, and their runway from several hundred meters to several kilometers. The height of the coal face varies from 1.5 to 4.0 meters.

The processed and transported to the surface coal extracted from the coal face by mining divisions is the main raw material sold by coal mines.

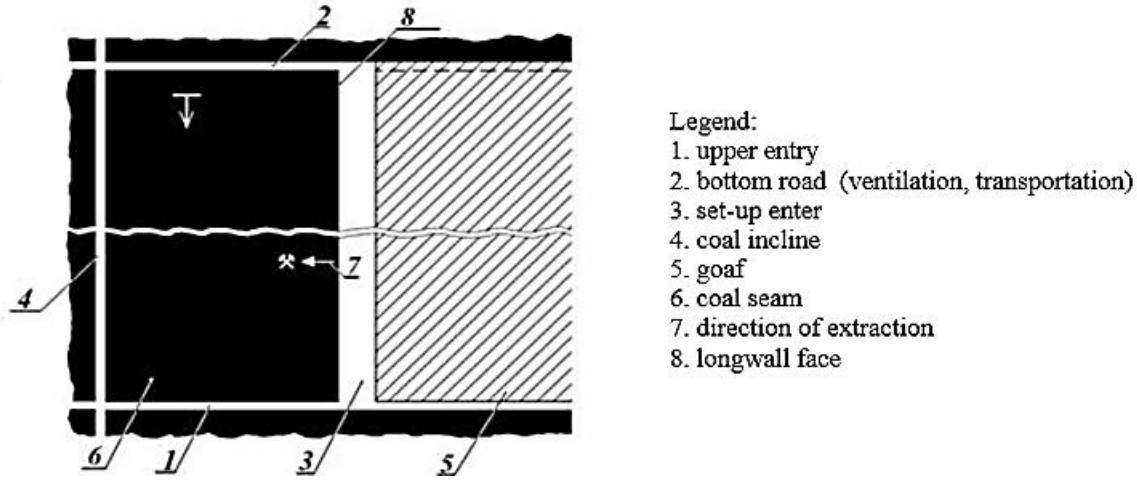

Figure 3. Overview diagram of the excavations around the coal face.

Source: own elaboration based on Honysz, 2011.

Figure 4. Dust in the coal face area of the G-1 mining division of X Mine.

Source: own study.

In the process of mining a coal seam by a longwall shearer, the greatest dusting of air occurs, which miners breathe for most of their working shift Fig. 3. Due to the limited spatial dimensions of the mine workings and the coal face itself, as well as the limited ventilation capacity and technological processes used, the mine air may contain other minerals including free crystalline silica in addition to crushed coal and stone particles.

As part of the study, air dust measurements were carried out in two mining divisions: G-1 - which conducts works in seam 405/1 with a thickness not exceeding 1.7m by a longwall system with shearer cavities, and G-2 - which conducts works in seam 507 with a thickness of 2.5 m by a longwall system without cavities.

The results of dust measurements at selected positions of the mining divisions of mine X are shown in Table 1, and the chemical substances in Table 2. The following numbers were assigned to the individual workstations: shearer - 1, shearer's helper - 2, sectional - 3, miner in transport - 4, conveyor operator - 5, miner in the shearer's bay - 6, blasting miner - 7, robber - 8.

Table 1.
Results of measurements of mine dust (coal-dust) air dust at individual workstations of mining divisions by the dosimetric method

Ward	Position	Dust concentration range, in the fraction [mg/m^3]		Indicator W_E [mg/m^3]		NDS		W indicator $_N$ (multiples of the NDS)	
		inhaled	respirabled	inhaled.	respirabled.	inhaled.	respirabled.	inhaled	resp.
G-1	1	0,60-37,54	0,38-18,52	35,62	16,32	10	2	3,6	8,2
	2	0,56-35,43	0,36-17,25	33,24	15,41	10	2	3,3	7,7
	3	0,55-33,12	0,30-15,48	30,42	13,25	10	2	3,0	6,6
	4	0,40-21,36	0,15-7,63	19,70	5,80	10	2	2,0	2,9
	5	0,46-26,70	0,28-15,33	24,44	13,46	10	2	2,4	6,7
	6	0,65-38,66	0,32-16,18	36,12	14,02	10	2	3,6	7,0
	7	0,62-36,92	0,40-18,26	34,50	16,73	10	2	3,5	8,4
	8	0,50-29,64	0,26-16,79	27,58	14,32	10	2	2,8	7,2
G-2	1	0,82-42,16	0,52-22,34	40,24	20,10	10	2	4,0	10,1
	2	0,78-41,36	0,50-21,73	39,75	19,34	10	2	4,0	9,7
	3	0,70-38,42	0,48-19,30	26,30	18,43	10	2	2,6	9,2
	4	0,65-34,50	0,42-17,40	32,48	16,28	10	2	3,2	8,1
	5	0,66-38,22	0,36-20,01	35,60	18,74	10	2	3,6	9,4
	8	0,63-36,28	0,36-19,49	33,19	17,32	10	2	3,3	8,7

Source: own study.

Circumstances of sampling during the 450-minute exposure included such activities performed by employees of mining divisions as:

- descent, exit by shaft to the mine, train ride to the longwall area, access and return from the workstation,
- preparatory work,
- operation of: shearer, conveyors, longwall equipment,
- combine mining, mining with explosives,
- mechanized housing control,

- drilling blasting holes and maintaining harvester cavities,
- transporting materials to the longwall, rebuilding longwall equipment behind the advance,
- robbing of roadway lining, reconstruction of intersections of roadway excavations with the coal wall,
- technology breaks.

Table 2.
The results of measurements of the chemical substance - crystalline silica at individual sites of mining divisions by the dosimetric method

Ward	Position	The concentration range of crystalline silica in the respirable fraction [mg/m^3]	Indicator W_E [mg/m^3]	NDS respirabled fraction	Indicator W_N (times of NDS)
G-1	1	0,032-0,411	0,402	0,1	4,0
	2	0,030-0,408	0,396	0,1	4,0
	3	0,032-0,356	0,332	0,1	3,3
	4	0,020-0,462	0,449	0,1	4,5
	5	0,028-0,374	0,353	0,1	3,5
	6	0,036-0,456	0,431	0,1	4,3
	7	0,036-0,440	0,432	0,1	4,3
	8	0,028-0,358	0,340	0,1	3,4
G-2	1	0,018-0,294	0,270	0,1	2,7
	2	0,018-0,280	0,262	0,1	2,6
	3	0,016-0,265	0,249	0,1	2,5
	4	0,012-0,214	0,196	0,1	2,0
	5	0,014-0,262	0,248	0,1	2,5
	8	0,017-0,202	0,186	0,1	1,9

Source: own study.

The study shows that all workplaces in the surveyed mining divisions are at risk of above-normal exposure to dust and harmful substances. The highest concentrations of dust are found at the position of the shearer and miners employed in the shearer's cavities, as well as at the position of the shearer's helper in non-cavity mining.

The decisive factor in the state of danger for working mining crews is undoubtedly the high fineness of the coal fraction and the presence of crystalline silica in the air inhaled by miners even in a longwall run in seam 507 where there is no trimming of the roof or bottom of the excavation, and there is little overgrowth of stone. As it turns out, the fresh air supplied to the coal faces already contains certain amounts of silica, which contribute to exceeding the currently applicable normative values for this chemical at the workplace. According to current regulations, the frequency of environmental measurements at the mine should therefore increase (Table 3). Following this, under Articles 101 and 222 of the Labor Code Act, the employer should take additional preventive measures to improve working conditions and monitor the health of those exposed to carcinogens.

To supplement the collected measurement results among 56 employees of the mining divisions (G-1, G-2) of the X mine, anonymous diagnostic tests of the respiratory system were also carried out to assess the prevalence of respiratory disorders among the surveyed miners.

Table 3.
Frequency of measurements depending on the concentrations of harmful factors found

Workplace number		Indicator W_N (times of NDS)	Research frequency
G-1	**G-2**		
Name of the harmful agent - coal (hard coal, lignite)			
		NDS < 0.1	*
		0.1 < W_N < 0.5 NDS	at least once every two years
1,2,3,4,5,6,7,8	1,2,3,4,5,8	IN_N > 0.5 NDS	at least once a year
Name of harmful substance - crystalline silica (quartz, cristobalite) - respirable fraction			
		0.1 < W_N < 0.5 NDS	At least once every 6 months (carcinogens or mutagens are present)
1,2,3,4,5,6,7,8	1,2,3,4,5,8	IN_N > 0.5 NDS	At least once every 3 months (carcinogens or mutagens are present)
*- in accordance with § 7. Ordinance of the Minister of Health dated 02.02.201 Ir. on tests and measurements of factors harmful to health in the work environment (Journal of Laws No. 33 of 201 Ir.), as amended.			

Source: own study.

The scope of diagnostic tests included:

a) Patient interview - the purpose of which was to learn about the employee's identification data; his personal characteristics such as age, height, weight; health complaints; past illnesses; family health burdens, lifestyle, addictions, working conditions. In this study, the CAT - COPD Assessment Test (Farnik et al., 2019) was used to assess the patient's current complaints, which identified the patient's presenting symptoms such as coughing, sputum retention, chest tightness, daily activities inside and outside the home, shortness of breath, anxiety and insecurity, sleep disturbances, and energy for activities (Table 4). The patient in the survey on a scale of 1-5 determined his attitude toward the ailment, where 1 meant no ailment and 5 meant great difficulty caused by the ailment.
b) A physical examination - whose purpose was to conduct a general assessment of the health and appearance of the worker under examination using the sensory organs of sight, hearing, touch. It included:
   - Viewing: the patient's skin and its discoloration; the shape and appearance of the chest in terms of its structure, the shape of the fingers of the hands.
   - Assessment of respiration: proportions of inhalations and exhalations, breathing tracks, chest mobility, number of breaths per minute, respiratory disorders.
   - Palpation examination: assessing the symmetry of respiratory movements of the chest, determining local rib soreness, evaluating vocal tremor and the presence of air in the subcutaneous tissue.
   - Chest auscultation: to determine the size and mobility of the lungs, identify pleural fluid or air in the pleural cavity or the airlessness of the lung parenchyma.

Table 4.
CAT test results of employees of X mine's mining divisions

Number of respondents	Age of respondents							
	≤ 20	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	**> 50**
respondents (smokers)	2 (0)	6 (2)	14 (5)	9 (6)	10 (5)	12 (6)	2 (2)	1 (0)
Occurring symptoms	number of subjects/(CAT score average)							
cough	-	1 (3,0)	4 (3,0)	2 (3,0)	5 (3,7)	5 (3,7)	1 (3,0)	-
lagging of sputum	2 (3,0)	2 (3,0)	10 (3,0)	6 (3,5)	9 (3,3)	10 (3,5)	2 (4,0)	1 (4,5)
chest tightness	-	-	-	-	2 (4,0)	4 (2,5)	1 (3,0)	-
shortness of breath and breathlessness	-	-	-	1 (3,0)	2 (3,5)	4 (3,5)	1 (4,0)	1 (3,5)
fatigue	-	-	2 (3,5)	4 (3,0)	4 (3,0)	8 (3,5)	1 (4,0)	1 (4,0)
fear and uncertainty	-	-	-	-	-	2 (3,5)	-	-
sleep disorders	-	-	-	-	1 (4,0)	2 (4,0)	-	-
lack of energy	-	-	1 (3,0)	-	6 (3,5)	3 (3,7)	1 (3,5)	-
CAT score	< 10	< 10	12,5	12,5	25	23,9	21,5	12,0
Interpretation of CAT scores: 1. 5 points - Upper limit of normal in healthy, non-smokers. 2. < 10 points - Little impact of illness on life. Most days good. Symptoms of fatigue 3. 10-20 points. - Medium impact of the disease on life. Appearing shortness of breath, cough, 1-2 exacerbations per year 4. 21-30 pts - Large impact on life. Illness prevents most activities. 5. > 30 points. Very high impact on life. Impaired performance of basic activities.								

Source: own study.

c) auscultation: enabling the detection of respiratory anomalies in the form of bronchial and pulmonary murmurs, crackles, wheezes and furls (Table 5).

Table 5.
CAT test results of employees of X mine's mining divisions

Recognized symptoms	Age and number of respondents							
	≤ 20	**21-25**	**26-30**	**31-35**	**36-40**	**41-45**	**46-50**	**> 50**
	2	**6**	**14**	**9**	**10**	**12**	**2**	**1**
	Number tested with symptoms							
skin lesions	-	-	-	-	-	-	-	-
chest deformity	-	-	-	-	-	2	-	-
clubbed fingers	-	-	-	-	1	4	-	-
shallowed breathing, breathlessness	-	-	4	-	2	4	1	1
extended exhalation	-	-	2	-	2	1	-	-
unilateral weakness of chest movements	-	-	-	-	2	3	1	-
reduction in the number of breaths	-	-	-	-	4	4	1	1
respiratory disorders	-	-	-	2	3	4	1	1
lowering of the lungs	-	-	-	-	1	2	-	-
muffled popping sound	-	-	-	-	2	2	-	-
drumming sound	-	-	-	-	-	1	-	-
voice tremor	-	-	-	-	1	2	-	1
bronchial or pulmonary murmurs	-	1	4	4	7	5	1	1
swish	-	-	1	1	3	4	1	-
furls	-	-	-	2	-	3	-	-
pleural friction	-	-	-	-	1	1	-	-

Source: own study.

- spirometry tests - whose purpose was to determine the lung capacity and volume of the studied workers and the airflow that occurs during the different phases of the respiratory cycle. The tests were performed with the Lungtest mobile spirometer from MES in accordance with the criteria for correctness and reproducibility of performing basic spirometry tests according to the recommendations of the ATS - American Thoracic Society (Boros, Mejza, Gomółka, 2020).

For the correctness of the tests, the instrument was calibrated before each measurement. Personal characteristics of the worker such as age, gender, height and weight were entered into the memory of the measuring device (spirometer). The test was performed in a sitting position with a nose clip in place. The test of taking air into the lungs and blowing air into the spirometer was repeated three times and was considered reliable if the results were similar. Airway obstruction was determined according to the recommendations of the GOLD report for COPD (López-Campos, Soler-Cataluña, Miravitlles, 2020) based on the finding of airflow limitation during expiration based on the obtained FEV1/FVC and FEV1 values (Table 6).

Table 6.
Degree of pulmonary impairment in spirometric study of workers in mining departments of X mine

Degree of obstruction	Eligibility criteria by FEV1	Age and number of respondents							
		≤ 20	21-25	26-30	31-35	36-40	41-45	46-50	> 50
		2	6	14	9	10	12	2	1
		Number tested with symptoms							
light	> 80%	-	1	1	1	1	1	-	-
moderate	50-80%	-	-	-	1	2	3	-	1
severe	30-50%	-	-	-	-	2	2	1	-
very difficult	< 30%	-	-	-	-	-	-	-	-

Source: own study.

A diagnostic study based on the interview and CAT Test showed that more than 11.7% of the miners of the X mine's mining divisions surveyed suffered from worrisome respiratory ailments, which worsened markedly after the age of 36 and after an average of 15 years of continuous exposure to dust. Increased symptoms were diagnosed in shearers, longwall cavity workers and longwall spoil haulage workers, despite the fact that 48.0% of workers with symptoms of respiratory disorders have never smoked cigarettes, and 96.3% are not exposed to industrial dust outside the mine. Minor discomfort manifested by lingering sputum and cough is experienced by the vast majority of respondents who try to get rid of contaminants entering the respiratory system on a daily basis during work. The result of the interview is also confirmed by the physical examination, especially auscultation, which in 32.1% of the subjects shows murmurs, wheezes and furls indicating narrowing of the airways lying inside or outside the chest and the presence of secretions in the airways. Interestingly, these conditions are observed not only in the elderly, but also in young workers between 20-30 years of age. Unfortunately, there may be cases of atelectasis, emphysema and decreased airflow of lung tissue among the workers surveyed, as can be evidenced by muffled and eardrum-like tapping noises (12.5% of

those surveyed). The study also shows the possibility of neoplastic changes in 2.4% of the subjects as manifested by pleural friction and clubbed fingers, which may indicate neoplastic fibrous changes of the lung tissue. This observation was also confirmed by spirometry tests, which showed a severe degree of respiratory obstruction of less than 35% in 7.1% of the subjects (Figure 5).

In total, features of respiratory obstruction were diagnosed in 11 people, i.e. 19.4% of those surveyed, which is a significant result, especially in a situation where, among the 56 employees of the X mine's mining divisions surveyed, none of the workers were under the supervision of a pulmonologist. Miners are therefore unaware of the causes of their ailments and health conditions. Their preventive examinations for the diagnosis of respiratory diseases were overwhelmingly limited to chest X-rays every few years. All those who were diagnosed with features of respiratory obstruction as part of the research conducted by the Department of Safety Engineering at the X mine were referred for further diagnostic testing.

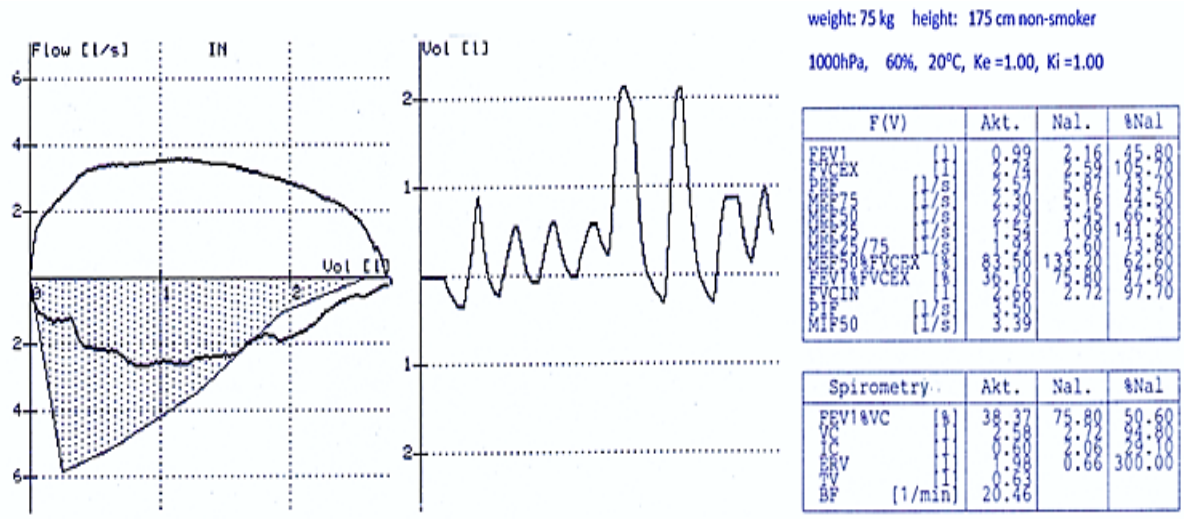

Figure 5. Spirometry results of the harvester of the G-1 division.

Source: own study.

The results of the study among employees of the mining divisions of the X mine are consistent with the presented results of the studies of the authors cited earlier, from the United States, China, Canada, and indicate similar reasons for the increase in the incidence of pneumoconiosis among miners of Polish coal mines. However, in Poland, in addition to exceeding several times the normative values of fibrosing dust in the air at individual workstations, the cause of the increase in occupational morbidity should be seen in the low awareness of miners about their health, fear of dismissal or the need to change jobs to less well-paid ones, and consequently delaying contact with a doctor.

5. Conclusions

The air measurements carried out in the mining divisions of the X mine show that mine dust (coal-dust) still poses a serious health risk to coal miners, especially in deep mines, so its constant monitoring should be a priority for every mine and mining plant. In succor of this recommendation is the amendment of the legislation of the European Union member states, which, following Directive of the European Parliament and of the Council (EU) 2017/2398 of December 12, 2017, mandates the inclusion of the respirable fraction of crystalline silica formed during work among carcinogenic substances. These measures have forced companies to increase the frequency of environmental measurements of mine dust and the recording of workers exposed to crystalline silica. However, this has not translated directly into increased occupational safety and lowered statistics on the occupational incidence of pneumoconiosis. As demonstrated by the staff of the Department of Safety Engineering at the Silesian University of Technology and *pulmonology* specialists, the study of working conditions and the health status of employees of the G-1 and G-2 mining divisions of the X mine, the measurement of dust concentrations in the air and the identification of its mineral composition alone will not contribute to reducing the morbidity of miners. Also, the use of even the best prophylactic measures to reduce dust in mine workings will not dramatically reduce morbidity statistics without covering miners with effective medical diagnostics to identify early symptoms of disease. Recognized lesions among miners of mining divisions are the result of many years of neglect of medical prophylaxis and proper cooperation between occupational physicians and the employer's occupational health and safety services, especially with regard to visits by medics to underground workplaces. The responsibility for this state of affairs, as the Labor Code's provisions show, rests with the employer, management and the employer's occupational health and safety services.

Therefore, along with increasing the frequency of measurements of air pollution in mining conditions, the occupational medical diagnostics of miners should also be expanded to include additional tests including spirometry, full-size chest X-ray, capillary blood gas test, peripheral blood count, or low-dose, high-resolution computed tomography allowing scrinig of lung cancer. It also seems expedient to increase the broadly defined safety culture and persuade employees to change their current habits and behaviors, as well as to shape them into desirable actions to protect their own health (White, 2012; Mocek, K., Mocek, P., 2023).

Only joint action in this regard by employers, doctors and the miners themselves can help reduce health risks and limit the drama of miners exposed for many years to above-normal exposure to mine (coal-dust) dust. However, if medics are not allowed into the process of hazard identification, risk assessment and environmental testing directly at workplaces, it is difficult to count on improvements in occupational safety.

The study further showed that: ensuring adequate working conditions is one of the elements that determine the effective use of human resources at a mine. This is best seen in the case of natural hazards, which, when well monitored, do not cause undue concern to coal mine miners. The identification of harmful factors at mines, the estimation of the risk of their impact on the human body, and ultimately the preventive measures taken to minimize them are not entirely effective. Errors and negligence in this regard by employers, services, OSH and management contribute to real financial losses for companies, increased morbidity statistics and new hidden illnesses among workers who should potentially be healthy.

Acknowledgements

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References

1. Akusztol, J., Kazanowska, D., Kazimierowska-Wasiołek, M., Pragacz, M. (2022). *Warunki pracy w 2022 roku*. Available: https://stat.gov.pl/obszary-tematyczne/rynek-pracy/warunki-pracy-wypadki-przy-pracy/warunki-pracy-w-2022-roku,1,17.html, 29.06.2023.
2. Almberg, K.S., Halldin, C.N., Blackley, D.J., Laney, A.S., Storey, E., Rose, C.S. et al. (2018). Progressive massive fibrosis resurgence identified in U.S. coal miners filing for black lung benefits, 1970–2016. *Ann Am Thorac Soc., vol. 15*, p. 1420-–1426. DOI:10.1513/AnnalsATS.201804-261OC
3. Antao, V.C. dos S., Petsonk, E.L., Sokolow, L.Z., Wolfe, A.L., Pinheiro, G.A., Hale, J.M. et al. (2005). Rapidly progressive coal workers' pneumoconiosis in the United States: geographic clustering and other factors. *Occup. Environ. Med., vol. 62*, pp. 670-674. DOI:10.1136/oem.2004.019679
4. Bałaga, D. (2019). Intelligent spraying installation for dust control in mine workings. *OP Conf. Ser.: Mater. Sci. Eng., No. 679*, 012019; DOI:10.1088/1757-899X/679/1/012019

5. Bałaga, D., Jedzianiak, M., Kalita, M., Siegmund, M., Szkudlarek, Z. (2015). Metody i środki zwalczania zagrożeń pyłowych i metanowych w górnictwie węgla kamiennego. *Maszyny górnicze, no. 3,* pp. 68-81; ISSN 0209-3693
6. Bałaga, D., Siegmund, M., Prostański, D., Kalita, M. (2016). Innowacyjny system tryskaczowy do wyrobisk ścianowych. *Maszyny górnicze, no. 3,* pp. 14-22; ISSN 2450-9442.
7. Barber, C., Fishwick, D. (2016) Pneumoconiosis. *Medicinae, Vol. 44(6),* pp. 355-358, DOI:10.1016/j.mpmed.2016.03.001
8. Biały, W. (2012). Environmental working conditions and occupational diseases in hard coal mining. *Science notebooks, no. 31*. Szczecin: Medical Academy, pp. 37-44. Available: http://repository.scientific-journals.eu/handle/123456789/388.
9. Blackley, D.J., Crum, J.B., Halldin, C.N., Storey, E., Laney, A.S. (2016). Resurgence of progressive massive fibrosis in coal miners—eastern Kentucky. *MMWR Morb Mortal Wkly Rep., Vol. 65,* pp. 1385-1389.
10. Blackley, D.J., Halldin, C.N., Laney, A.S. (2018). Continued increase in prevalence of coal workers' pneumoconiosis in the United States, 1970-2017. *Am. J. Public Health, Vol. 108,* pp. 1220-1222. doi: 10.2105/AJPH.2018.304517
11. Boros, P., Mejza, F., Gomółka, P. (2020). Performing spirometry according to the American Thoracic Society and European Respiratory Society 2019 standards. *Practical Medicine, no. 6,* pp. 48-55.
12. Brodny, J., Tutak, M. (2018). Exposure to Harmful Dusts on Fully Powered Longwall Coal Mines in Poland. *International Journal Of Environmental Research And Public Health, vol. 15(9),* 1846; DOI: 10.3390/ijerph15091846
13. Chao, Z., Xinglong, W., Shugang, Li., Bingyou, J., Cheng, Z., Chuanjie, Z., Guanhua, Ni. (2022). Development and application of a new compound wetting agent for coal seam water infusion. *Fuel, Vol. 314,* 122767. DOI: 10.1016/j.fuel.2021.122767
14. Cohen, R.A., Rose, C.S., Go, L.H.T., Zell-Baran, L.M.S., Almberg, K., Sarver, E.A., Lowers, H.A., Iwaniuk, C., Clingerman, S.M., Richardson, D.L., Abraham, J.L., Cool, C.D., Franko, A.D., Hubbs, A.F., Murray, J., Orandle, M.S., Sanyal, S., Vorajee, N.I., Petsonk, E.L., Zulfikar, R., Green, F.H.Y. (2022). Pathology and Mineralogy Demonstrate Respirable Crystalline Silica Is a Major Cause of Severe Pneumoconiosis in U.S. Coal Miners. *Annals of the American Thoracic Society, Vol. 19, Iss. 9,* DOI: 10.1513/AnnalsATS.202109-1064OC
15. Cohen, R.A., Petsonk, E.L., Rose, C., Young, B., Regier, M., Najmuddin, A. et al. (2016). Lung pathology in U.S. coal workers with rapidly progressive pneumoconiosis implicates silica and silicates. *Am. J. Respir. Crit. Care Med., vol. 193,* pp. 673-680. doi: 10.1164/rccm.201505-1014OC
16. EUR-Lex (1989). Council Directive of June 12, 1989 on the introduction of measures to encourage improvements in the safety and health of workers at work OJ L 183, 29.6.1989,

pp. 1-8 *European Parliament*. Document 31989L0391. Available: https://eur-lex.europa.eu/legal-content/PL/TXT/?uri=celex%3A31989L0391

17. EUR-Lex (2017). Directive (EU) 2017/2398 of the European Parliament and of the Council of 12 December 2017 amending Directive 2004/37/EC on the protection of workers from the risks related to exposure to carcinogens or mutagens at work. OJ EU L 345, 27.12.2017 *European Parliament* Document 32017L2398. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32017L2398
18. Farnik, M., Bożek, G., Czajkowska-Malinowska, M., Krenke, R., Kania, A., Trzaska-Sobczak, M., Połtyn, B., Miszczuk, M., Celejewska-Wójcik, N., Kuziemski, K., Barczyk, A. (2019). Validation of Polish language version of CAT questionnaire. *Polish Archives of Internal Meddicine, vol. 129, no. 9*, pp. 605-611, doi: 10.20452/pamw.14929
19. Hall, N.B., Blackley, D.J., Halldin, C.N., Laney, A.S. (2019). Current Review of Pneumoconiosis Among US Coal Miners. *Curr Environ Health Rep., Vol. 6(3),* pp. 137-147; DOI: 10.1007/s40572-019-00237-5
20. Han, S., Chen, H., Harvey, M.A., Stemn, E., Cliff, D. (2018). Focusing on Coal Workers' Lung Diseases: A Comparative Analysis of China, Australia, and the United States. *Int. J. Environ. Res. Public Health, Vol. 15(11),* 2565; DOI: 10.3390/ijerph15112565
21. Honysz, J. (2011). *Górnictwo*. Katowice: Wydawnictwo Naukowe "Śląsk", p. 124.
22. ISAP (1997). Rozporządzenie Ministra Pracy i Polityki Socjalnej z dnia 26 września 1997 r. w sprawie ogólnych przepisów bezpieczeństwa i higieny pracy (Dz.U. 1997, nr 129, poz. 844). *Parliament of the Republic of Poland.* Available: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu19971290844
23. ISAP (2011). Rozporządzenie Ministra Zdrowia z dnia 2 lutego 2011 r. w sprawie badań i pomiarów czynników szkodliwych dla zdrowia w środowisku pracy (Dz.U. 2011, Nr 33, poz. 166). *Parliament of the Republic of Poland*. Available: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20230000419
24. ISAP (2018). Ustawy z dnia 26 czerwca 1974 r. - Kodeks pracy (Dz.U. z 2018 r., poz. 917, 1000 i 1076). *Parliament of the Republic of Poland*. Available: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=wdu19740240141
25. ISAP (2018a). Rozporządzenie Ministra Rodziny, Pracy i Polityki Społecznej z dnia 12 czerwca 2018 r. O maksymalnych dopuszczalnych stężeniach i natężeniach czynników szkodliwych dla zdrowia w środowisku pracy (Dz.U. 2018, poz. 1286 z późn. zm.). *Parliament of the Republic of Poland*. Available https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20180001286
26. ISAP (2020). Rozporządzenie Ministra Zdrowia z dnia 24 stycznia 2020 r. zmieniające rozporządzenie w sprawie substancji chemicznych, ich mieszanin, środków lub procesów technologicznych o działaniu rakotwórczym lub mutagennym w środowisku pracy. *Parliament of the Republic of Poland*. Available https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20200000197

27. ISAP (2021). Rozporządzenie Ministra Zdrowia z dnia 24 lipca 2012 r. w sprawie substancji chemicznych, ich mieszanin, środków lub procesów technologicznych o działaniu rakotwórczym lub mutagennym w środowisku pracy z późniejszymi zmianami. - tekst jednolity (Dz.U. z 2021 r., poz. 2235). *Parliament of the Republic of Poland*. Available: https://isap.sejm.gov.pl/isap.nsf/DocDetails.xsp?id=WDU20210002235
28. Ji, Y., Ren, T., Wynne, P., Wan, Z., Ma, Z., Wang, Z. (2016). A comparative study of dust control practices in Chinese and Australian longwall coal mines. *Int. J. Min. Sci. Technol., no. 26,* pp. 199-208; DOI: 10.1016/j.ijmst.2015.12.004
29. Johann-Essex, V., Keles, C., Rezaee, M., Scaggs-Witte, M., Sarver, E. (2017). Respirable coal mine dust characteristics in samples collected in central and northern Appalachia. *Int. J. Coa.l Geol., vol. 182,* pp. 85-93. Doi: 10.1016/j.coal.2017.09.010
30. Kozioł, L., Piechnik-Kurdziel, A., Kopeć, J. (2000). *Zarządzanie zasobami ludzkimi w firmie – teoria i praktyka.* Warszawa: Biblioteka Pracownicza, p. 25.
31. Kuczera, Z., Ptaszyński, B. (2019). Dust control in the Polish mining industry. *Mineral Engineering, Vol. 21(1/2),* pp. 191-187; DOI: 10.29227/IM-2019-02-31
32. Laney, A.S., Weissman, D.N. (2014). Respiratory diseases caused by coalmine dust. *Journal of Occupational and Environmental Medicine, Vol.* 56, pp. 18-22, DOI: 10.1097/JOM.0000000000000260
33. Liao, X., Wang, B., Wang, L., Zhu, J., Chu, P., Zhu, Z., Zheng, S. (2021). Experimental Study on the Wettability of Coal with Different Metamorphism Treated by Surfactants for Coal Dust Control. *ACS Omega, no. 6(34),* pp. 21925-21938. Cited 3 times. DOI: 10.1021/acsomega.1c02205
34. Liu, T., Liu, S.H. (2020). The impacts of coal dust on miners' health: A review. *Environ. Res., Vol. 190,* pp. 34-49, 109849; DOI: 10.1016/j.envres.2020.109849
35. López-Campos, J.L., Soler-Cataluña, J.J., Miravitlles, M. (2020). Global Strategy for the Diagnosis, Management, and Prevention of Chronic Obstructive Lung Disease 2019. Report: Future Challenges. *Archivos de Bronconeumología, Vol. 56, Iss. 2,* pp. 65-67, PMID: 31320191. DOI: 10.1016/j.arbres.2019.06.001
36. Lutynski, L. (2020) Zagrożenia pyłowe i ich kontrola w zakładach przeróbki mechanicznej kopalń węgla kamiennego. *Inżynieria mineralna, no. 1(1),* pp. 13-18. DOI: 10.29227/IM-2021-01-02
37. Maciejewska, A. (2012). Zastosowanie spektrometrii w podczerwieni (FT-IR) do identyfikacji azbestu w próbkach materiałów. *Medycyna Pracy, no. 63(2),* pp. 181-189. Łódź.
38. Mocek, K., Mocek, P. (2023). Proper control of working conditions as a stimulator for reducing the incidence of pneumoconiosis in the coal mining industry. *Mining Machines, Vol. 41. No. 2,* pp. 93-106.
39. Mocek, P. (2021). Efektywność zarządzania zasobami ludzkimi w aspekcie zagrożenia hałasem w górniczym środowisku pracy. *Bezpieczna i efektywna organizacja. Zagadnienia*

wybrane, Monografia, no. 923. Gliwice: Politechnika Śląska, p. 266, ISBN 978-83-7880-814-5

40. Peng, H., Nie, W., Zhang, S., Cheng, W., Liu, Q., Guo, C., Ma, Q., Zhou, Z., Xu, C., Hua, Y., Zhang, H. (2022). Research on negative pressure jet dust-removal water curtain technology for coal mine cleaner production. *Fuel, vol. 310, no. 122378.* DOI: 10.1016/j.fuel.2021.122378
41. Perret, J.L., Plush, B., Lachapelle, P., Hinks, T.S.C., Walter, K., Clarke, F., Irving, L., Brady, P., Dharmage, S.C., Stewart, A. (2017). Coal mine dust lung disease in the modern era. *Asian Pac. Soc. Respirol., Vol. 22,* pp. 662-670; DOI: 10.1111/resp.13034
42. Perret, J.L., Miles, S., Brims, F., Newbigin, K., Davidson, M., Jersmann, H., Edwards, A., Zosky, G., Frankel, A., Johnson, A.R., Hoy, R., Reid, D.W., Musk, A.W., Abramson, M.J., Edwards, B., Cohen, R., Yates, D.H. (2020). Respiratory surveillance for coal mine dust and artificial stone exposed workers in Australia and New Zealand: A position statement from the Thoracic Society of Australia and New Zealand. *Respirology, Vol. 25(11),* pp. 1193-1202. doi: 10.1111/resp.13952.
43. Rey, C.H. Torres Pinilla, M., Ibañez., Briceño Ayala, L., Checa Guerrero, D.M., Morgan Torres, G., Groot de Restrepo, H., Uribe, M. Varona (2015). Underground Coal Mining: Relationship between Coal Dust Levels and Pneumoconiosis, in Two Regions of Colombia. *BioMed research international,* 647878; doi: 10.1155/2015/647878
44. Sarver, E., Keles, C., Afrouz, S.G. (2021). Particle size and mineralogy distributions in respirable dust samples from 25 US underground coal mines. *Int. J. Coal Geol., vol. 247,* 103851. DOI**:** 10.1016/j.węgiel.2021.103851
45. Shi, P., X Xing, Xi, S., Jing, H., Yuan, J., Fu, Z. et al. (2020). Trends in global, regional and national incidence of pneumoconiosis caused by different aetiologies: an analysis from the Global Burden of Disease Study 2017. *Occup. Environ. Med., Vol. 77,* pp. 407-414, DOI: 10.1136/oemed-2019-106321
46. Suarthana, E., Laney, A.S., Storey, E., Hale, J.M., Attfield, M.D. (2011). Coal workers' pneumoconiosis in the United States: regional differences 40 years after implementation of the 1969 Federal Coal Mine Health and Safety Act. *Occup. Environ. Med., vol. 68,* pp. 908-913.
47. Świątkowska, B., Hanke, W. (2023). *Choroby zawodowe w Polsce w 2022 roku.* Łódź: Instytut Medycyny Pracy, pp. 6-50.
48. Tomášková, H., Šplíchalová, A., Šlachtová, H. et al. (2017). Mortality in Miners with Coal-Workers' Pneumoconiosis in the Czech Republic in the Period 1992-2013. *Int. J. Environ. Res. Public Health, Vol. 14(3),* p. 269; DOI: 10.3390/ijerph14030269
49. Trechera, P., Querol, X., Lah, R., Johnson, D., Wrana, A., Williamson, B., Moreno, T. (2022). Chemistry and particle size distribution of respirable coal dust in underground mines in Central Eastern Europe. *International Journal of Coal Science & Technology, Vol. 9, no. 3.*

50. Weissman, D.N. (2022). Progressive massive fibrosis: An overview of the recent literature. *Pharmacology & Therapeutics,* Vol. 240, DOI: 10.1016/j.pharmthera.2022.108232
51. Xu, J., Wang, H. (2021). Underground Intelligent Dry Dust Collector in the Coal Mine. *IOP Conf. Ser.: Earth Environ. Sci*., *Vol. 647,* 012051; DOI:10.1088/1755-1315/647/1/012051
52. Zosky, G.R., Hoy, R.F., Silverstone, E.J., Brims, F.J., Miles, S., Johnson, A.R., Gibson, P.G., Yates, D.H (2016). Coal workers' pneumoconiosis: An Australian perspective. *MJA - The Medical Journal of Australia*, *Vol. 204(11),* pp. 414–418; DOI:10.5694/mja16.00357

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COMPARISON OF THE SUPPLY QUALITY POLICY IN SELECTED INDUSTRIAL ENTERPRISES

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Purpose: The objective of this article is to present the results of research concerning the assessment of the actually implemented Quality Policy (QP) in supply area of selected industrial enterprises. The objective of the research was a multi-faceted assessment and analysis of implemented quality policies.
Design/methodology/approach: The deliberations are based on the related subject literature and an analysis of the long-term survey results. The detailed research methodology is described in section 2. of this article.
Findings: Based on the results of the research carried out in the surveyed group of 166 companies, it was found that medium and large enterprises are most firmly focused on ensuring the quality of supplies through cooperation with proven suppliers.
The quality policy of the largest enterprises is also most strongly focused on caring for relations with suppliers. Enterprises from the small group take better care of the relationships with suppliers. The research results prove that large enterprises implement a quality policy more strongly focused on the supply quality.
Originality/value: Knowledge of quality management issues has been increased. The article raises the issue of implementing quality policies in companies. The quality policy was characterized by selected QP aspects that illustrate the actual focus of the surveyed enterprises on the quality of supply. An evaluation of these aspects in selected enterprises was carried out, and differences dividing quality policies among independent and dependent enterprises in the implementation and supervision of quality standards were identified.

Keywords: quality policy, quality management, quality management system, improvement, Total Quality Management.

Category of the paper: Research paper.

1. Introduction

The dynamic development of technology, competition pressure, the need to minimize the negative impact on the environment and the continuous increase in customer requirements and maintaining social responsibility (Hąbek, 2017) are just a few of the challenges faced by today's managers. To stay on the market, such a business context means that every company needs an adequately defined strategy and policy and their implementation through an effective management system that will be the basis for development and operational improvement (Sułkowski, Wolniak, 2016).

One of the key elements influencing the success of an organization is the policy of enterprises in the area of quality, i.e., meeting the requirements, both set by customers and resulting from applicable legal and normative regulations. As a consequence, a properly adopted and implemented quality policy is extremely important, which is defined by managers as part of the frequently implemented quality management system in accordance with the ISO 9001 standard (Midor, 2013; Mourougan, Sethuraman, 2017; Pacana, Ulewicz, 2020; Bugdol, Hajduga, 2023; Ligarski, 2020).

One of the areas of the company's operation defined under the quality policy is the area of supply quality as a key determinant of the quality of products and services. Without an appropriate policy that will be the basis for the assessment, selection and quality of relations and cooperation with suppliers, it is not possible to guarantee, let alone improve, the quality of products and services.

The article contains the results of a survey conducted among 166 industrial enterprises operating in Poland. The objective of the research was a multi-faceted assessment and analysis of implemented quality policies. The results provided in this article refer only to two selected aspects of quality policy that relate to procurement. Statistical analysis of the research results made it possible to assess the level of focus on quality in terms of selection and relations with suppliers and to compare the results in groups of enterprises with different employment levels and varying degrees of independence in setting internal quality standards.

The basic research problem whose solution is presented in this paper, are the following research questions:

- what is the quality policy actually implemented in the area of supplier quality management in the surveyed industrial enterprises?
- do differences exist in the implemented quality policy in groups of enterprises classified depending on their size and the so-called degree of independence in setting policy?

2. Research process description and methodology

Studying the quality policy in an organization is a major challenge. As mentioned earlier, declarations contained in QP text often do not have a lot in common with the actual goodwill of the organization. Therefore, to get to know the real quality policy concerning suppliers, it was necessary to conduct an anonymous survey.

The quality policy survey sheet described 35. aspects (behaviors) characteristic of a strongly quality-oriented organization, close to the TQM philosophy. The results provided in this article refer to two selected QP aspects that illustrate the actual focus of the surveyed enterprises on the quality of supply. They include: Aspect #A1 – The organization cooperates with proven suppliers and Aspect #A2 – The organization takes care of relations with suppliers.

Respondents indicated how the behavior described in the survey is characteristic of the organization where they work. The described aspects were rated by respondents on a scale of 1 to 5. The scale adopted reflects the strength of the similarity of the behavior described in the survey to the situation in each organization.

The results of the practical research described in this article are based on a survey of supervisory employees and middle managers, who represented the enterprise by filling out a single survey sheet (self-assessment sheet).. Data was entered into the sheet based on expert judgement. Expert judgment is a technique in management process that refers to making judgment based on skill, expertise, or specialized knowledge in a particular area.

The surveyed group of companies (166) was not a research sample. When analyzing the survey results, no parameter estimation was made on the population of Polish enterprises.

Because opinions were anonymous, we were able to examine the real quality policy in a wide range and relatively reliably.

The survey was conducted in 2015-2019 among 166. enterprises operating in Poland. During the survey, independence in setting quality policy was identified for 164 enterprises. These were manufacturing enterprises from various industries. Enterprises were selected on the basis of proposals issued to conduct a survey.

3. Supply quality policy

Policy is generally a method of operation adopted by the decision-making center of a formalized social group, e.g., the management of an organization, aimed at achieving the set goals through specific means. The policy in the organization should be directly derived from the mission and strategy of the company. This policy is the basis for setting quality goals, building a process structure and setting internal quality standards. It should also determine the

actual manner of quality management, managerial practices and employee behavior. As a consequence, it should determine the perception of the company on the market and the ultimate business success.

According to the ISO 9001 standard, each organization should define, document and implement a quality policy. The ISO 9000 standard defines quality policy as "the totality of an organization's intentions and orientation regarding quality as formally expressed by top management". Notably, the standard does not define requirements for the essence of the policy. This is an autonomous decision of enterprise managers. Therefore, even ISO 9001-certified organizations define and maintain their own policies in line with their overall business strategy.

The quality policy is often considered in the literature as a key document of the quality management system containing the declaration of the top management regarding many aspects of activity, in particular regarding the seven principles of quality management (ISO 9000). Therefore, the policy contains declarations of the organization regarding such issues as the approach to customers, commitment to continuous improvement and approach to relations with suppliers. The quality policy in ISO 9001-certified enterprises is identified with a formal document through which the top management expresses its commitment to the functioning of the quality management system. In managerial practice, it is treated only as a document required by the ISO 9001 standard, having no impact on management processes and organizational behavior. This approach to quality policy marginalizes its significant role in building a culture of quality (Miller et al., 2014), i.e., an organization strongly focused on quality in accordance with the TQM philosophy (Calvo-Mora et al., 2014; Chen et al., 2016; Sharma et al., 2013; Silva et al., 2014).

Industrial enterprises operate in a cooperative system, a network of logistics connections, supplier-recipient relations that allow for building efficient and effective supply systems (Drljača, 2019; Hysa, 2004; Kot et al., 2020; Pałucha, 2016). It is normal that the quality of products supplied to the market is determined, among other things, by the quality of supply processes (Matusek, 2016). This dependence first entails the need to carefully select the supplier and then maintain lasting relationships based on trust. The requirements for the selection and assessment of suppliers are included in the ISO 9000 series standards. The standard requires enterprises to have a transparent process of selecting suppliers and cooperators (Midor, Biały, 2019). This process should be carried out on the basis of accepted methods, in particular, established decision-making criteria for the evaluation and selection of partners. These criteria should directly derive from the supply quality policy adopted by the top management, which should be based on the seventh principle of quality management. It reads that "in order to achieve lasting success, organizations manage their relationships with stakeholders such as suppliers". As we can read from the justification of the principle, "significant stakeholders influence the performance of the organization". Sustainable success is more likely to be achieved when an organization manages relationships with all stakeholders to optimize their impact on performance (ISO 9000).

The management of a company that wants to implement the aforementioned Principle 7 precisely defines, first of all, key suppliers. Areas of cooperation in the short and long term are established for these partners. In industrial enterprises, this cooperation is strategic. If we take the automotive industry as an example, key suppliers are treated almost as part of the organization. In the areas of key components, there is a need to carry out joint long-term research and development works, investment processes, and even extensive integration of IT systems, which is necessary for quick communication between partners. Therefore, such aspects of the quality policy in the area of supply as the selection and relationship with suppliers/cooperators, are critical.

4. Supply quality policy – research results

The obtained research results allow concluding that enterprises are significantly focused on ensuring the quality of suppliers and caring for relations with them. The average value of indications of all surveyed enterprises for aspect #A1 was 4.0 points, and for aspect #A2 – 3.79 points. Detailed statistical data on the results obtained are included in Table 1. The overall results of the research on each aspect of the policy are presented in Figure 1.

Table 1.

Descriptive statistics of research results for each aspect

Statistics	Aspect #A1	Aspect #A2
Count (N)	162	164
Mean	4,0	3,79
Standard Error	0,071	0,085
Standard Deviation	0,905	1,088
Confidence level (95,0%)	0,140	0,167

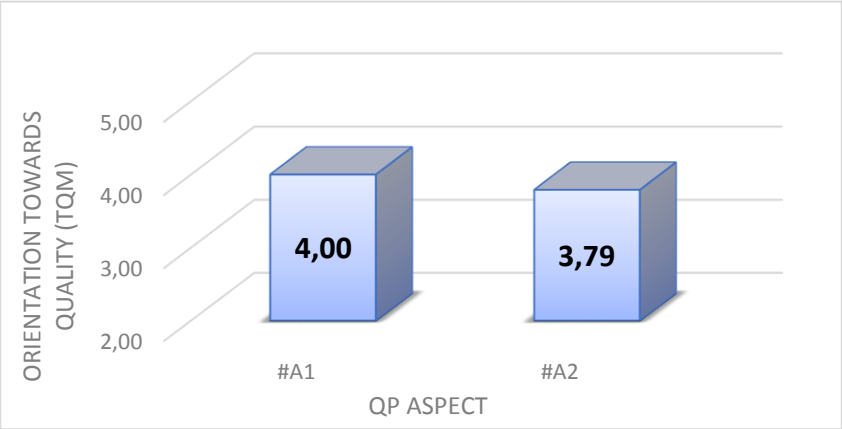

Figure 1. Comparison of the level of strength of orientation to quality in terms of the QP aspects under consideration.

Source: Own study.

The number of enterprises for which the policy in respect of aspect #A1 was identified was 162, while in respect of aspect #A2, it was 164. The number of enterprises that assessed the attitude towards cooperation with proven suppliers as very strong (5 points) is 58, which is 35% of all surveyed enterprises (162 enterprises). It was not much lower, as 54 enterprises assessed this attitude as strong and assigned it 4 points (33%). Among 42 companies, an average attitude (3 points) to cooperation with proven suppliers was noted. The rating of 2 points was given to only 8 enterprises. The lowest possible scores (1 point) were not recorded. The results prove that the quality policies of the surveyed enterprises in the field of cooperation with suppliers are diversified and the three largest groups stand out. Most of them are enterprises strongly or very strongly focused on cooperation with reliable suppliers. The results of the research on the approach to suppliers are presented in Figure 2.

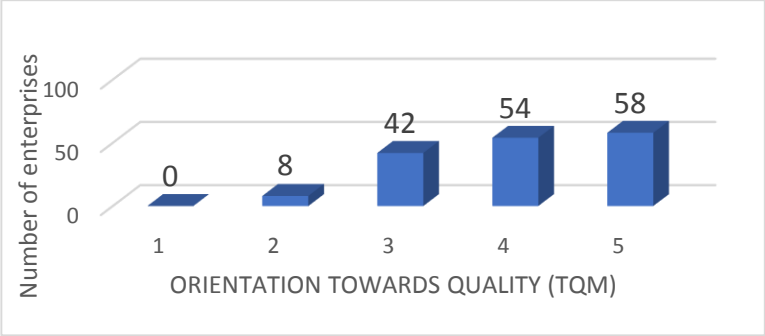

Figure 2. The structure of enterprises for the assessment of cooperation with proven suppliers only(#A1).

Source: Own study.

The results prove that the quality policy of the surveyed enterprises in terms of caring for relations with suppliers is also varied. The number of enterprises that rated caring for the relationship as very strong and assigned 5 points to is 44, which is 26% of all enterprises that responded in this regard (164 enterprises in total). The largest group of 71 enterprises assessed the level of caring for relations as good and assigned 4 points (43%). The score of 1 or 2 points was given to a total of 19 companies whose quality policy is not focused on caring for relationships. The results of the research in the discussed scope are presented in Figure 3.

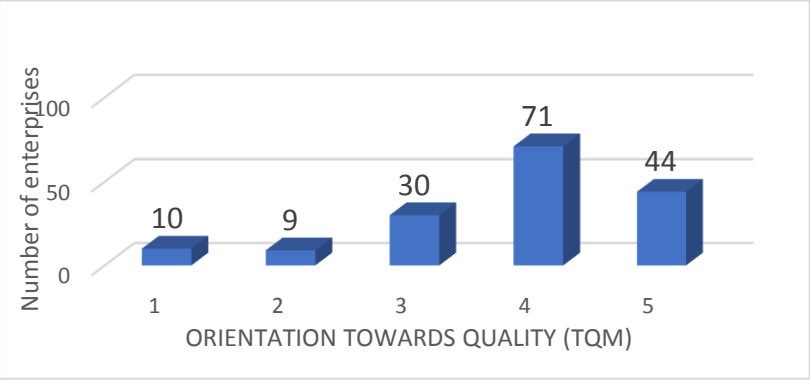

Figure 3. The structure of enterprises taking into account the level of care for relations with suppliers (#A2).

Source: Own study.

A comparison of the values of the average ratings of the analyzed aspects in groups of enterprises with different employment sizes is presented in Figure 4. In the research process, enterprises were classified into a group based solely on their employment size. The small ones are those employing up to 50 people. Employment in large enterprises exceeded 250 people. It is worth emphasizing that in the studied group of representatives there were 26 small, 40 medium and 100 large enterprises.

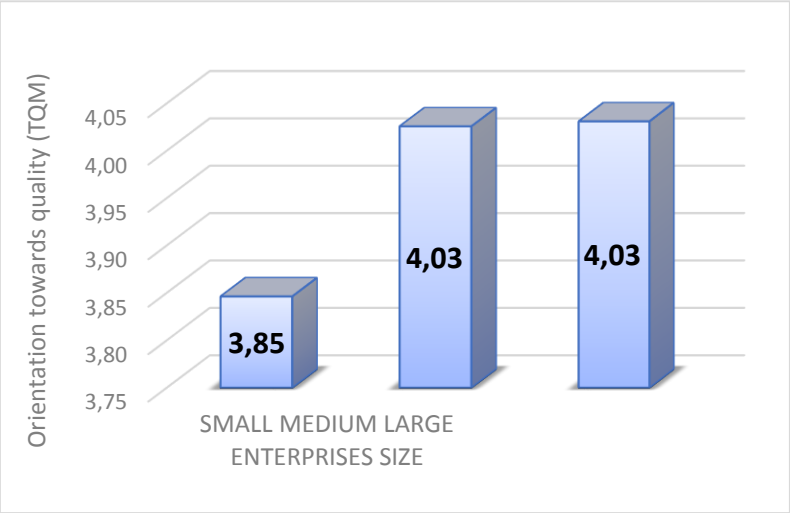

Figure 4. Comparison of levels of attitude towards cooperation with proven suppliers among enterprises of various sizes.

Source: Own study.

Based only on the values of the average ratings, the research results presented in Figure 4 prove that the quality policy is more strongly focused on certain suppliers and is conducted by large and medium-sized enterprises. These two groups of enterprises obtained the best result, namely, 4 points on average.

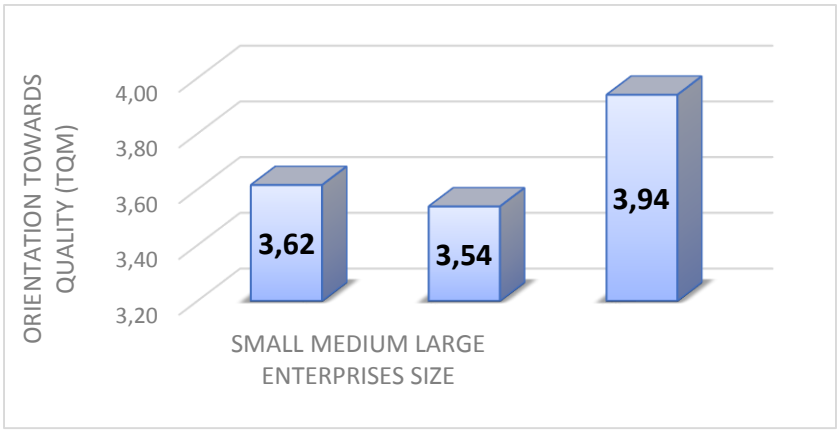

Figure 5. Comparison of the levels of caring for relations with suppliers among enterprises of various sizes.

Source: Own study.

The results of the research show the difference between the focus on supplier qualification and taking care of supplier relationships. Research shows that these relationships are best maintained by large companies. The average value in this group was 3.94 points. Small enterprises show greater care for relationships (3.62 points) than medium-sized enterprises, which recorded a score of 3.54 points. The results of the research in the discussed scope are presented in Figure 5.

The factor shaping the quality policy is the independence of the company's top management in defining and implementing it. It is normal that ownership and capital, licensing or, for example, franchise ties cause external power centers to impose quality standards and supervise their implementation. In the course of the research, the independence of the company in terms of setting quality standards within the meaning of organizational practices was identified. In the surveys, the respondents indicated the source of setting formal standards, which allowed them to be classified into one of the following groups:

- full independence – quality standards are set by the direct management of the company,
- national dependence – standards are set by an external national board,
- foreign dependence – standards are set by external foreign management.

The research results presented in Figure 6 concern 164 enterprises for which the independence form was determined. In the studied group of enterprises, 68 claimed full independence, 19 stated national dependence, and 77 declared their dependence in terms of quality on foreign management.

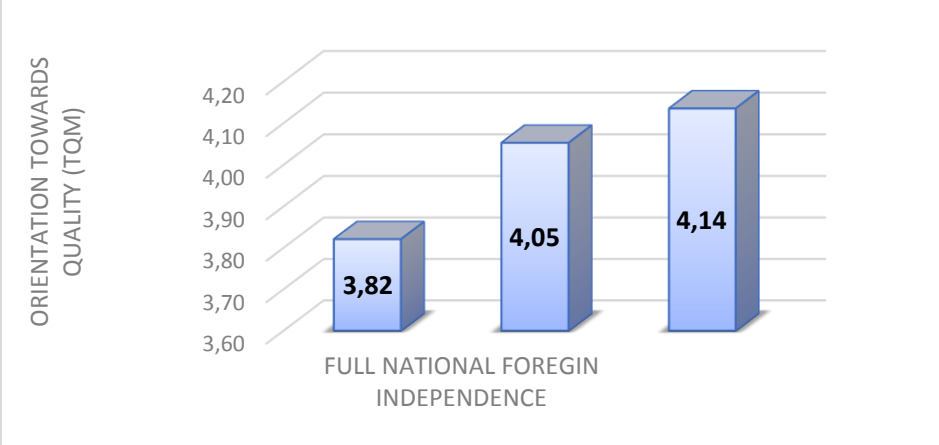

Figure 6. Comparison of attitude levels towards cooperation only with proven suppliers among enterprises of various independence.

Source: Own study.

Research shows that the focus on cooperation only with proven suppliers is the strongest in companies with foreign sources of quality standards. These enterprises obtained an average of 4.14 points. Enterprises with national dependence are slightly less focused on quality in the examined aspect (4.05 points). The group of independent enterprises achieves the worst result in this comparison, i.e., 3.82 points. It turns out that some supervision pressure from external centers results in a natural increase in quality orientation in selecting qualified suppliers.

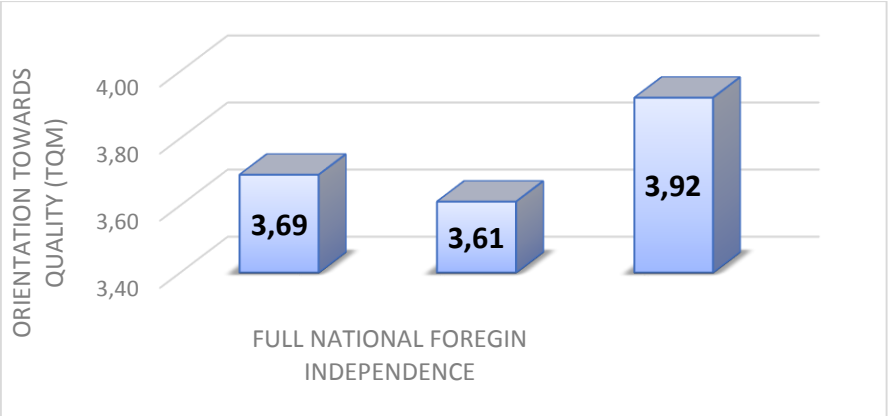

Figure 7. Comparison of the levels of caring for relations with suppliers among enterprises of various independence.

Source: Own study.

Companies dependent on foreign boards are most concerned with maintaining good supplier relations (3.92 points). Interestingly, enterprises with national dependence look the worst in this ranking (3.61 points). Independent enterprises fare slightly better in this respect (3.69 points). The test results regarding aspect #A2 in the scope are included in Figure 7.

5. Conclusions

The analysis of the research results proves that based on the average value of the ratings, it can be concluded that the surveyed companies are well-oriented towards cooperation with proven, reliable suppliers. The average value of this strength is 4.0 points (on a scale 1-5). To a lesser extent, the surveyed enterprises care about relations with partners. This is evidenced by the average value of the grades, which is 3.79 points in the entire study group.

Medium and large enterprises are most firmly focused on ensuring the quality of supplies through cooperation with proven suppliers. The greater power of influence on suppliers by larger enterprises allows them to adopt and apply high requirements in selecting and evaluating suppliers. The quality policy of the largest enterprises is also most strongly focused on caring for relations with suppliers. The average value is 3.94 points. Notably, enterprises from the small group take better care of the relationships (3.64 points). In the group of medium-sized enterprises, the value is lower – 3.54 points. The research results prove that large enterprises implement a quality policy more strongly focused on the supply quality.

Enterprises dependent on foreign boards are more intensely focused on cooperation with proven suppliers (4.14 points) compared to those managed from the domestic HQ (4.05 points) and completely independent (3.82 points). Similarly, enterprises dependent on foreign boards care the most about supplier relations (3.92 points). Entirely independent enterprises perform worse in this respect (3.69 points). Interestingly, enterprises with national dependence are the least successful in building supplier relationships (3.61 points).

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References

1. Bugdol, M., Hajduga, D. (2023). Possibilities of using quality management systems to undertake innovation activities in an organisation belonging to the chemical industry. *Scientific Papers of Silesian University of Technology. Organization and Management series, no. 172*, pp. 73-87
2. Calvo-Mora, A., Pico´n, A., Ruiz, C., Cauzo, L. (2014). The relationships between soft-hard TQM factors and key business results. *International Journal of Operations & Production Management, vol. 34, no. 1*, pp. 115-143.
3. Chen, C.K., Lee, J.D., Dahlgaard, J.J. (2016). A stepwise ISO-based TQM implementation approach using ISO 9001:2015. *Management and Production Engineering Review, 4*, pp. 65-75.
4. Drljača, M.,(2019). Reversible supply chain in function of competitiveness. *Production Engineering Archives, 22,* pp. 30-35.
5. Hąbek, P. (2017). Koncepcja wykorzystania metody FMEA dla potrzeb zrównoważonego wytwarzania. *Systemy Wspomagania w Inżynierii Produkcji, tom 6, nr 4.* Wyd. PŚ, pp. 49-55.
6. Hysa, B. (2004). TQM in logistics. *Zesz. Nauk. PŚl., Org. Zarz., z. 20, cz. 2*, pp. 39-43.
7. Kot, S., ul Haque, A., Baloch, A. (2020). Supply chain management in SMEs: Global perspective. *Montenegrin Journal of Economics, 16(1),* pp. 87-104.
8. Ligarski, M. (2020) Study on disruptions in the quality management system in compliance with ISO 9001:2015. *Scientific papers of Silesian University of Technology Organization and Management Series, no. 142*, pp. 195-204.
9. Matusek, M. (2016). Czynniki sukcesu triadycznej strategii zakupowej - studium przypadku. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, nr 89.* Wydawnictwo Politechniki Śląskiej, pp. 291-306.
10. Midor, K. (2013). An innovative approach to the evaluation of a quality management system in a production enterprise. *Scientific Journals Maritime University of Szczecin, nr 34,* pp. 73-79.

11. Midor, K., Biały, W. (2019), Methods of assessment of suppliers for buisnesses. *Systemy Wspomagania w Inżynierii Produkcji, tom 8, nr 1*. PA NOVA, pp. 290-299.
12. Miller, J., Wroblewski, M., Villafuerte, J. (2014). *Kultura KAIZEN. Budowanie i utrzymywanie kultury ciągłego doskonalenia.* Warszawa: MT Biznes sp. z o.o.
13. Mourougan, S., Sethuraman, K. (2017). Understanding and Implementing Quality Management System. *IOSR Journal of Business and Management, Vol. 19,* pp. 41-51.
14. Pacana, A., Ulewicz, R. (2020). Analysis of causes and effects of implementation of the quality management system compliant with ISO 9001. *Polish Journal of Management Studies. Vol. 21 No. 1*, pp. 283-296.
15. Pałucha, K. (2016). Organization of the process of the supply shopping. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, Nr 99.* Wyd. PŚ, pp. 349-361.
16. Roszak, M. (2021). Doskonalenie systemu zarządzania jakością wsparciem doskonalenia organizacji. *Quality, no. 10*, pp. 32-33.
17. Sharma, P., Jain, N., Pruthi, K. (2013). TQM: Implementation, Scope and Myths - A Review. *Research Journal of Engineering Sciences, Vol. 2(6),* pp. 40-44.
18. Silva, G., Gomes, P., Lages, L., Pereira, Z. (2014). The role of TQM in strategic product innovation: an empirical assessment. *International Journal of Operations & Production, vol. 34, iss. 10,* pp. 1307-1337.
19. Sułkowski, M., Wolniak, R. (2016). Przegląd stosowanych metod oceny skuteczności i efektywności organizacji zorientowanych na ciągłe doskonalenie. *Zeszyty Naukowe Politechniki Śląskiej. Seria Organizacja i Zarządzanie, 67,* pp. 63-74.

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ASSESSING THE POTENTIAL OF POLISH REGIONS TO DEVELOP INTERMODAL TRANSPORT

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Purpose: One of the most important factors for the development of intermodal transport is the potential of the country and its regions in this respect. The purpose of the article is to assess the potential of the Polish regions for the development of intermodal transport.
Design/methodology/approach: In order to achieve the stated purpose of the article, a literature review on the determinants of intermodal transport development was carried out. It allowed to extract a set of key factors influencing the potential of regions for intermodal transport development. On this basis, a synthetic index for the assessment of the region's potential for the development of intermodal transport (IRPIT - Index of the Region's Potential for Intermodal Transport) was developed, based on a taxonomic measure of development in the form of the so-called Hellwig pattern.
Findings: In the conducted research, the IRPIT indicator was determined for 16 regions (provinces) of Poland. Recommendations were indicated for provinces with lower levels of the indicator.
Originality/value: The article presents a methodology for assessing the potential of Polish regions for the development of intermodal transport. The advantage of the developed indicator is the ability to evaluate regions and their linear order in terms of the analysed potential.

Keywords: intermodal transport, regional potential assessment, taxonomy.

Category of the paper: Research paper.

1. Introduction

The development of intermodal transport is driven by the contemporary transport policy outlined in the White Paper on Transport (European Commission, 2011), which aims to relieve road transport and reduce external transport costs. This policy envisions the creation of an integrated and sustainable freight transport system in which multimodal and intermodal transport will play a significant role. Currently, road transport dominates freight transportation

in Europe. In Poland, in 2022, 86.8% of all transported goods were carried by road, accounting for 81.7% of the transport work (GUS, 2023, p. 8). For comparison, in 2015, these figures were 83.5% and 75.7%, respectively (GUS, 2016, p. 89). Therefore, there is an unfavorable trend associated with the substantial share of road transport in cargo transportation, and it is also on the rise. In such a situation, it is necessary to consider actions that would reduce the reliance on road transport while simultaneously increasing intermodal transport.

One of the key factors for the development of intermodal transport is the potential of a country and its regions in this respect. The potential is understood as a set of resources available in a given area (e.g. economic, demographic, social, technological, geographical, etc.), manifested in the quantity, quality and efficiency of their use (Nazarczuk, 2013, pp. 73-74). Therefore, the aim of the article was to assess the potential of Polish regions for the development of intermodal transport. The following research questions were formulated in relation to the task undertaken:

1. Which measure should be used to assess the potential of regions for the development of intermodal transport?
2. Which regions in Poland have the highest potential for the development of intermodal transport?

In order to achieve the aim of the article and to answer the research questions posed, the first part of the article carried out a literature review. This made it possible to identify a number of key factors that influence the potential of regions to develop intermodal transport. It also allowed a taxonomic measure of development to be proposed to assess this potential. The next section of the article proposes a methodology for assessing the potential of regions to develop intermodal transport. This assessment uses a synthetic index to evaluate a region's potential for the development of intermodal transport (IRPIT - Index of the Region's Potential for Intermodal Transport), which is based on the aforementioned taxonomic measure of development. It allows a linear ordering of the regions studied in relation to the so-called development pattern. In our study, we determined the IRPIT index for 16 regions (voivodeships) of Poland. The results, together with their discussion, are presented in the next part of the article. The whole article is concluded with conclusions, which highlight the contribution of the article to the science and practice of management, as well as the limitations and directions of our further research.

2. Theoretical background

The potential of a region to develop freight, intermodal transport is a category that is difficult to measure. This is mainly due to the very concept of "potential of a region", as well as its multidimensionality and the selection of appropriate tools that allow

a comprehensive assessment. The development potential of a region can most often be seen as a set of resources available in a given area, manifested in the quantity, quality and efficiency of their use. They are also the unique and distinctive features of a region that allow it to develop (Nazarczuk, 2013, pp. 73-74). Wyszkowska and Godlewska (2019, p. 104) identify development potential with the conditions of an area, with the resources it possesses, its skills and the possibilities to use them. Nadolny (2018, p. 219) interprets development potential as the ability of a regional economic system to self-develop, become richer and develop, with its own resources, competitive, improved or and innovative products, services and knowledge. As the literature shows, the development potential of a region consists of a number of components that can be divided into several groups. Among them, the following are mentioned: demographic and social potential, natural and cultural potential, economic potential, space potential, institutional potential (Bański et al., 2014, p. 100). Milczarek (2005, p. 9), on the other hand, points primarily to economic, demographic-social, technological and geographical resources. Nazarczuk (2013, pp. 78-79) distinguishes five groups of factors: economic potential, human potential, infrastructure potential, scientific and research potential, and quality of life potential. At the same time, he emphasises that external resources cannot replace the factors accumulated in the region. If a region does not have a developed potential, even significant external assistance will not be able to dynamise the pace of development in the region.

On the basis of the literature reviewed, the potential of a region for the development of intermodal transport is understood as: the set of resources present in a given area together with the capacity to use them to support the implementation of intermodal transport. Intermodal transport is the concept of transporting goods in a single unalterable unit load, using different modes of transport along the entire route, with the assumption that most of the route is carried by sea, rail or inland waterway, while road transport is minimised (Li et al., 2023, p. 2; Caris et al., 2013, p. 105). It leads to sustainability by, among other things, reducing negative environmental impacts or congestion and increasing the efficiency of supply chains (Krstić et al., 2022, p. 1). The development of intermodal transport depends on a number of exogenous and endogenous factors. For example, Zieliński (2010, p. 284) includes the following among the key factors influencing the development of transport in a region: geographical location, wealth of natural resources, level of economic development, location of entities participating in a given transport system, supply potential (production and distribution), absorption potential (demand of entities), transport distances, capacity of the transport network - routes and nodes. Research on the identification of key factors influencing the potential of regions to develop intermodal transport was conducted by Dohn, Przybylska, Żebrucki (2019, pp. 15-30). For this purpose, they identified a list of 17 factors that were subjected to expert research. The experts participating in the study were asked to rate the importance of the proposed factors on a scale from 0 to 100 points (the higher the number of points, the higher the importance of the factor). Taking into account the scores obtained, the authors selected the key factors,

i.e. all those factors with an average score of at least 60 points. The results of the evaluation of the factors are presented in Table 1 (key factors are highlighted in grey).

Table 1.
Factors influencing the region's potential for intermodal transport development

No.	Factor	Weight
1.	number of intermodal logistics centres	78
2.	number of storage areas available	82
3.	number of intermodal transhipment terminals	89
4.	number of production and trade companies	69
5.	number of employees in transport and storage (according to PKD 2007 section H)	68
6.	number of logistics operators, including operators with the potential for intermodal transport	74
7.	number of enterprises in Section H according to PKD 2007	83
8.	length and quality of roads: railways, waterways, motorways	85
9.	number and condition of container vans	55
10.	number and condition of trailers, semi-trailers	42
11.	number of transport and logistics colleges and the associated number of graduates	26
12.	number and condition of available rolling stock	31
13.	number and condition of container platform wagons	36
14.	modern ro-ro transhipment systems	48
15.	infrastructure and capacity of transhipment terminals	58
16.	number of innovations by transport and logistics companies	35
17.	number of transport-related R&D institutions	34

Source: Dohn, Przybylska, Żebrucki (2019, p. 17).

The key factors identified in the table are confirmed by the literature review. Kovač et al. (2023, p. 2) emphasise the need for continuous development of the entire logistics network, which includes both nodes and connections between them. Important nodes are all types of facilities involved in the flow of goods, mainly warehouses, logistics centres, ports and intermodal terminals. Connections between them are provided by linear road, rail, sea or inland waterway infrastructure. Zieliński (2010, p. 284) also emphasises the importance of linear and point infrastructure for the development of intermodal transport, paying special attention to the location of logistics centres in the region. Antonovich (2022, pp. 112-113) not only stresses the importance of the existence of line and point infrastructure, but also draws attention to its condition, which is crucial for the development of intermodal transport. Ližbetin (2019, p. 1) also stresses the importance of a high-quality infrastructure and technical base for the development of intermodal transport. A multi-branch and integrated intermodal transport network must be based on a modern and well-designed infrastructure. Furthermore, an important element of freight transport is the forecasting of future transport needs, which influences the development of transport networks (Pyza, Jachimowski, 2019, p. 1). These needs related to freight transport are mainly represented by manufacturing and trading companies. Kędzior-Laskowska and Kownacka-Waśkiewicz (2022, p. 84) also draw attention to the volume of demand for freight transport, including intermodal transport, in a given area. On the other hand, Šakalys, Batarlienė (2017, p. 282) attribute an important role in the formation of the transport system to both the mentioned transport flows and the operators serving these flows. From the point of view of the development of intermodal transport,

a lot of attention is paid to intermodal terminals in the literature. They are indicated as key elements of intermodal transport, providing connections between different transport modes (Ližbetin, 2019, p. 1; Ližbetin, Caha, 2016, p. 1198; Kovač et al.,2023, p. 2). Due to the use of different transport modes in intermodal transport, they can be of different nature - land, sea, inland waterways (Pyza, Jachimowski, 2019, p. 2). They should be designed and operated to enable efficient loading and unloading, minimising the time and cost of moving goods. In addition, they can help reduce congestion and improve traffic flow throughout the transport network. This is influenced by the choice of transhipment technologies used at the terminal, together with the transhipment facilities used (Krstić et al., 2022, p. 14). Transshipment facilities are identified as key elements that determine the competitiveness of an intermodal transport network (Bassalo-Triana et al., 2023, p. 2). The number, location and capacity of intermodal terminals is also an important issue (Ližbetin, 2019, p. 1; Kędzior-Laskowska, Kownacka-Waśkiewicz, 2022, p. 87; Bassalo-Triana et al., 2021, pp. 1-2). In addition to intermodal terminals, the potential of the study areas is also influenced by linear infrastructure. In their study of the potential for the development of intermodal transport in various countries, Kędzior-Laskowska and Kownacka-Waśkiewicz (2022, pp. 84-87) highlight linear infrastructure in the context of rail transport by referring to the length of rail tracks, the length of rail lines or the density of rail lines. In addition, the capacity of linear infrastructure, the average commercial speed of transport and the coordination of linear infrastructure managers are important parameters (Šakalys, Batarlienė, 2017, p. 282; Antonovich, 2018, 112-113). Dohn et al. (2019, p. 54) also highlight the importance of linear infrastructure for the development of intermodal transport. In addition to railways, they also stress the importance of inland waterways and their parameters for classification into different navigability classes. Special attention is paid to the need to develop waterways of an international character. The research by Przybylska et al. (2017, pp. 195-206) also emphasises the role of line and point infrastructure in the development of intermodal transport (e.g. the number and equipment of terminals, the uniformity of terminal distribution, the existence of logistics centres, the quality of line infrastructure in different modes of transport). However, in addition to infrastructure, the authors also draw attention to other factors, such as the number of operators involved in intermodal transport or the availability of qualified staff.

The presented diverse group of factors influencing the potential of regions in the development of intermodal transport indicates the significant multidimensionality of this issue from the perspective of measurement and assessment. At the same time, focusing separately on individual factors does not allow for a comprehensive assessment. Therefore, it is proposed to use a synthetic indicator that enables a complete picture of the potential of individual regions for the development of intermodal transport and allows for comparison between them. Such a synthetic indicator can be the so-called taxonomic development measure, belonging to the group of taxonomic methods (Dohn et al., 2019, p. 101). Taxonomic methods, including the taxonomic development measure, are often used to analyze the level of development of regions

considering various research areas (e.g., innovation, economic development, and many others). Taxonomy can be seen as a scientific discipline creating principles of ordering (Tarka, 2010, p. 194). In other words, taxonomy is the science of classification, understood as a division into classes consisting of objects with common properties (Gatnar, 1998). Taxonomic analysis involves assessing the level of differentiation of different objects described by a set of statistical features (Tarka, 2010, p. 194). In taxonomy, linear and non-linear ordering methods are used. Linear ordering in a geometric approach involves projecting points representing objects placed in a multidimensional space of variables onto a line. It is used when determining the hierarchy of objects, i.e., arranging objects from the highest to the lowest in the hierarchy. Mainly used in this area are methods like Czekanowski's method, taxonomic development measure by Hellwig, and patternless development measure. On the other hand, non-linear ordering in a geometric approach involves projecting objects placed in a multidimensional space of variables onto a plane. In this method, similarities between objects can be determined without indicating their hierarchy, e.g., the dendrite method known as Wrocław taxonomy, cluster analysis using the Ward method (Łogwiniuk, 2011, p. 13).

Taking into account the analysis of the literature on both the factors influencing the potential of regions to develop intermodal transport and the possibility of using taxonomy to assess this potential, in our research we used linear ordering with a taxonomic measure of development.

3. Methodology

A taxonomic measure of development in the form of the so-called Hellwig pattern was used to assess the potential of individual regions of Poland in terms of intermodal transport development. This measure allows for the construction of a synthetic indicator based on a number of partial measures testifying to certain aspects of the development of the analysed objects (Łogwiniuk, 2011, p. 13). Its advantage is the high transparency of the result, which is associated with the presentation of the results by means of a single synthetic numerical value (Koszel, Bartkowiak, 2018, p. 90). The aim of using a taxonomic measure of development in research is to develop a so-called synthetic index for assessing the potential of a region for the development of intermodal transport (IRPIT - Index of the Region's Potential for Intermodal). This index will make it possible to present the potential of the regions taking into account the different levels of the variables studied. It will also make it possible to perform a linear ranking, i.e. to rank the regions described by many heterogeneous diagnostic variables in terms of this potential, taking into account the distance from the so-called reference region. In this way, the analyses carried out will make it possible to identify the regions with the highest potential for the development of intermodal transport and those with the lowest potential. At the same time, it will be possible to identify regions with similar development potential.

The methodology of the research carried out is presented in Figure 1.

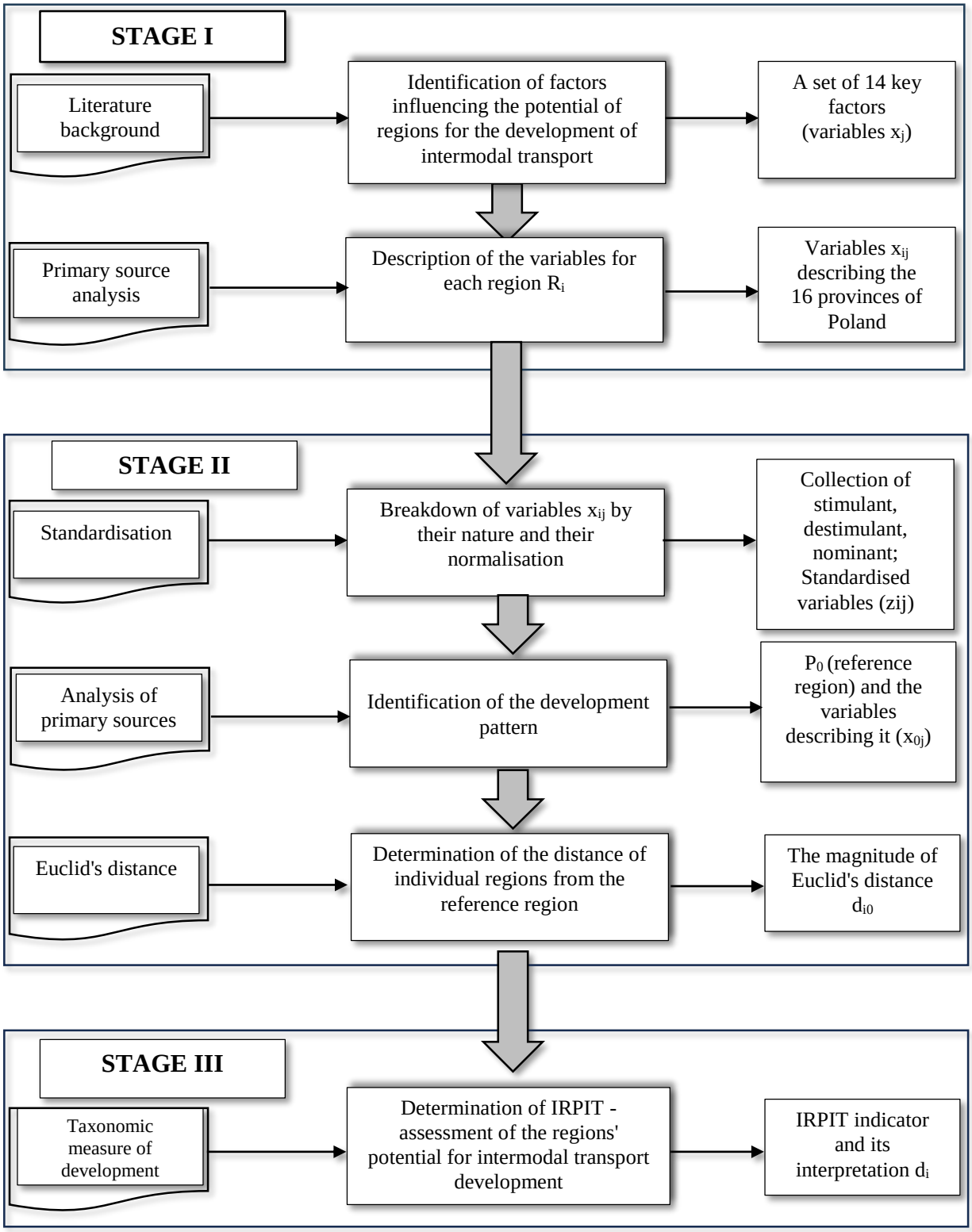

Figure 1. Methodology for assessing the potential of regions for the development of intermodal transport.

Source: own elaboration.

The used methodology consists of three stages divided into six steps. The first stage consists of two steps. The first step focused on conducting a literature review that identified a set of key factors influencing a region's potential for intermodal transport development. These factors are at the same time characteristics of the analysed regions (xj, where j = 1, …, m – the number of factors). In the second step, the studied regions Ri were identified (where i = 1, …, n – number of regions). Due to the subject of the article, the studied regions were individual voivodships of Poland. This approach is a result of the chosen administrative division of the country. Thus, 16 regions (voivodships) were distinguished for the study: Dolnośląskie, Kujawsko-Pomorskie, Lubuskie, Lubelskie, Łódzkie, Mazowieckie, Małopolskie, Opolskie, Podkarpackie, Podlaskie, Pomorskie, Śląskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie, Zachodniopomorskie. All identified Ri regions were then described taking into account the key factors identified in step one that influence the potential for intermodal transport development. Thus, each region was described by a set of characteristic variables (features) xij (where: i = 1, …, n – number of regions; j = 1, …, m – number of factors). In order to obtain data on the characteristics of each region, a primary source analysis was carried out using a number of reports and statistical studies, mainly data from the Railway Transport Office (UTK, 2023), reports on the warehouse market (Colliers, 2023), data from the Central Statistical Office (CSO, 2023) and data from the Ministry of Maritime Affairs and Inland Navigation (MI, 2023).

The second stage of the research carried out consisted of three steps (steps 3-5). In the third step, according to the idea of taxonomic methods, the collected variables xij were divided into three groups, taking into account their nature. These are (Mazur, Witkowska, 2006, p. 252):

- Stimulants - characteristics for which higher values of the variables indicate a higher level of development of the phenomenon in question.
- Destimulants - characteristics for which higher values have a negative effect on the phenomenon under study.
- Nominants - characteristics for which the best value is a fixed quantity or numerical range.

The collected variables describing the potential of the regions were then normalised. This is a result of the variables describing the regions being captured in different units, depending on the type of characteristic being described. Normalisation makes it possible to transform the values of the variables into a comparable form. This is the so-called additivity condition (Feltynowski, Nowakowska, 2009, p. 15). Normalisation was carried out by standardisation according to the formula:

$$z_{ij} = \frac{x_{ij} - \overline{x}_j}{S_j} \quad (1)$$

where:

z_{ij} - the standardised values of the j-th characteristic in the i-th object,

x_{ij} - initial values of the jth characteristic in the i-th object,

$\overline{x}_j$ - arithmetic mean of the j-th characteristic,

S_j - standard deviation of the j-th characteristic.

In the fourth step, we determined the so-called development pattern P_0 which is described by the best values of the individual variables analysed ($P_0 = \{x_{01}, x_{02}, x_{03}, \ldots, x_{0m}\}$, where x_{0j}, for j = 1, …, m – the values of the variables for the reference object). It can therefore be concluded that a development benchmark is such an ideal region (not necessarily an existing one) that can be proposed as a model in terms of its potential for intermodal transport development. The benchmark values (desired values of variables characterising the benchmark object) have been established on the basis of an analysis of primary sources (reports and statistical studies). It should be remembered that the best values for stimulating variables are the maximum values, while the best values for discouraging variables are the minimum values. In the fifth step, we determined the distances (d_{i0}) between a given reference object P_0, and each of the study regions R_i. When using distance measures, it should be borne in mind that an increase in their values means an increase in the degree of differentiation of the regions under study. The function that is a measure of the distance (d) between two regions X and Y has the form (Gatnar, 1998, p. 27):

d: Ω ´ Ω ® $R^{+,}$ (where Ω is a finite set of objects subject to taxonomic analysis)

and meets the conditions:

- d (X,Y) = 0, if X=Y
- d (X,Y) ³ 0
- d (X,Y) = d (Y,X)
- d (X,Z) £ d (X,Y) + d (Y,Z)

For characteristics represented by quantitative variables, examples of distance measures are (Gatnar, 1995, pp. 6-7): Euclidean distance, squared Euclidean distance, Chebyshev distance (Chebychev), urban distance (Block), Minkowski distance (Minkowski) which is a generalisation of Euclidean distance, urban distance and Chebyshev distance, user-defined (Customised). In practice, the Euclidean distance is most often used to determine the distance between the studied objects and the development pattern P_0, expressed by the formula:

$$d_{i0} = \sqrt{\left[\sum_{j=1}^{m}\left(x_{ij} - x_{0j}\right)^2\right]} \quad (2)$$

In our research, we also used the aforementioned Euclidean distance to determine the distance of individual regions (R_i) from the developmental pattern (P_0).

The third stage of the research included step six, which was the determination of a **synthetic indicator to assess the region's potential for intermodal transport development** (**IRPIT**). This indicator is based on a taxonomic measure of development. The calculation was carried out according to the following formula:

$$IRPIT = d_i = 1 - \frac{d_{i0}}{d_0} \quad (3)$$

where:

d_i – taxonomic measure of development for i-th object,

d_{i0} – Euclidean distance of object i-th from the reference object P_0 (pattern 2),

d_0 – Is expressed by the relation:

$$d_0 = \overline{d_0} + 2 \cdot s_0 \tag{4}$$

where:

$\overline{d_0}$ – the arithmetic mean of the values of d_{i0}, expressed by the formula:

$$\overline{d_0} = \frac{1}{n} \sum_{i=1}^{n} d_{i0} \tag{5}$$

s_0 – standard deviation of the distance from the reference, expressed by the formula:

$$s_0 = \left[\frac{1}{n} \cdot \sum_{i=1}^{n} \left(d_{i0} - \overline{d_0} \right)^2 \right]^{\frac{1}{2}} \tag{6}$$

By calculating the IRPIT indicator for each region according to the steps outlined above, we obtain information on the extent to which the region under study deviates from the benchmark and whether it has the potential to develop intermodal transport. It should be emphasised that as the IRPIT indicator approaches unity, the level of a region's potential for intermodal transport development increases. Based on the guidelines of Dohn, Przybylska, Żebrucki (2019, p. 19), the following interpretation of the IRPIT indicator was adopted in the study:

- from 0-20% – the region has no potential for intermodal transport development;
- from 21-40% – the region has very low potential for intermodal transport development;
- from 41-60% – the region has a medium potential for the intermodal transport development, and considerable investment is needed to strengthen the identified factors;
- from 61-80% – the region has strong potential for the intermodal transport development;
- from 81-100% – the region has very strong potential for the intermodal transport development.

4. Results

The literature review identified eight factors that can be considered as key factors in assessing the potential of regions for the development of intermodal transport. These are: the number of intermodal logistics centres in the region, the number of available storage areas in the region, the number of intermodal transhipment terminals in the region, the number of manufacturing and trading companies operating in the region, the number of people employed in transport and storage, the number of logistics companies, including those with the potential to provide intermodal transport, the number of transport and logistics companies in the region, the length and quality of rail, water and road routes. Taking into account the above-mentioned factors, the conditions in Poland and the analysis of primary sources, we collected a set of data describing all 16 regions of Poland studied (Table 2).

Table 2.
Set of factors taken into account in assessing the potential of regions to develop intermodal transport

No.	Factors by Dohn, Przybylska, Żebrucki (2019)	Factors taken into account in the study
1	number of intermodal logistics centres in the region	• number of intermodal logistics centres in the region
2	the number of warehousing facilities available in the region	• existing storage stock/regional area, • stock under construction/regional area
3	the number of inter-branch transhipment terminals present in the region	• density of intermodal terminals present in the region (number of terminals/area of region)
4	the number of manufacturing and trading companies operating in the region	• number of manufacturing and trading companies operating in the region
5	number of persons employed in the transport and storage sector	• average employment in the transport and storage sector in the region/number of inhabitants in the region
6	number of logistics operators, including those with the potential for intermodal transport	• according to the classification system of enterprises adopted in Poland (PKD 2007), the category of logistics operators is not distinguished in the statistics. Hence, in a direct way this group was not mentioned separately in the research. On the other hand, this does not indicate that these enterprises were not included in the research in any way. In accordance with the adopted classification, these enterprises are included in the group of entities of the so-called "Transport and warehouse management" section (item 7 of the table)
7	number of transport and logistics companies in the region	• number of enterprises within the section: land and pipeline transport, • number of enterprises within the section: water transport, • number of enterprises within the section: air transport, • number of enterprises within the section: warehousing and support activities for transport
8	the length and quality of rail, waterways and motorways	• density of motorways (number of motorways/area of region), • density of motorways and motorways (number of motorways and expressways/area of region), • density of railways (number of railways/area of region), • density of waterways (number of waterways/area of region)

Source: own elaboration.

As shown in Table 2, based on the factors influencing the potential of regions for the development of intermodal transport identified in the literature review, we identified 14 variables for further research. They were used to describe all analysed regions in Poland. When analysing the variables collected for the study, it was found that:

- In Poland, there are four main intermodal logistics centers (one each in the Silesian and Pomeranian voivodeships, and two in the Pomeranian voivodeship).
- The highest density of intermodal terminals is found in the Silesian voivodeship (4.05 terminals/10,000 km^2). Three voivodeships do not have a single intermodal terminal. In two voivodeships, the density exceeds the level of three terminals/ 10,000 km^2, while the remaining 10 voivodeships have a density ranging from 0.56 to 2.18 terminals/10,000 km^2.

- The Mazowieckie voivodeship has the highest amount of existing warehouse space [m^2] as well as warehouse space under construction. Meanwhile, the Silesian voivodeship has the highest density for both of these mentioned parameters. The lowest density of warehouse space is significantly observed in the Podlaskie voivodeship.
- The highest number of manufacturing and trading companies, as well as companies operating in the transportation and warehouse management sector, is located in the Mazowieckie voivodeship. The second position in this regard is held by the Silesian voivodeship.
- The highest average employment in the transportation and warehouse management sector per 1000 residents is found in the Mazowieckie voivodeship.
- The highest density of overall roadways, as well as specifically motorways and expressways, is present in the Silesian voivodeship (1.78 km/km^2 and 0.03 km/km^2, respectively).
- The highest density of railway lines is found in Silesia (0.15 km/km^2). At the same time, this density is significantly higher than that of all other regions, with the second highest voivodship having a density of 0.089 km/km^2.
- Lubuskie has the highest density of inland waterways (0.028 km/km^2).

According to the adopted research methodology, all collected variables were classified as stimulants and then subjected to normalization. As part of the fourth step of the study, a so-called reference object (region) P_0 was determined. Unfortunately, both the literature and economic practice do not indicate or describe a reference region in terms of intermodal transport development. Therefore, an ideal, non-existent region characterized by the best parameters in the analysis of the region's potential was chosen as the reference region. Table 3 presents the values of variables describing the created reference region.

Table 3.
Values of factors describing the reference region P_0

No.	Name of factor	Value of the factor for the reference region P_0	
		Numerical value of the factor (x_{0j}) (voivodeship)	Normalized value of the factor (z_{0j})
1.	Number of intermodal logistics centers	2 (wielkopolskie)	3,031088913
2.	Density of intermodal terminals [10 000 m^2/km^2].	4,054163626 (śląskie)	2,200927241
3.	Number of entities - sections C and G in the PKD 2007 classification	255902 (mazowieckie)	2,764549353
4.	Average employment in transport and storage (according to PKD 2007 section H) per 1000 residents	55,35761478 (mazowieckie)	3,399416561
5	Division 49 of section H - land and pipeline transport	43345 (mazowieckie)	2,800273099
6	Division 50 of section H - water transport	437 (małopolskie)	2,854967966
7	Division 51 of section H - air transport	934 (mazowieckie)	3,628237334
8	Division 52 of section H - warehousing and transportation support activities	6599 (mazowieckie)	3,162961334
9	Density of motor roads (length of roads/area of region [km/km^2])	1,781148139 (śląskie)	2,13202115

Cont. table 3.

10	Density of highways and expressways (length of roads/area of the region [km/km^2])	0,029506203 (śląskie)	2,233883777
11	Density of railroads (length of roads/area of the region [km/km^2])	0,151787886 (śląskie)	3,207874011
12	Density of inland waterways (length of roads/area of region [km/km^2])	0,027881041 (lubuskie)	2,557517978
13	Density of available storage resources (m^2/area of region [km/km^2])	393,2538717 (śląskie)	2,882527173
14	Density of storage resources under construction (m^2 /area of region [km/km^2])	46,39584854 (śląskie)	2,658586562

Source: own elaboration.

As can be seen from Table 3, the model region (P_0) is a combination of the values of the factors of the Mazowieckie and Silesian provinces in the first place, as well as the Wielkopolskie province (in terms of the number of logistics centres), the Małopolskie province (in terms of the number of water transport companies) and the Lubuskie province (in terms of the density of inland waterways).

According to the subsequent research steps, the Euclidean distances of the individual provinces from the designated benchmark region P_0 shown in Table 2, were determined. On the basis of these distances, the IRPIT index (Index of the Region's Potential for Intermodal Transport) was calculated according to the formulas described in the methodology (Fig. 2).

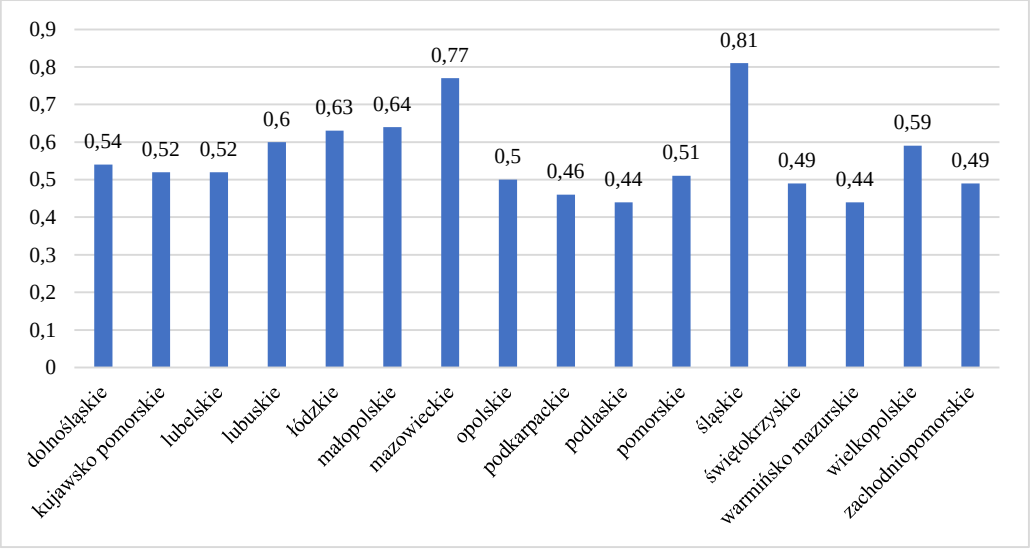

Figure 2. IRPIT indicator.

Source: own study.

As shown in Figure 2, the highest IRPIT index and thus the highest potential for the development of intermodal transport is in the Silesian province (0.81). The second highest is in Mazowieckie (0.77). The other regions have an index between 0.44 and 0.64.

Figure 3 presents a histogram showing the distribution of the IRPIT indicator obtained for each region. This distribution is not symmetrical, but takes the form of a right-skewed distribution. The first thing that stands out is the absence of regions for which the indicator would be below 0.44. At the same time, it can be seen that as the value of the IRPIT indicator

increases within the accepted ranges, the number of regions representing them decreases. In the last interval, where the value of the indicator is the highest, there are only two regions: the Silesian and Mazowieckie voivodships.

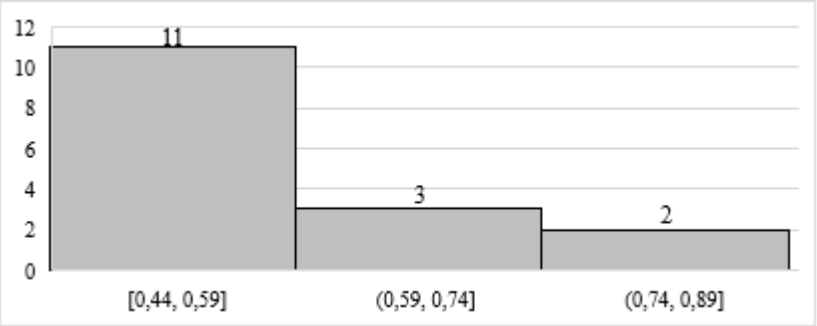

Figure 3. Histogram for the IRPIT indicator.

Source: own study.

Figure 4 below shows the detailed distribution of the IRPIT index for the regions studied, using the interpretation proposed in the research methodology.

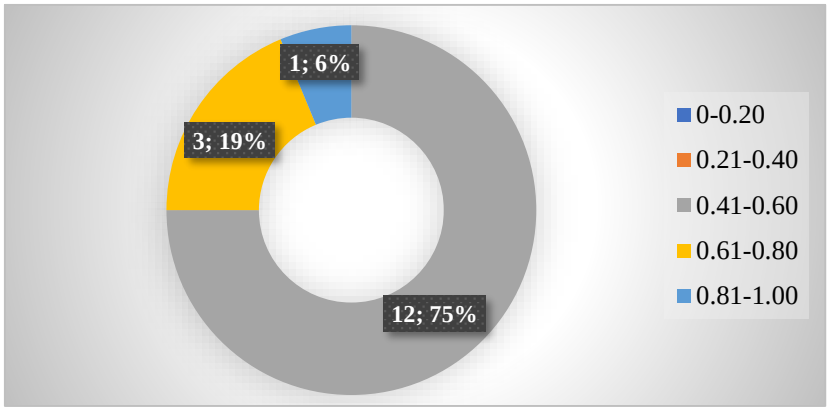

Figure 4. Distribution of the IRPIT indicator according to the adopted interpretation (number of regions and percentage value).

Source: own study.

On the basis of this indicator and Figure 4, it is possible to identify the potential of each region for the development of intermodal transport:

- In the case of one voivodship (6% of the surveyed collective), the indicator is in the range of 81-100% (Silesian Voivodship). It should be noted that this region has a very strong (and highest) potential for the development of intermodal transport;
- In the case of 3 provinces (19% of the surveyed collective) the index is in the range of 61-80%, which means that these provinces have a significant potential for the development of intermodal transport. Among these provinces, Mazowieckie stands out with an IRPIT index of 0.77 (77%), which is in the upper limit of the assumed range. The other two are Łódzkie and Małopolskie, which are at the lower end of the range;

In the case of 12 provinces (75%), the indicator is in the range of 40-60%, which means that these provinces have an average potential for the development of intermodal transport. At the same time, three provinces in this group have an indicator within the range of 44-46%, i.e. at the lower end of the range (Podlaskie, Warmian-Masurian and Subcarpathian provinces). It is also worth noting the Wielkopolska and Lubuskie provinces, whose indicators are practically at the limit of the range (59% and 60% respectively).

5. Conclusions

The article presents a methodology for assessing the potential of Polish regions for the development of intermodal transport. For this purpose, a synthetic IRPIT indicator based on the taxonomic measure of development was developed. The advantage of the indicator is the ability to evaluate regions and their linear order in terms of the analysed potential. It should be noted that the adopted methodology for determining the indicator and its interpretation is universal. However, its application was presented for 16 regions in Poland. The study of Polish regions showed that one province (Silesia) obtained the highest level of the IRPIT index (0.81), which indicates its highest development potential in the field of intermodal transport. A high level of the IRPIT index was also achieved by three other provinces, of which Mazowieckie stands out. It obtained an index of 0.77, which is slightly lower than that of Silesia. Therefore, it can be assumed that these two provinces currently have the potential to take a leading role in the development of intermodal transport in Poland. On the positive side, no voivodship was placed in the ranges indicating a total lack or very low potential for intermodal transport development (index at 0-0.4). On the other hand, the existence of 12 voivodships (75%) with a potential defined as medium indicates the need to take a number of measures to increase this potential. Such measures would be fully in line with the current transport policy.

The study carried out is not without its limitations. The main one is that the assessment of the regions' potential did not take into account factors of a qualitative nature, which cannot be quantified, but which are also important for the development of intermodal transport. This was the result of the construction of the IRPIT index, which is based on a taxonomic measure of development that only takes into account quantified characteristics. The second limitation is the acquisition of accurate, reliable and up-to-date data describing the factors included in the study. These data are often difficult to obtain because they are scattered and often not collected or published.

Taking into account the relevance of the topic addressed and the assumptions and limitations of the analyses presented, two main directions for future research have been identified. The first is to try to include in the index factors of a qualitative nature that influence the potential of regions for the development of intermodal transport. The second is to carry out research using the developed indicator in regions of other European countries.

References

1. Antonowicz, M. (2018). Czynniki rozwoju przewozów intermodalnych w Polsce. *Studia i Prace Kolegium Zarządzania i Finansów, 170,* pp. 105-120.
2. Bański, J., Czapiewski, K., Mazur, M. (2014). Potencjały rozwojowe województwa podkarpackiego – diagnoza i ocena. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, 26,* pp. 98-112.
3. Bassalo-Triana, M.J., Bravo-Bastidas, J.J., Contreras, I., Cordeau, J.F., Vidal-Holguín, C.J. (2023). Intermodal hub network design with generalized capacity constraints and non-synchronized train–truck operations. *Transportation Research Part B, 174*, pp. 1-29.
4. Bassalo-Triana, M.J., Vidal-Holguín, C.J., Bravo-Bastidas, J.J. (2021). Planning and design of intermodal hub networks: A literature review. *Computers and Operations Research, 136,* pp. 1-18.
5. Caris, A., Macharis, C., Janssens, G.K. (2013). Decision support in intermodal transport: A new research agenda. *Computer in Industry, 64,* pp. 105-112.
6. Colliers (2023). *Polska. Rynek magazynowy, Raport roczny rozszerzony*, pp. 1-57.
7. Dohn, K., Knop, L., Kramarz, M., Przybylska, E. (2019). *Transport intermodalny w kontekście rozwoju intermodalnego*. Toruń: Dom Organizatora.
8. Dohn, K., Przybylska, E., Żebrucki, Z. (2019). Evaluation of the cross-border area regions potential for the development of intermodal transport. *Research in Logistics & Production, Vol. 9, No. 1*, pp. 15-30.
9. Feltynowski, M., Nowakowska, A. (2009). Metoda oceny potencjału innowacyjnego regionów. In: A. Nowakowska (ed.), *Zdolności innowacyjne polskich regionów* (pp. 11-23). Łódź: Wydawnictwo Uniwersytetu Łódzkiego.
10. Gatnar, E. (1995). *Klasyfikacja danych za pomocą pakietu statystycznego SPSS for Windows*. Warszawa: Wyd. PLJ.
11. Gatnar, E. (1998). *Symboliczne metody klasyfikacji danych.* Warszawa: PWN.
12. GUS (20217) *Transport. Wyniki działalności w 2016 r., Informacje i opracowania statystyczne.* Warszawa.
13. GUS (2023). *Bank Danych Lokalnych*, https://bdl.stat.gov.pl/bdl/start, 30.09.2023.

14. GUS (2023). *Transport - wyniki działalności w 2022 r., Informacje statystyczne*, Warszawa/ Szczecin.
15. Kędzior-Laskowska, M., Kownacka-Waśkiewicz, J. (2022). Prospects for the development of intermodal transport in the Visegrad countries, Germany and Italy – selected aspects. *Olsztyn Economic Journal, 17(1),* pp. 83-95.
16. Komisja Europejska (2011). *Biała Księga. Plan utworzenia jednolitego europejskiego obszaru transportu – dążenie do konkurencyjnego i zasobooszczędnego systemu transportu,* https://eur-lex.europa.eu/legal-content/PL/TXT/?uri=celex%3A52011DC0144, 12.09.2023.
17. Koszel, M., Bartkowiak, P. (2018). Taksonomiczna miara zrównoważonego rozwoju obszarów metropolitalnych w Polsce. *Zeszyty Naukowe Uniwersytetu Ekonomicznego w Krakowie, 3*, pp. 83-100.
18. Kovač, M., Tadić, S., Krstić, M., Elia, V., De Leo, F. (2023). Stochastic financial evaluation: The case of an intermodal terminal. *Sustainable Futures, 5*, 1-8.
19. Krstić, M., Tadić, S., Elia, V., Massari, S., Umar Faroooq, M. (2023). Intermodal terminal subsystem technology selection using integrated fuzzy MCDM model. *Sustainability, 15*, pp. 1-17.
20. Li, L., Wang, J., Wang, H., Jin, X., Du, L. (2023). Intermodal transportation hub location optimization with governments subsidies under the Belt and Road Initiative. *Ocean and Coastal Management, 231*, pp. 1-15.
21. Ližbetin, J., Caha, Z. (2016). Theoretical criteria for the evaluation of the operational performance of intermodal transport terminals. *Procedia Engineering, 161*, pp. 1197-1203.
22. Ližbetin, J. (2019). Methodology for determinining the location of intermodal transport terminals for the development of sustainable transport systems: a case study from Slovakia. *Sustainability, 11*, 1-17.
23. Łogwiniuk, K. (2011). Zastosowanie metod taksonomicznych w analizie porównawczej dostępu do infrastruktury ICT przez młodzież szkolną w Polsce. *Economy and Management, 1*, pp. 7-23.
24. Mazur, A., Witkowska, D. (2006). Zastosowanie wybranych mierników taksonomicznych do oceny nieruchomości. *Zeszyty Naukowe Szkoły Głównej Gospodarstwa Wiejskiego. Ekonomika i Organizacja Gospodarki Żywnościowej, 60*, pp. 251-258.
25. Milczarek, D. (2005). Potencjał Unii Europejskiej w stosunkach międzynarodowych (cz. 1). *Studia Europejskie, nr 1*, pp. 9-27.
26. Ministerstwo Infrastruktury (2023). *Mapa śródlądowych dróg wodnych w Polsce*, https://www.gov.pl/web/infrastruktura/srodladowe-drogi-wodne, 28.09.2023.
27. Nadolny, M. (2018). Proces koncentracji potencjału rozwojowego regionów na przykładzie wybranych województw. *Roczniki Kolegium Analiz Ekonomicznych, nr 49.* Szkoła Główna Handlowa, pp. 219-232.

28. Nazarczuk, J.M. (2013). *Potencjał rozwojowy a aktywność inwestycyjna województw i podregionów Polski*. Olsztyn: Wydawnictwo Uniwersytetu Warmińsko-Mazurskiego.
29. Przybylska, E., Żebrucki, Z., Kruczek, M. (2017). Identyfikacja czynników rozwoju transportu intermodalnego w Polsce. *Zeszyty Naukowe Politechniki Śląskiej, seria: Organizacja i Zarządzanie, z. 103,* 195-206.
30. Pyza, D., Jachimowski, R. (2019). Designing of transshipment terminals in the aspect of selected intermodal transport systems. *MATEC Web of Conferences, 294*, pp. 1-7.
31. Šakalys, R., Batarlienė, N. (2017). Research on Intermodal Terminal Interaction in International Transport Corridors. *Procedia Engineering*, *187*, pp. 281-288.
32. Tarka, D. (2010). Własności cech diagnostycznych w badaniach typu taksonomicznego. *Economy and Management*, *4*, pp. 194-205.
33. UTK (2023). https://dane.utk.gov.pl/sts/transport-intermodalny/opis-terminali, 29.09.2023.
34. Wyszkowska, D., Godlewska, A. (2019). Potencjał rozwojowy Białegostoku na tle miast wojewódzkich w Polsce. In: B. Cieślińska (ed.), *Oblicza dużego miasta: instytucje, organizacje, procesy* (pp. 87-106). Wydawnictwo Uniwersytetu w Białymstoku.
35. Zieliński, K. (2010). Zarządzanie transportem w regionie – regionalny system transportowy. *Prace naukowe Uniwersytetu Ekonomicznego we Wrocławiu, z. 110*, pp. 279-286.

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ORGANIZATIONAL STRUCTURE AS A DETERMINANT OF BUSINESS PROCESS MANAGEMENT IMPLEMENTATION IN COMMUNITY OFFICES

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Purpose: The purpose of this article is to assess the potential of the organizational structure existing in the community offices in Poland to support the implementation and development of Business Process Management in these entities.
Design/methodology/approach: In order to achieve the article's objective, a literature review was performed. Secondly, a research was carried out that aimed at assessing to what extent some special features of the organizational structure are implemented in the community offices from the Warmian-Mazurian voivodship.
Findings: The conducted research provides basis for stating that the community offices in Poland, in terms of organizational structure, do not encounter significant barriers that could thwart the introduction and development of Business Process Management in these entities. The factors indicated as present by respondents from all types of surveyed offices were: appointing process owners, existence of small number of hierarchical levels in the organizational structure of the offices and the existence of efficient horizontal communication.
Research limitations/implications: The limitation of the study may be the fact that it was conducted on the basis of a survey questionnaire. It is, therefore, an opinion survey.
Practical implications: Expanding knowledge of managers of public organizations in the field of possible actions that would be aimed at increasing the probability of success in introducing and increasing the degree of use of Business Process Management.
Originality/value: The added value of the article is the presentation of a topic about which there is a research gap.

Keywords: Business Process Management, community office, organizational structure, BPM determinants.

Category of the paper: Research paper.

1. Introduction

Business Process Management (BPM), even though it is no longer a recent creation as a management concept (it dates back to the 1980s[1]), is still one of the leading proposals used in various types of organizations (Lizano-Mora et al., 2021). Managers can currently implement a number of different concepts supporting management of organizations, but the constantly growing BPM market in the world proves that this concept is still perceived as a good alternative to other proposals. While the global BPM market size was valued at USD 14.46 billion in 2022, it is even expected to expand at a compound annual growth rate of 19.9% from 2023 to 2030 (Business Process Management Market Size…, 2023). This fact is not surprising, because the benefits of applying BPM principles have been noticed for years and are undeniable. Citing, for example, the research of K.P. McCormack and W.C. Johnson, it can be concluded, among others, that the more process-oriented an organization is, the better results it achieves, the climate of commitment, cooperation and internal communication in the organization improve and the occurring conflicts are minimized. Similar conclusions were reached by R. Škrinjar, M.I. Štemberger and T. Hernaus, who noticed that as the focus on processes in organizations increases, organizations achieve better financial results. In addition, the authors observed a strong impact of the application of the process approach on the non-financial results, i.e. on the satisfaction of organizations' employees, customers and suppliers (McCormack, Johnson, 2001; Škrinjar et al., 2007).

As mentioned above, Business Process Management can be used in organizations regardless of their type, due to, among others, the universality of its principles, i.e., designating process owners, process knowledge and orientation, customer focus, process standardization and informatization, organizing work in process teams, process measure and improvement etc. (Armistead, 1996; Trkman, 2010; vom Brocke et al., 2014). And indeed, BPM is successfully used not only in business organizations, but also in public and social ones. The benefits of implementing BPM in different organizations are similar. But the barriers of introducing that concept in organizations may be more severe for non-business ones. This is due to the different conditions of operation of specific types of organizations. When analyzing the determinants of the implementation and development of BPM in organizations, researchers usually focus on specifying the conditions in the field of organizational culture, organizational strategy, existing ICT infrastructure and the possibilities of its development, preparation of employees, including those from the highest levels, and organizational structure (do Amaral Castro et al., 2020; Alibabaei et al., 2009). In the case of public organizations, particular attention is paid to a certain rigidity and specificity of their organizational culture and to the low flexibility of the organizational structure existing in them, which often takes the form of a silo (Krukowski, 2013;

[1] The 1980s are indicated, in the literature on the subject, as the "2nd wave" in the development of BPM, which gave shape to the concept and significantly influenced its current perception (Lizano-Mora et. al., 2020).

Kregel et al., 2022). And among others, these elements are often seen as barriers to the implementation and development of the use of BPM in public organizations, preventing the full potential of the discussed concept from being fully exploited.

Community offices are a special type of public organizations, playing an important role for citizens. Many important issues are resolved there, which is why the efficient functioning of these units is very important in the context of building the well-being of citizens. One of the ways to improve the efficiency of community offices is to introduce modern management concepts, including BPM.

The aim of this article is to assess the potential of the organizational structure existing in community offices in Poland to support the implementation and development of Business Process Management in these entities. The article presents the results of the research carried out in the community offices from the Warmian-Mazurian voivodship.

2. Theoretical background

The nature of the organizational structure supporting the implementation and development of the process approach in organizations, including public ones, has already been outlined by M. Hammer and J.A. Champy. Propagators of the reengineering concept stated that: "In a process-oriented company, it is the process, not functions or geography, that will constitute the basis of the organizational structure" (Hammer, Champy, 1996, p. 122). R.L. Manganelli and M.M. Klein noticed that an organizational structure that aspires to be a process structure should, first of all, minimize the number of boundaries through which processes pass. For this purpose, members of the team implementing a given process should be placed in the same organizational unit, with one common manager (Manganelli, Klein, 1998). This is due to the fact that dominance of horizontal organizational processes creates a structure of variable relationships that should be based on multi-entity and team work. In this regard, it is recommended to create interdisciplinary teams (Bitkowska, 2009). The aspect of the need to reduce the boundaries across which the processes carried out in the organization run is also emphasized by, among others, T. Zawistowski and P. Grajewski. The first author underlines the fact that most processes carried out in organizations do not take place in one, but in several departments. Therefore, efficient execution of processes requires eliminating artificial divisions between organizational departments, at the junction of which the so-called "bottlenecks" or minimum factors are generated, caused by e.g. poor information flow (Zawistowski, 2001). In turn, P. Grajewski notes that by habitually placing the participants of a given process in several departments of the organization, not only does their communication become more difficult, but also the amount of necessary work increases, inconveniences occur in the coordination and synchronization of the activities of process contractors, as well as the

probability of making mistakes is bigger, among others: resulting from greater efforts in the areas of security, control, reconciliation and interpretation of various issues (Grajewski, 2012).

The literature on the subject lists a number of characteristics and assumptions regarding the nature of the process structure. One such aspect is flexibility. However, this characteristic should not be perceived as a lack of certain order, but rather as an adjustment in the use of human resources where they are needed at a given moment, and not only in the system to which they are formally assigned (Grajewski, 2012). P. Grajewski also distinguished the structural features of the process organization in terms of configuration, centralization, specialization, formalization and standardization (Table 1). They may also constitute necessary assumptions as to how to transform the traditional functional structure into a process structure.

Table 1.
Features of the process structure according to P. Grajewski

Structural feature	Characteristic
Configuration	- limiting hierarchical levels to two levels above the process level, - choosing the type of client as the main criterion for dividing the process structure, - the occurrence of systemic coordination, - creation of a new entity system by designating organizational roles that have not existed before, i.e. process teams, process owners.
Centralization	- the occurrence of significant decentralization of powers, - introducing the principle of responsibility for results, - popularization of the relationship between supplier and client (recipient) of processes.
Specialization	- radical giving up on the functional division of labor for the multidimensional work, - mastering skills aimed at continuous change, which will result in increasing employee competences up to the limits of the entire, often multifunctional process in which a given employee participates.
Formalization	- the presence of descriptions of the organization's operations in documents, i.e. process maps, maps of relations, organizational structure diagrams.
Standardization	- the occurrence of standardization of these types of activities (in particular the methods used), the dissemination of which guarantees contractors a greater scope of freedom and implementation efficiency (however, it should not be carried too far, so as not to limit innovative activities and behaviors, etc.), - standardizing the behavior of contractors according to formulas considered best, as well as eliminating the risk of undesirable behavior.

Source: (Grajewski, 2012).

Designing organizational structures that would be clearly "tailored" to the nature of a given organization (in this case, process one), is, as P. Grajewski claims, a very difficult task. In practice, entities that call themselves process-oriented either do not introduce any changes to their organizational structure, or the changes are minor, limited to, for example, the selection of process owners. This situation is most often dictated by managers' reluctance to deviate from established hierarchical solutions (Grajewski, 2012).

It is worth considering here whether, in view of the above, in order to implement or/and to increase the scope of implementation of the BPM in organizations (what can be directly understood as increasing the process maturity of an organization), it is necessary to make appropriate adaptations in the organizational structure.

The literature on the subject contains the views of authors who believe that this action is necessary. For example, T.R. Gulledge and R.A. Sommer claim that the implementation of BPM is associated with the absolute necessity of rejecting the hierarchical structure (Gulledge, Sommer, 2002). Similar views are presented by A. Bitkowska, who believes that the implementation of the discussed concept should be accompanied by "proper" shaping of the organizational structure. The author also claims that the contradictions between the functional and process areas of the organizational structure can be perceived as one of the most important barriers related to the introduction of BPM into organizations. And the elimination of functional divisions contributes to the creation of more independent units that can act faster and respond to possible customer behavior (Bitkowska, 2016). However, S. Dyla, A. Szeptuch and D. Zwolińska claim that increasing the scope of use of the BPM is basically impossible without making the required modifications in the organizational structure, but also in the strategy of a given organization (Dyla et al., 2013).

In opposition to the above views, we can cite voices of authors who adopt a completely different perspective on this topic, believing that it is possible for two areas of coordination (horizontal and vertical) to coexist. However, maintaining both functional and process organization at the same time results in, among others: competition between the functional and process areas for resources, underestimation of the importance of processes and their contribution to the implementation of the strategy, possible increase in the costs of operating the organization, or difficulties in building a coherent motivation system (Skrzypek, Hofman, (2010). It is for these reasons, among others, that M. Hammer and S. Stanton reject the possibility of coexistence of the functional and process areas (Hammer, Stanton, 1999).

Authors tending to emphasize the need to introduce changes to the organizational structures of entities implementing and expanding the process approach, however, often assume that they should be disseminated in an evolutionary manner, instead of making sudden and radical changes (Bitkowska, 2009). We can recall here the views of G. Bełz, who emphasizes that the restructuring of the organization towards a process orientation is of a long-term nature, and the introduction of quick changes is basically impossible due to their complexity (Bełz, 2000). J. Brilman distinguished three phases of the evolution of functional organization towards process organization (Table 2).

Table 2.
Evolution of functional organization towards process one according to J. Brilman

Phase	Characteristic
1	The logic of organizational processes is based on functions and professional specialties. The characteristics of the organization's operations include processes configured in accordance with the principle of adapting activities to the expectations of the end customers of the processes. Individual activities in processes are assigned to functional entities, according to their specialization, which may lead to changes in tasks and roles, or even to their transfer between functions.
2	A matrix structure is established and a horizontal system responsible for the implementation of processes is introduced into the organization. The division into functional departments is still maintained, but their managers receive additional tasks and become responsible for one or several processes (they become their owners). The process structure is "overlaid" on the classic functional structure - thus creating an intersection of two management lines: vertical (specialized) and horizontal (process).
3	There is a transition to a horizontal process structure - the entire organization is organized around processes, in which, among others: most employees are assigned to processes, and former managers are transformed from traditional managers into experts or trainers whose task is to monitor and support the development of employee competences.

Source: (Brilman, 2002).

Another interesting proposal for reaching the target process structure consists of four stages (Grajewski, 2016):

I. at this stage, the organization has a functional structure. However, when necessary, task teams are created to support horizontal coordination between individual functional departments. In the long term, the disadvantage of such a solution is the risk of duplicating the activities of individual organizational units by the mentioned teams;
II. at this stage, in addition to the existing functional structure, permanent teams for project implementation appear. Project managers use resources assigned to individual functional departments, and the implementation of projects is supervised by both the project manager and functional managers, which may cause conflicts between them. However, the advantage of such a situation is a potential change in the mentality of functional managers who begin to perceive the work performed in the organization in a broader sense by focusing on the implementation of projects as processes;
III. at this stage, as a result of identifying and institutionalizing a number of processes occurring in a given unit, a process-matrix organization is created. Process implementation teams are established with permanently assigned process owners. Although these teams still coexist with functional areas, the role of the latter is systematically decreasing, being limited mainly to performing administrative functions or improving human resources. The disadvantage of this solution, similarly to the third stage, is the possible competition of the functional and process systems.
IV. at this stage, a fully formed process organization is created in which functional areas have been completely eliminated and their competences have been transferred to the owners of identified processes. Human resources management, previously the responsibility of the functional area, has also become one of the organizational processes implemented.

The process structure, i.e. the target construct of the organizational structure in an entity implementing and developing the use of BPM, is quite utopian. M. Hammer himself was aware of this fact, proposing to organizations that wanted to strive to be the so-called process organization, rather using solutions typical of a process-matrix structure (Figure 1).

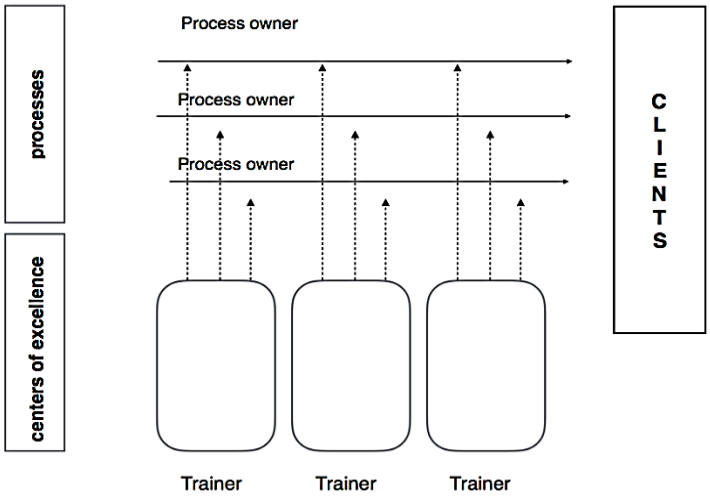

Figure 1. Concept of the process structure according to M. Hammer.
Source: (Hammer, 1999).

The above presented Figure shows two main centers for improving the structure's implementation activity: one - horizontal, implementing processes, and the other - vertical, focusing on preparing employee resources for efficient operation (centers of excellence) (Hammer, 1999).

What is also worth mentioning, the nature of the structure implemented in organizations depends, among others, on the strategy implemented by a given entity. According to A. Zakrzewska-Bielawska, each change of the organization's strategy requires appropriate structural transformations (Zakrzewska-Bielawska, 2006). The literature on the subject also shows the relationships between key strategic factors, structure (in this case - resources) and key processes (Osterloh, Frost, 1996). Therefore, various dependencies can be expected between the strategy and the implementation and increasing the scope of using BPM in organizations.

3. Methods

The aim of the paper, what was underlined in the Introduction part, is to assess the potential of the organizational structure existing in community offices in Poland to support the implementation and development of Business Process Management in these entities. In order to achieve this goal, in the first stage, a literature review was performed, based on the formulated

research question, i.e. *Does the existing organizational structure in community offices in Poland have the potential to support the implementation and development of BPM in these entities*? Based on the question asked, keywords were formulated and entered into the EBSCO electronic database, which was searched for existing literature on the subject in the world, including Poland. Referring to the classification of the literature review proposed by H.M. Cooper (Cooper, 1988), during the conducted process the emphasis was placed on research results and theories, the perspective of a neutral presentation of the issue was adopted and a historical approach to a given issue was used, focusing attention on a specific concept, i.e. on the relationships between the organizational structure as a determinant of the implementation and development of BPM in organizations. Thus, it was noticed that there is a research gap in the topic discussed in the article, which translates into the existence of a small number of scientific publications dealing with the relationship between the organizational structure of strictly public organizations and the use of BPM in those entities (from the point of view of the organizational structure as a condition for the implementation of this concept). In particular, there is a lack of literature on community offices in this area.

Secondly, a research was carried out that aimed at assessing to what extent some special features of the organizational structure are implemented in the community offices in Poland. In order to fulfil the goal of the research, a survey was constructed in compliance with the Brewer's Split Sample Method (Brewer, 2006). This approach was intended to eliminate Common Method Bias (CMB) by using one sample of respondents to evaluate independent variable and the other to measure a dependent variable. In case of the presented research, the independent variable, i.e., the type of community office, was the administrative data (Podsakoff et al., 2012; Jakobsen, Jensen, 2015).

The survey was then carried out in the community offices (offices) from the Warmian-Mazurian voivodship. The questionnaire used in the survey contained questions from different areas, which potentially determine the implementation of BPM in public organizations, including the questions from the organizational structure area. The part of the questionnaire devoted to that specific area listed 8 factors, which are:

F1 – Appointing process owners, i.e. employees responsible for the processes from its beginning to its end.
F2 – Sharing some of the department managers' power with process owners.
F3 – Assigning the office's resources to processes, not to its departments.
F4 – Existence of small number of hierarchical levels in the organizational structure of the office.
F5 – Existence of teamwork (also between different departments of the office).
F6 – Existence of efficient horizontal communication.

F7 – Carrying out training in the so-called process teams (the criterion for delegating an employee to training is participation in the implementation of a given process, and not work in a specific department of the office).

F8 – Linking the motivation system with the results of process implementation (e.g. speed of decision making, number of customers served, low complaint rate, etc.).

The basis for the selection of the above factors were the works of various researchers studying the features of the process structure[2]. The factors were evaluated on a five-point Likert scale[3] by the office secretary and another employee, designated by the secretary, with the experience in implementation of BPM concept in the office. When choosing the secretary for the respondent, they were guided by their position in the organizational structure of the community office, as well as the scope of duties, often requiring extensive knowledge about the community office's functioning processes, applied methods and management concepts in the office etc. What is worth mentioning is that the respondents were to assess the present occurrence of factors, which should also reduce the risk of the CMB. The questionnaire was sent to the respondents by mail or delivered to the offices personally.

As mentioned before, the research was conducted in one of the voivodships of Poland - the Warmian-Mazurian voivodship[4] and all of the community offices from that region (116) were included in the survey. The final study sample included 99 community offices (Figure 2).

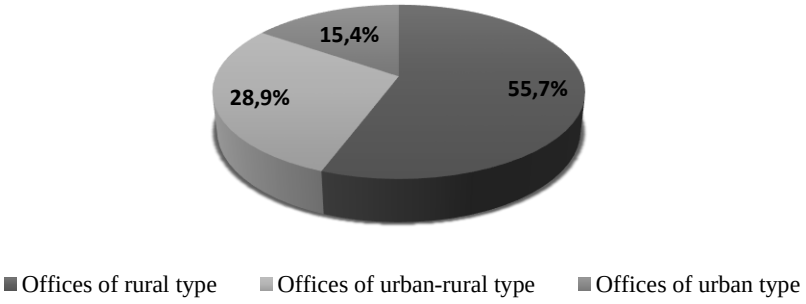

Figure 2. Participation of various types of community offices in the final research sample.

Source: Own work based on research results.

The community offices of rural type were a large majority of the entities from the final sample (55.7%). They were followed by the offices of urban-rural type (28.9%), and the offices of urban type accounted for the smallest group of the entities, in which the study was conducted (15.4%). So, the responses with varying degrees of completeness were received from 99 offices

[2] See the "Theoretical background" part.

[3] The respondents could evaluate the occurrence of different factors from the organizational structure in a given community office, where: 1- a factor does not occur, 2 - a factor occurs to a small extent, 3 - a factor occurs to a medium extent, 4 - a factor occurs to a big extent, 5 - a factor always occurs.

[4] Despite the fact that the presented research was conducted in a single voivodship of Poland, in the author's opinion, its results can be extended to the entire population of the community offices in Poland. This assumption was made basing on the results of other research in this area, which proves that geographical distribution does not affect the specificity of the functioning of these entities and, thus, does not determine the possibility of introducing and expanding the scope of use of BPM in them. See e.g. (Krukowski, 2016).

(198 completed questionnaires), which was a response rate of 85%. 194 questionnaires - 97 pairs from different community offices - were qualified for further analysis. Therefore, the final number of respondents was 194. The empirical material from the selected questionnaires was entered into an electronic database and analysed in the IBM SPSS Statistics 24.

As a next step, the Cronbach's alpha test and the Kaiser-Meyer-Olkin test were performed (Table 3).

Table 3.
Measurement properties

Variable	Cronbach's Alpha Test	Kaiser-Meyer-Olkin Test
Organizational structure	0,829	0,807

Source: Own work based on research results.

Thanks to the Cronbach's Alpha and the Kaiser-Meyer-Olkin test results obtained, the reliability of the research tool was confirmed – it can be assumed that the tool used is internally consistent and that there are dependencies between the variables.

Finally, a one-way analysis of variance for independent samples was conducted (by the statistic method developed by R. Fisher) in order to verify whether individual types of the community offices differed with respect to the occurrence of the eight distinguished factors from the area of organizational structure. The results of the analysis are presented in the next section of the paper.

4. Results and discussion

Table 4 shows the result of one-way analysis of variance for independent samples. The F ratio is greater than 1, which means that the test is statistically significant. Moreover, it can be observed that there are statistically significant differences between the offices of urban, urban-rural and rural communes in the occurrence of factors in the discussed area (the effect size η^2, the level of $p < 0.05$, was 0.05).

Table 4.
Measurement properties

Dependent variable	Type of the community office	M	SE	LL	UL	*F*	*p*	η^2
Organizational structure	urban	3,59	0,13	3,34	3,85	4,77	0,009*	0,05
	urban-rural	3,24	0,09	3,06	3,42			
	rural	3,15	0,07	3,01	3,28			

*$p < 0,5$
Where: M – mean, SE – standard deviation, LL – lower limit, UP – upper limit.

Source: Own work based on research results.

It can also be noted that the average answers provided by respondents were always higher in the offices of urban type than in the entities of urban-rural and rural type. Also, respondents from urban-rural offices gave, on average, higher answers within the discussed area than the respondents from the offices of rural type.

In order to illustrate the disproportions between various types of community offices in the use of factors within the area of the organizational structure, an analysis of the frequency of occurrence of these factors was carried out. A rule was adopted that in order for a particular factor to be classified as one of those used in a given type of office, the sum of respondents' declarations about its frequent and absolute occurrence (indication 4 and 5 on the numerical scale in the survey questionnaire) should be equal or higher than 50%.

Table 5.
Frequency of indications of factors related to organizational structure in the community offices from the Warmian-Mazurian voivodship (in %)

Factor	Type of the community office														
	urban					urban-rural					rural				
	answers (in%)														
	1	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**	**1**	**2**	**3**	**4**	**5**
F1	-	16,7	20	**20**	**43,3**	8,9	7,1	25	**28,6**	**30,4**	13,9	12	24,1	**29,6**	**20,4**
F2	-	6,7	30	**33,3**	**30**	-	8,9	42,9	30,4	17,8	8,3	10,3	25,9	**43,5**	**12**
F3	6,6	26,7	26,7	20	20	14,3	28,6	30,4	8,9	17,8	23,2	12	34,3	18,5	12
F4	3,3	10	36,7	**30**	**20**	3,6	10,7	32,1	**28,6**	**25**	2,8	8,3	32,4	**31,5**	**25**
F5	-	-	26,6	**36,7**	**36,7**	1,8	7,1	46,4	19,7	25	0,9	9,3	22,2	**52,8**	**14,8**
F6	-	-	33,3	**46,7**	**20**	-	12,5	32,1	**26,8**	**28,6**	-	9,3	25	**49**	**16,7**
F7	-	13,3	53,3	16,7	16,7	7,1	30,4	25	21,4	16,1	14,8	12	19,4	**42,6**	**11,2**
F8	-	33,3	20	36,7	10	7,1	35,7	35,7	16,1	5,4	9,3	27,8	25	28,6	9,3

Where: F1-F8 – see the Methods part.

Source: Own work based on research results.

The table above contains bold values representing factors that occur, according to the adopted methodology, in individual types of the community offices. It can therefore be noted that representatives of the surveyed entities indicated 3 factors that, in their opinion, existed in each of the surveyed types of offices. These factors were: F1 – "Appointing process owners, i.e. employees responsible for the processes from its beginning to its end" (respectively: 63.3% for urban community offices, 59% for urban-rural community offices and 50% for rural community offices), F4 – "Existence of small number of hierarchical levels in the organizational structure of the office" (50%, 53.6% and 56.5%, respectively), as well as F6 – "Existence of efficient horizontal communication" (66.7%, 55.4% and 65.7%, respectively). The fact that in the surveyed community offices a process owner is designated can be considered satisfactory. As mentioned earlier, this is an essential and required element when introducing BPM to organizations (Armistead, 1996; Trkman, 2010; Grajewski, 2012). Thus, the research results may indicate that there are at least some manifestations of the discussed concept in the surveyed organizations, and office managers are aware of the need to change the organizational structure if it is to support the development of the use of BPM in the entities in which they work. In the case of the factor F4, different research results were obtained

than those conducted by I. Kregel, B. Distel, A. Coners and K. Krukowski who claim, in their independent researches, that the organizational structure present in public organizations is not conducive to the introduction and development of BPM in these organizations. Therefore, in the light of the research presented in this article, it can be concluded that, at least in the community offices in Poland, their existing hierarchy does not constitute such a barrier. It is also worth noting that the percentage of offices in which respondents indicated a small number of hierarchical levels was the highest in the case of rural community offices, which, according to the author, results from the fact that rural communes usually have a smaller number of inhabitants than other types of communes, which translates into a smaller number of officials (office's employees) employed in the corresponding entities. And a smaller number of employees usually results in flatter organizational structures (Fedczuk, 2017). Moreover, the existence of a small number of hierarchical levels is considered one of the factors determining efficient horizontal communication (Farace et al., 2017), which was also confirmed by the above research results.

Based on the conducted research, it can also be concluded that factors F3 – "Assigning the office's resources to processes, not to its departments" and F8 – "Linking the motivation system with the results of process implementation (e.g. speed of decision making, number of customers served, low complaint rate, etc.)" are not specific to any type of office. Their existence was indicated only, for F3, by 40% of respondents from urban community offices, 26.7% from urban-rural community offices and 30.5% from rural community offices. In the case of factor F8, it was 46.7%, 21.5% and 37.9%, respectively. The results obtained are puzzling because, in principle, there are no formal obstacles to allocating resources in offices to processes rather than to departments, or to link the bonuses awarded to officials on the basis of the results of processes they implement. These issues are regulated by the offices' internal regulations[5]. The absence of such provisions in the regulations proves that the full potential resulting from the introduction of the BPM concept to the community offices is not used in them, but also, on the other hand, provides the opportunity to expand activities in this area.

The conducted research also provided the basis for the conclusion that there is variation in the occurrence of factors related to organizational structure between different types of community offices in the analyzed voivodship. Thus, respondents from urban community offices and rural ones indicated that in the entities where they work, department managers share some power with process owners (F2) (63.3% and 55.5%, respectively). It is worth noting, however, that almost half of the surveyed people from rural community offices also indicated the presence of this factor in these entities (48.2%), which is a satisfactory result. Sharing some responsibility among functional managers with designated process owners is necessary in organizations that want to implement and develop the scope of BPM, using the potential offered by structural conditions in this topic. In order to develop the process structure, according to the

[5] See e.g. Regulamin wynagradzania pracowników Urzędu Miasta Olsztyna, Zarządzenie nr 13 z dnia 20.01.2020.

step-by-step scheme presented by P. Grajewski, it is necessary not only to appoint process owners, but also to give them real responsibility for managing the process within a given department - of course, with the coexistence of the functional and process structures. The characteristic factor, according to the indications, for urban community offices and rural ones was F5 – "Existence of teamwork (also between different departments of the office)" (73.4% and 67.6%, respectively). In the case of urban-rural community offices, it was 44.7%. The presence of this factor in most or almost half of the surveyed entities (in the case of urban-rural commune offices) is a very satisfactory result. Organizing work in teams is, as indicated by, among others, C. Armistead, P. Trkman or P. Grajewski, a necessary condition for introducing and developing the scope of using BPM in organizations. And in the case of factor F7 – "Carrying out training in the so-called process teams (the criterion for delegating an employee to training is participation in the implementation of a given process, and not work in a specific department of the office)" was indicated only by the representatives of rural community offices (53.8%). In the case of respondents from other types of offices, the results were lower: 33.4% for urban community offices and only 21.5% for urban-rural ones, respectively. It may be found interesting that rural community offices achieved such a result. Perhaps the reason for this situation is the fact that usually relatively few employees work in those entities, which may translate into the creation of multidisciplinary and interdepartmental teams, which are then trained in the so-called process teams.

5. Conclusion

Based on the research carried out and presented in this article, it can be concluded that in community offices in Poland, in terms of organizational structure, the barriers of introducing Business Process Management do not exclude the proper implementation of this process. The conducted research showed that the organizational structures of the community offices are not hierarchically extensive, the number of management levels is small in most of them, and horizontal communication is efficient. Process owners are also appointed in the surveyed entities, which may indicate that they consciously adopt a process perspective.

However, in all surveyed organizations it was pointed out that resources are not assigned to processes, but to office departments, and the motivation system is not linked with the results of process implementation, which strictly results from internal legal acts regulating the functioning of these entities. Therefore, it can be concluded that full transformation of the organizational structure of community offices towards constructs supporting the implementation and development of the BPM concept in these entities encounters the legal limitations, which, however, are not difficult to overcome and require increasing the process awareness of higher-level managers of public organizations.

The research also showed that there are statistically significant differences in occurrence of factors from the discussed area between different types of the offices. But still, in general, the presence of factors such as sharing some of the department managers' power with process owners, existence of teamwork and carrying out training in the so-called process teams can be considered a good forecast for the introduction and development of the scope of use of BPM in the surveyed entities.

The conducted research is not free from certain limitations. First of all, it is an opinion survey, although attempts were made to eliminate the creation of CMB by applying the procedures indicated in Methods part during the research process. It was also concluded that the geographical scope of the study does not constitute a barrier to drawing conclusions on the entire population of the community offices in Poland, however, further research could focus on examining another voivodeship in terms of the presence of factors from the discussed area, or offices of a selected type throughout the whole country. An interesting direction would also be to conduct a study that would seek answers to the question: *What is the presence of factors in the area of organizational structure at particular levels of process maturity of municipal offices in Poland?*

References

1. Alibabaei, A., Bandara, W., Aghdasi, M. (2009). *Means of Achieving Business Process Management Success Factors.* Mediterranean Conference on Information Systems (MCIS). Retrieved from: http://aisel.aisnet.org/mcis2009/122, 2.09.2023.
2. Armistead, C. (1996). Principles of business process management. *Managing Service Quality*, *Vol. 6, No. 6,* pp. 48-52, doi: 10.1108/09604529610149239.
3. Bełz, G. (2000). *Reorientacja procesowa struktury funkcjonalnej*. Kraków: Wydawnictwo Akademii Ekonomicznej w Krakowie.
4. Bitkowska, A. (2009). *Zarządzanie procesami biznesowymi w przedsiębiorstwie*. Warszawa: Vizja Press&IT.
5. Bitkowska, A. (2016). Implementacja zarządzania procesowego we współczesnych przedsiębiorstwach. *Przegląd Organizacji*, *No. 9(920),* pp. 4-11, doi: 10.33141/ po.2016.09.01.
6. Brewer, G.A. (2006). All Measures of Performance are subjective. In: G.A. Boyne, K.J. Meier, L.J. O'Toole, R.M. Walker (Eds.), *Public Service Performance: Perspectives on Measurement and Management* (pp. 35-54). Cambridge: Cambridge University Press.
7. Brilman, J. (2002). *Nowoczesne koncepcje i metody zarządzania*. Warszawa: PWE.
8. Business Process Management Market Size, Share & Trends Analysis Report By Solution (Automation, Process Modelling), By Application, By Deployment, By End-user, By

Region, And Segment Forecasts, 2023-2030 (2023). Retrieved from: https://www.grandviewresearch.com/industry-analysis/business-process-management-bpm-market, 12.09.2023.

9. Cooper, H.M. (1988). Organizing knowledge syntheses: A taxonomy of literature reviews. *Knowledge in society, Vol. 1(104),* doi: 10.1007/BF03177550.
10. do Amaral Castro, B., Dresch, A., Veit, D.R. (2020). Key critical success factors of BPM implementation: a theoretical and practical view. *Business Process Management Journal, Vol. 26, No. 1,* pp. 239-256, doi: 10.1108/BPMJ-09-2018-0272.
11. Dyla, S., Szeptuch, A., Zwolińska, D. (2013). Badanie procesowych, kulturowych i strukturalnych uwarunkowań zarządzania strategicznego w organizacjach. *Zarządzanie i Finanse, No. 1*, *Part 1,* pp. 143-158. Retrieved from: http://bazekon.icm.edu.pl/bazekon/element/bwmeta1.element.ekon-element-000171277229, 3.09.2023.
12. Farace, R.V., Taylor, J.A., Stewart, J.P. (1978). Criteria for Evaluation of Organizational Communication Effectiveness, Review and Synthesis. *Annals of the International Communication Association, Vol. 2, No. 1,* pp. 271-292, doi: 10.1080/23808985.1978.11923730.
13. Fedczuk, J. (2017). Leadership and Performance in Various Group Dynamics. *Business/Business Administration, Vol. 38.* Retrieved from: https://scholarsarchive.library.albany.edu/honorscollege_business/38, 2.09.2023.
14. Grajewski, P. (2012). *Procesowe zarządzanie organizacją*. Warszawa: PWE.
15. Grajewski, P. (2016). *Organizacja procesowa*. Warszawa: PWE.
16. Gulledge, T.R. Jr, Sommer, R.A. (2002). Business process management: public sector implications. *Business Process Management Journal, No. 2,* pp. 364-376, doi: 10.1108/14637150210435017.
17. Hammer, M. (1999). *Reinżynieria i jej następstwa*. Warszawa: PWN.
18. Hammer, M., Champy, J. (1996). *Reengineering w przedsiębiorstwie*. Warszawa: Key Text.
19. Hammer, M., Stanton, S. (1999). How process enterprises really work. *Harvard Business Review*. Retrieved from: https://hbr.org/1999/11/how-process-enterprises-really-work, 14.05.2023.
20. Jakobsen, M., Rasmus, J. (2015). Common method bias in public management studies. *International Public Management Journal, Vol. 18(1),* pp. 3-30, doi: 10.1080/10967494.2014.997906.
21. Kregel, I., Distel, B., Coners, A. (2022). Business Process Management Culture in Public Administration and Its Determinants. *Bussines & Information System Engineering, Vol. 64, No. 2,* pp. 201-221, doi: 10.1007/s12599-021-00713-z.
22. Krukowski, K. (2013). Struktury organizacyjne urzędów miast w kontekście zarządzania procesowego. In: A. Noworól (Ed.), *Zarządzanie organizacjami publicznymi, Vol. 14(13), Part 3* (pp. 139-151). Łódź: Wydawnictwo Społecznej Akademii Nauk.

23. Krukowski, K. (2016). *Kulturowe uwarunkowania dojrzałości procesowej urzędów miast*. Toruń: Wydawnictwo Naukowe Uniwersytetu Mikołaja Kopernika w Toruniu.
24. Lizano-Mora, H., Palos-Sánchez, P.R., Aguayo-Camacho, M. (2021). The Evolution of Business Process Management: A Bibliometric Analysis. *IEEE Access, Vol. 9.* Retrieved from: https://ieeexplore.ieee.org/document/9380411, 3.09.2023.
25. Manganelli, R.L., Klein, M.M. (1998). *Reengineering. Metoda usprawniania organizacji.* Warszawa: PWE.
26. McCormack, K.P., Johnson, W.C. (2001). *Business Process Orientation. Gaining the e-business competitive advantage.* Boca Raton/London/New Jork/Washington: St. Lucie Press.
27. Osterloh, M., Frost, J. (1996). *Proceßmanagement als Kernkompetenz. Wie Sie Business Reengineering strategisch nutzen können*. Wiesbaden: Gabler Verlag.
28. Podsakoff, P.M., MacKenzie, S.B., Podsakoff, N.P. (2012). Sources of Method Bias in Social Science Research and Recommendations on How to Control It. *Annual Review of Psychology, Vol. 63,* pp. 539-69, doi: 10.1146/annurev-psych-120710-100452.
29. Regulamin wynagradzania pracowników Urzędu Miasta Olsztyna, Zarządzenie nr 13 z dnia 20.01.2020.
30. Škrinjar, R., Štemberger, M.I., Hernaus, T. (2007). *The Impact of Business Process Orientation on Organizational Performance.* Proceedings of the 2007 Informing Science and IT Education Joint Conference, pp. 171-185, doi: 10.28945/3150.
31. Skrzypek, E., Hofman, M. (2010). *Zarządzanie procesami w przedsiębiorstwie. Identyfikowanie, pomiar, usprawnianie*. Kraków: Wolters Kluwer.
32. Trkman, P. (2010). The Critical Success Factors of Business Process Management. *International Journal of Information Management, Vol. 30, No. 2,* pp. 125-134, doi: 10.1016/j.ijinfomgt.2009.07.003.
33. vom Brocke, J., Schmiedel, T., Recker, J., Trkmn, P., Mertens, W., Viaene, A. (2014). Ten principles of good business process management. *Business Process Management Journal, Vol. 20, Iss. 4*, pp. 530-548, doi: 10.1108/BPMJ-06-2013-0074.
34. Zakrzewska-Bielawska, A. (2006). Strategia jako czynnik determinujący strukturę organizacyjną przedsiębiorstwa. In: A. Stabryła (Ed.), *Doskonalenie systemów zarządzania w społeczeństwie informacyjnym, Vol. 2.* (pp. 499-508). Kraków: Wydawnictwo Akademii Ekonomicznej w Krakowie.
35. Zawistowski, T. (2001). Procesowe zarządzanie organizacją. *Problemy jakości*, pp. 34-36.

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REGIONAL REINDUSTRIALIZATION AND DEINDUSTRIALIZATION ON THE EXAMPLE OF POLAND

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Purpose: The aim of this paper is to assess the diversity of changes in Poland's industrial sector, distinguishing the ICT section, on a regional basis, and to classify the regions according to the value of the location quotient index.
Design/methodology/approach: The article uses the following methods: critical analysis of the literature and analysis of statistical data using selected statistical tools. On the basis of the data, obtained from the Local Data Bank (GUS), the dynamics and share of production and employment in the industrial sector were calculated, also including the ITC sector. The analysis covered 16 provinces from 2000 to 2021.
Findings: Analysis of selected variables in the analyzed years confirmed the existence of regional disparities in Poland, the presence of both reindustrialization and deindustrialization processes and the leading role of the Mazowieckie voivodeship in the ITC sector.
Research limitations/implications: The research conducted in the article represents only one aspect of the assessment of regional disparities. In the course of a broader, more detailed study, it is possible to conduct research at a more local level and to apply additional indicators and methods to evaluate the economic situation of the regions.
Practical implications: Knowledge of the mechanisms and regularities of regional development is the basis for shaping policies that would ensure, on the one hand, high and sustainable development dynamics, and, on the other hand, lead to the reduction of regional inequalities.
Social implications: A situation of excessive inequalities can lead to conflicts and tensions within communities. Therefore, one of the goals of the state's economic and social policies should be to reduce regional disparities, in favor of sustainable development and improving the quality of life in the country.
Originality/value: The article analyzes using the most current statistical data of selected variables and statistical tools. Thus, it can provide another element towards learning about the regularities of regional inequality in the Polish economy.

Keywords: reindustralisation, deindustralisation, regional disparities, location quotient.

Category of the paper: Research paper.

1. Introduction

For several decades, there has been a growing interest in the development of regions, both economically, socially and environmentally. Discussions about the concept and definition of a region have been going on since the 1930s. Attempts to define the spatial division, types, role and importance of regions in the national and world economy were made by various researchers such as: Odum and Moore (1938), Dziewoński (1967), Whittlesey (1954), Tinkler (1973), Chojnicki (1988), Barrios et al. (2008), Grzybowska (2013), Czyż (2016). In the 1960s the concept of region developed in geographical sciences and became the basis for the considerations of the new discipline of regional science (Chojnicki, Czyż, 1992). Also on the economic level, both in theory and practice, the region began to form as an important, even crucial 'competitive space' (Bristow, 2010). It has become a site of economic development and a force for competitive advantage in the economy as a whole (Storper, 1997) and should therefore be the most important area of economic policy influence (Lovering, 1999). Regions are characterised by a specific demographic, geographical and economic structure (Chojnicki, 1996). With this statement, one can begin to try to explain the differences between regions, as well as their impact on the performance of the economy as a whole (Barclays, 2002). The issue of regional studies has also been taken up by Polish scholars: Grzybowska (2013), Chojnicki (1996), Czyż (2016), Micek et al., (2022), Malina (2004), Malaga (2004), Łaźniewska et al. (2011), Smętkowski (2015), Gorzelak (2010). The authors of these works publish extensive literature studies and empirical analyses in order to explain regional processes in the Polish, European and world economies. The scope and conclusions of the studies are mainly focused on the first decade of the 21st century and confirm the thesis existing also in foreign literature about the existence of a large interregional differentiation. Knowledge of the mechanisms and regularities of regional development is the basis for shaping policies that would ensure, on the one hand, high and sustainable development dynamics, and, on the other hand, lead to the reduction of regional inequalities.

2. Industrialisation, deindustrialisation, and reindustrialisation. Literature review

The issue of the categorisation of industrial processes, the causes and conditions of their emergence and disappearance has a very broad representation in the literature. Various studies have been written on this subject: from the concept of stage development (e.g. List, Buchner, Schmoller or Sombart), cyclical development (Mitchell, Kondratiev), the so-called "three sector theory" (Fisher, Clark, Fourastie), their later follower Kuznets (1955), and many others,

such as Rostow, Schumpeter, Chenery, Hoffman. The subject of changes in economic structures was also of interest to Polish scientists (Karpinski, 1986; Kempny, 1991; Klamut,1996; Swadźba, 1994). Most studies indicate the occurrence of certain phenomena in the industrial sphere, characteristic and common to most societies. One can mention such processes as industrialisation, deindustrialisation and reindustrialisation. Their distinction is related to specific, observed, universal changes in the share of the industrial structure in total national output. The first wave that changed world production was the process of industrialisation of the economy. Industrialisation is a phenomenon that can be defined as the process of increasing the share of industrial production in national output. The event that started this process, considered by Rostow (1971) as the starting point for industrial society, was the First Industrial Revolution, understood as the totality of technical, economic and social changes. The technological leap that took place in the 18th century was also, according to Kondratiev (1926), the beginning of the recovery stage of the business cycle, as the sudden introduction of a new technology, stimulated investment, industrial development and an increase in production and productivity. Thus, it can be considered that from the end of the 18th century, technical and technological progress began to be considered the main driving force of production, having the strongest impact on the structure of industrial production, in which, over time, a dual process of the appearance of new, with the simultaneous disappearance of old areas of production begins (Karpinski, 1986). It can be stated that as a result of technical progress, quantitative and qualitative changes are made to the factors of production in the production process, which makes it possible to improve existing products, reduce their production costs, increase productivity and create completely new products. The level of industrialisation can be defined as "expressed by a set of appropriate quantitative and qualitative measures, the degree and extent of the impact of industry on the national economy of a country, a group of countries or larger economic systems" (Jaworska, Skowrońska, 2001). One of the methods of measuring the level of industrialisation, is the fulfilment of certain structural conditions for a country to be considered industrialised. These conditions are as follows: the share of industry in national income should be at least 25%, the share of manufacturing in total industry should be no less than 60% and at least 10% of the population should be employed in industry (Sutcliffe, 1971, p. 17). It is estimated that the stabilisation of the share of industry in the national product took place in highly developed countries at the level of 12-15 thousand dollars per capita, and about 6-8 thousand dollars in later developed countries (Swadźba, 1994).

In the 1970s, highly developed countries began to see a decline in industrial employment. This process occurred together with a systematic increase in employment level in services. This phenomenon was called deindustrialisation or servitisation (Swadźba, 1994). Deindustrialisation is defined by many researchers as a decreasing share of the industrial sector in total production, in favour of an increasing share of the service sector (Bryson and Taylor,2008; Baumol, 1967; Fuchs, 1968). Caincross (1982) and Lever (1991) define the process of deindustrialisation as characterised by a reduction in output and/or employment in

the industrial sector and a reduction in the share of industrial products in foreign trade, independent of changes in the agricultural or services sector. According to Crafts (1992), in a deindustrialisation situation, industrial production grows relatively slowly, industrial employment declines and the trade balance becomes decline. Singh (1977) takes a negative view of the process of deindustrialisation, describing it as a pathological state, i.e. a state of inability and limitation of the economy to achieve its full potential for economic growth, employment and resources. Alderson (1999) considers and extends the concepts of positive and negative deindustrialisation introduced earlier by Rowthorne and Wells (1987). Alderson (1999) points out that positive deindustrialisation is the result of economic development and labour productivity growth. Negative deindustrialisation, on the other hand, occurs as a result of structural constraints in the economy and causes income stagnation and increased unemployment. Priewe (1993) and Dasgupta and Singh (2009) introduced the term premature deindustrialisation occurring in situations where the economy has not reached a high level of industrial production. This was attributed to such organisational and technological innovations that led to an increase in industrial labour productivity (Rowthorn and Ramaswamy, 1999). Moreover, Rowthorn and Coutts (2004) point out that productivity growth is responsible for more than 60 % of the decline in the share of workers in industry. Some authors believed that deindustrialisation was due to the extinction of already all the cultural and technological forces that had pushed industrialism (Lisikiewicz et al., 1990; Bluestone, Harrison, 1982). In the late 19th and early 20th centuries, the service sector steadily increased its share of national income generation at the expense of the declining share of the manufacturing sector. It should be noted, however, that in the economic development of countries (Karpinski, 1986) deindustrialisation of the economy will only occur when countries pass the stage of industrialisation (Karpinski, 1986). Such beliefs point to the importance of the industrial sector in economic development. Despite the decline in its share in the creation of national income, service activities alone cannot replace industry.

Until recently, in many theories, the adoption of the service model was the preferred path of economic development. Whether in the three sector theories or the theories of stage development, the service sector economy was the latter, the culmination of economic development. This path of structural change was also the most common assessment of the competitiveness of economies. Countries that, from the 1970s onwards, were characterised by an increasing share of the service sector in the economic structure were called highly developed countries. One of the first authors to present a different view was Naisbitt (1997), who considered the late 1950s to be a phase of reindustrialisation, involving the production and distribution of information (Klamut, 1998). The use of new resources and information, as a new phenomenon in economic development, was also referred to by the American futurologist A. Toffler (2003). Being a proponent of the concept of stadial social development, he believed that since the end of the 20th century, the economy is already in the next, third wave of industrialisation using information. Recent studies of industrial development trends indicate

that the concept of industrialisation, born in the 19th century, has taken on a new meaning today. It is often referred to in the literature as post-industrial (Bell, 1999) super-industrial (Valakati, 1999), third wave (Toffler, 2003), reindustrialisation and information society (Naisbitt, 1997). A significant date in the perception and description of contemporary economic change was 2016, when Schwab published his book entitled, The 4th Industrial Revolution (Schwab, 2018). The fourth revolution using the achievements of the previous phase will involve blurring the boundaries between the real, digital and biological spheres of human beings. The similarity to the previous ones is the emergence of an impetus in the form of technical and technological advances in specific industries, making the most of digitisation and robotisation processes. Thus, a new phase of industrial presence in economic development, reindustrialisation, is taking place, involving the growth of more intellectually intensive industries, also known as Industry 4.0.

This raises the question about what changes in the industrial sector are taking place in Poland today, in the 21st century. Can these changes in Polish economy be considered as de-industrialisation or reindustrialisation, and can these changes described above be differentiated regionally. Therefore, the aim of this paper is to assess the diversity of changes in Poland's industrial sector, distinguishing the ICT (Information and Communications Technology) section, on a regional basis, and to classify the regions according to the value of the concentration quotient index. The changes faced by Poland in the last two decades may have had a significant impact on the dynamics of changes in the industrial sector and its structure in individual regions. This issue is also in line with the 158th article of the Treaty of the European Union, which formulates the Union's aim, in the implementation of regional policy, to: "to reduce disparities between levels of development in the various regions".

3. Methods

The research in this article is based on annual indicators of the level, dynamics and share of production and employment of industry sector in total production and employment and the ICT industry to production and employment in the whole Polish economy. The ICT sector or Information and Communications Technology according to the Polish Central Statistical Office (GUS) provides products and services of information processing systems for scientific, economic, financial, administrative and social applications, which include the manufacture, sale and service of digital equipment, magnetic-optical media and the production and provision of software, as well as the following services: consulting, data processing, telecommunications, internet and similar services. Based on these indicators, an analysis of deindustrialisation and reindustrialisation processes will be carried out. An assessment of the scale of disparities in industrial processes will be made by using Florence's location quotient (Florence,1929).

This is an index used by researchers mainly in studies in socio-economic geography to reflect the degree of concentration of a phenomenon in particular regions in relation to a reference area (Czyż, 2016; Antonowicz, 2014; Mądry, 2021). The location quotient (LQ), also called the regional specialisation index for a given spatial unit (region), is the ratio of the value of the index of a specific economic or social activity S in spatial unit (region) to the value to the value of that index A in a higher spatial unit (country) (Czyż, 2016). The location quotient formula is as follows: LQ = S/A.

The authors provide different interpretations of the LQ results. Czyż (2016) proposes that regions where LQ > 1, have an 'over-representation' of an activity, and a relative 'shortage' when LQ < 1. The 'over-representation' could be interpreted positively as regional specialisation. Mądry (2021), on the other hand, gives a slightly more detailed interpretation by class:

Class A – high concentration (LQ > 1.5),

Class B – medium concentration (1.5 > LQ > 1.0),

Class C – low medium concentration (1.0 > LQ > 0.5),

Class D – very low medium concentration (0.5 > LQ > 0.25),

Class E – trace occurrence (0.25 > LQ).

The statistics, presented according to the NUTS-2 classification, come from 16 Polish voivodships (also called regions): Dolnośląskie, Kujawsko-Pomorskie, Lubelskie, Lubuskie, Łódzkie, Małopolskie, Mazowieckie, Opolskie, Podkarpackie, Podlaskie, Pomorskie, Śląskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie and Zachodniopomorskie. The main source of data is the Local Data Bank of the Central Statistical Office in Poland (GUS-Local Data Bank). In order to analyse changes in the above-mentioned indicators, statistical data from a period of more than twenty years, from 2000 to 2021, was collected. Only statistics for the employment in ICT industry cover the period from 2011-2021, due to the lack of availability of data from earlier years. These measures will be used to present and interpret changes in selected indicators, on a regional basis. All figures and tables are presented in the Appendix.

4. Results and Discussion

Analysing the growth of the industrial sector production and employment in the years 2000-2021, one can see a regular increase in the volume of industrial production and emplyment in all voivodeships (Figure 1 and Figure 2). Figure 3 illustrates changes in the share of the industrial production sector in Poland and the 16 voivodeships in 2020-2021. On its basis, it can be concluded that in the period studied, a slow reindustrialisation, is characteristic of all countries. Reindustrialisation because industrialisation in Poland took place in the 20th century. Considering the conditions which must be met for a country to be considered industrialised, in almost the entire analysed period the share of industrial production in total production of

more than 25% is recorded in Poland and the following voivodships: Dolnośląskie, Kujawsko-Pomorskie, Lubuskie, Łódzkie, Opolskie, Podkarpackie, Pomorskie Śląskie, Świętokrzyskie, Warmińsko-Mazurskie and Wielkopolskie. Only the Lubelskie, Małopolskie, Mazowieckie, Podlaskie and Zachodniopomorskie voivodships are characterised by the share of the industrial sector in total production below 25% throughout the analysed period. According to the definition given earlier, these regions cannot be considered industrialised. As Figure 3 also shows, at the beginning of the analysed period, the highest share of the industry sector is characteristic for the Śląskie voivodship (32.8%), while at the end of the analysed period the Opolskie voivodship (34.3%), which also records the highest increase in this value. The lowest values of growth are characteristic for the Śląskie and Lubelskie voivodeships. In the analysed period there is an increase in all voivodeships, except for Małopolskie. An upward trend in the share of industry in added value is also visible for Poland. The statistics presented show that in 2016 or 2015 the maximum value of the share of industrial production is reached in Poland and the following voivodeships: Kujawsko-Pomorskie, Lubelskie, Lubuskie, Łódzkie, Mazowieckie, Podkarpackie, Pomorskie, Warmińsko-Mazurskie, Wielkopolskie, Zachodnio-pomorskie. On the other hand, Śląskie reached the maximum level of this share earliest, in 2004.

The dynamics of change in the share of employment in the total employment between 2000 and 2021(Figure 4) is positive for the following provinces: Dolnośląskie, Lubuskie, Łódzkie, Małopolskie, Podkarpackie, Podlaskie, Pomorskie, Warmińsko-Mazurskie, Wielkopolskie. The remaining voivodeships and Poland record a decrease in the size of employment in industry in total employment. Figure 4 shows that the largest increase in the share of employment in industry in total employment is recorded in the Wielkopolskie Voivodeship (19.8%), and the largest decrease in Śląskie (-13.6%). However, in all the voivodeships and in Poland there is a decrease in the share of employment in industry in total employment. At the beginning of the analysed period, the highest share is in Śląskie (48.37%), together with Wielkopolskie (43.39) and Pomorskie (42.88%). The Silesian Voivodeship also has the highest share at the end of the period (29.07%), despite the highest decrease in this share. The lowest values of this share characterise the Mazowieckie (13.87%), Małopolskie (18.99%) and Podlaskie (18.74%) voivodeships. On the other hand, in all regions in the analysed period the share of employment in industry to total employment was greater than 10%.

As can be seen in Figure 5 the dynamics of change in the share of the ICT industry's output between 2000 and 2021 is highest in Małopolskie (9.46%), Dolnośląskie (7.91%), Wielkopolskie (6.35%) and Pomorskie (5.33%). The remaining voivodeships have a growth rate lower than the value for Poland (4.35%). When analysing changes in the share of the ICT industry sector in added value in the years 2000-2021, one can see a systematic growth in all the voivodeships analysed, except for Opolskie. The highest share at the beginning of the period is in the Mazowieckie voivodeship (6.64%). For Poland, the share is 3% in 2011, and in the remaining voivodeships its value is lower. At the end of the analysed period,

Mazowieckie also has the largest share (8.51), while the Małopolskie (6.36%) and Pomorskie (5.12%) voivodeships already have a larger share than Poland (4.64%). The presented statistical data indicate that at the end of the analysed reach the maximum value of the share of industrial production in Poland and the following voivodeships: Dolnośląskie, Kujawsko-Pomorskie, Łódzkie, Małopolskie, Podlaskie, Pomorskie, Śląskie, Wielkopolskie, Zachodniopomorskie. On the other hand, Lubelskie, Lubuskie, Świętokrzyskie and Warmińsko-Mazurskie reached the maximum level of this share earliest in 2002, while Mazowieckie in 2004 and Podkarpackie in 2008. The above analysis indicates a territorial diversification of the ICT sector's production, while there is a systematic increase.

Figure 6 shows, that the dynamics of change in employment in the ICT sector between 2011 and 2021 is positive in all voivodeships, except for Podkarpackie, which records a decrease. The highest growth is characteristic for Kujawsko-Pomorskie voivodeship (189.63%), Małopolskie voivodeship (166.51%) and Pomorskie voivodeship (117.76%). As can be seen in Figure 6, at the beginning of the analysed period, the highest share of employees in ITC to total industry was recorded in the voivodeships of Mazowieckie (4.80%), Pomorskie (1.43%) and Małopolskie (1.42%). The remaining voivodeships have share figures lower than for Poland, for which the figure is 1.48%. An increase in the share of employment in the ITC industry occurs only in the voivodeships: Dolnośląskie, Kujawsko-Pomorskie, Lubelskie, Małopolskie. At the end of the period, Małopolskie voivodship has the largest share (2.08%) among the analysed voivodships. The lowest share at the beginning of the period is characteristic for Opolskie voivodeship (0.30%) and Świętokrzyskie voivodeship (0.30%), and at the end for Podkarpackie voivodeship (0.05%). The analysed period shows large differences between regions in both the dynamics of production and employment and their shares in total production and employment respectively.

The calculated employment and production location quotients are presented in two tables. Table 1 shows the classification of the provinces according to the calculated location quotients of employment and production in the industrial sector. More than half of the voivodeships are characterised by an average concentration in both production and employment in the total industry sector. Among them, the highest growth in industrial production in the analysed years takes place in the following voivodeships: Dolnośląskie Wielkopolskie and Lubuskie. In addition the following voivodships: Dolnośląskie, Lubuskie, Łódzkie, Kujawsko-Pomorskie. Podkarpackie and Warmińsko-Mazurskie, Opolskie are characterised by the highest increases in the location quotient in the analysed period (Figure 7 and Figure 8). They can be called growth voivodeships, as they are also characterised by increases in both production dynamics and employment in industry (here the only exception is Opolskie, where the coefficient was lower). The Śląskie voivodeship, despite a high quotient, is characterised by a low growth of industrial production together with a decrease in the dynamics of employment (Figure 7 and Figure 8). It can be called a stagnant voivodeship. Low concentraion, both at the level of production and employment, is characterised by the following voivodeships: Lubelskie,

Małopolskie, Mazowieckie. Zachodniopomorskie, Lubelskie and Świętokrzyskie voivodeships, have growth, albeit small, in industrial production, with low spatial saturation. They can therefore be considered as emerging regions. The classification of voivodeships in the ICT sector in Table 2 is slightly different. The unquestionable leader is the Mazowieckie voivodeship, which can be described as a Class A voivodeship, with high concentration of the ICT sector. The voivodeships with medium concentration, Dolnośląskie, Małopolskie, and Pomorskie are at the same time characterised by high increases in this quotient, together with high growth rates of production and employment in the ICT sector, which may be conducive to achieving an even better position. The low level of the location quotient of Lubelskie, Lubuskie, Łódzkie, Podlaskie, Świętokrzyskie and Wielkopolskie voivodships, together with the growth of production dynamics and employment in the ICT sector (Figure 9 and Figure 10), means that these voivodships can be considered only emerging. The situation in Kujawsko-Pomorskie, Opolskie, Podkarpackie, Śląskie and Zachodniopomorskie Warmińsko-Mazurskie voivodships, characterised by a low level of concentration quotient, together with its decreasing tendency in the analysed period, can be considered unfavourable due to a decrease in the share of high-tech production.

5. Summary

The paper attempts to assess the diversity of changes in Poland's industrial sector, distinguishing the ICT section, at the regional level and classifying the regions according to the value of the concentration quotient indicator at the NUTS-2 classification level. The collected data from the first two decades of the 21st century allow for the formulation of several conclusions. As can be seen from the presented results of the calculations, in the Polish economy some similarities and differences can be observed in changes in the dynamics and share of production and employment of total industry and the ICT sector at the regional level. The analysis of these variables allows us to conclude that in most voivodeships a systematic reindustrialisation is taking place. However, there are also voivodeships that are characterised by a low (below 25%) share of industrial production in total production. As regards the share of employment in industry, in all voivodeships the value is high and exceeds 10% of the share in total employment, which is characteristic for industrialised countries. The highest industrialised regions are Dolnośląskie and Śląskie. At the end of the analysed period, many voivodeships are experiencing a phenomenon of some slight deindustrialisation: Dolnośląskie, Lubuskie, Łódzkie, Wielkopolskie, Śląskie, which could be considered as positive one. A slightly opposite situation occurred in the share of employment in the industry sector in total employment, where almost all voivodeships, after an initial decline in this share, experienced an increase by the end of the analysed period. The analysis of the ITC sector indicates

Mazowieckie as the leader both in terms of the share of production in this sector and employment. However, it is worth emphasising that all voivodeships record an average increase in the share of production and ITC in total production, as well as in the share of employment in ITC in total industry employment. Disparities between voivodeships also occur in the value of the location quotient. The value of this indicator for production and employment in industry divides the voivodeships into two groups. None of the voivodeships belongs to the group of high concentration. Voivodeships as: Dolnośląskie, Lubuskie, Łódzkie, Kujawsko-Pomorskie. Podkarpackie, Opolskie, Śląskie, Warmińsko-Mazurskie and Wielkopolskie are characterised by medium concentration, while the others were characterised by low concentration. More varied results concerned the classification of voivodeships by production and employment in the ICT sector. In this respect, Mazowieckie is a voivodeship with high concentration, Małopolskie, Pomorskie and Dolnośląskie can be considered a voivodeship with medium concentration, while Kujawsko-Pomorskie, Lubelskie, Lubuskie, Łódzkie Podkarpackie, Podlaskie, Śląskie Wielkopolskie and Zachodniopomorskie are characterised by low or very low concentration and traces even in Opolskie and Świętokrzyskie. The results of the analysis indicate the existence of both reindustrialisation and low deindustrialisation in the analysed regions. Moreover, they prove the existence of regional diversification. In the course of a broader, more detailed study, it is possible to conduct research at a more local level and to apply additional indicators and methods to evaluate the economic situation of the regions.

References

1. Alderson, A.S. (1999). Explaining Deindustrialization: Globalization, Failure, or Success? *American Sociological Review, Vol. 64, No. 5,* pp. 701-721.
2. Antonowicz, P. (2014). Zastosowanie współczynnika lokalizacji LQ i krzywej koncentracji w badaniach nad przestrzennym zróżnicowaniem upadłości przedsiębiorstw w gospodarce. *Zarządzanie i Finanse, Vol. 12, No. 3,* pp. 53-63.
3. Barrios, S., Mas, M., Navajas, E., Quesada, J. (2007). *Mapping the ICT in EU Regions: Location, Employment, Factors of Attractiveness and Economic Impact*. Luxembourg: Impact, Office for Official Publications of the European Communities.
4. Baumol, W. (1967). Macroeconomics of Unbalanced Growth. *American Economic Review, Vol. 57, No. 3,* pp. 415-26.
5. Bell, D. (1999). *The Coming of Post-Industrial Society*. New York: Basic Books.
6. Bluestone, B., Harrison, B. (1982). *The deindustrialization of America*. New York: Basic Books.
7. Bristow, G. (2010). *Critical Reflections on Regional Competitiveness*. London: Routledge.

8. Bryson, J.M., Taylor, M. (2008). Commercializing "creative" expertise: business and professional services and region economic development in the west Midlands, United Kingdom. *Politics and Policy, Vol. 36, No. 2*.
9. Cairncross, A. (1982). What is deindustrialisation? In: F. Blackaby, *Deindustrialisation* (pp. 5-17). London: National Institute of Economic and Social Research, Economic Policy Papers, Heinemann Educational Books.
10. Chojnicki, Z., Czyż, T. (2006). *Aspekty regionalne gospodarki opartej na wiedzy w Polsce*. Poznań: Bogucki Wydawnictwo Naukowe.
11. Chojnicki, Z. (1996). Region w ujęciu geograficzno-systemowym. In: T. Czyż, *Podstawy regionalizacji geograficznej* (pp. 7-43). Poznań.
12. Chojnicki, Z., Czyż T. (1992). Region, regionalizacja, regionalizm. *Ruch Prawniczy, Ekonomiczny I Socjologiczny, Vol. 54, No. 2,* pp. 1-18.
13. Crafts, N. (1996). Deindustrialisation and Economic Growth. *The Economic Journal, Vol. 106, No. 434,* pp. 172-183.
14. Czyż, T. (2016). Metoda wskaźnikowa w geografii społeczno-ekonomicznej. *Rozwój Regionalny i Polityka Regionalna, Vol. 34,* pp. 9-19.
15. Dasgupta, S., Singh, A. (2009). *Manufacturing, Services and Premature Deindustrialization in Developing Countries: A Kaldorian Analysis*. World Institute for Development Economic Research (UNU-WIDER), Working Paper Series RP2006/49.
16. Dziewoński, K. (1967). Teoria regionu ekonomicznego. *Przegląd Geograficzny, Vol. 39, No. 1,* pp. 33-50.
17. Florence, P.S. (1929). *The statistical method in economics*. London: Kegal Paul.
18. Gorzelak, G., Smętkowski, M. (2010). Regional Development Dynamics in Central and Eastern European Countries. In: G. Gorzelak J. Bachtler, M. Smętkowski, *Regional Development in Central and Eastern Europe Development processes and policy challenges.* Oxon/New York: Routledge.
19. Grzybowska, B. (2013). Przestrzenna koncentracja potencjału innowacyjnego w przemyśle spożywczym. *Roczniki Naukowe Ekonomii Rolnictwa i Rozwoju Obszarów Wiejskich, Vol. 100, No. 2,* pp. 53-64.
20. *GUS – Bank Danych Lokalnych*. Available online: https://bdl.stat.gov.pl/BDL/start, 15.10.2023.
21. Jaworska, M., Skowrońska, A. (2001). *Zmiany strukturalne w przemyśle polskim w okresie transformacji systemowej*. Wrocław: Wydawnictwo AE we Wrocławiu.
22. Karpiński, A. (1986). *Restrukturyzacja gospodarki w Polsce i na świecie*. Warszawa: PWE.
23. Kempny, D. (1991). *Konwersja strukturalna w przemyśle*. Katowice: AE w Katowicach.
24. Klamut, M. (1996). *Ewolucja struktury gospodarczej w krajach wysoko rozwiniętych*. Wrocław: Wydawnictwo AE we Wrocławiu.
25. Kuznets, S. (1955). Economic growth and economic inequality. *American Economic Review, Vol. 45, No. 1,* pp. 1-28.

26. Łaźniewska, E., Górecki, T., Chmielewski, R. (2011). *Konwergencja regionalna*. Poznań: Wydawnictwo Uniwersytety Ekonomicznego w Poznaniu.
27. Lever, W.F. (1991). Deindustrialisation and the Reality of the Postindustrial City. *Urban Studies, Vol. 28, No. 6,* pp. 983-999.
28. Lovering, J. (1999). Theory Led by Policy. In: *The Inadequacies of the 'New Regionalism'* (Illustrated from the Case of Wales).
29. Mądry, C.M., Kuzyshyn, A. (2022). Spacial differentiation of the social sphere: benchmarks of the postwar reconstruction of Ukraine. *Czasopismo Geograficzne, Vol. 93,* pp. 523-560. https://doi.org/10.12657/czageo-93-21
30. Malaga, K. (2004*). Konwergencja gospodarcza w krajach OECD w świetle zagregowanych modeli wzrostu.* Poznań: Akademia Ekonomiczna w Poznaniu.
31. Malina, A. (2020). Analiza przestrzennego zróżnicowania poziomu społeczno-gospodarczego województw Polski w latach 2005-2017. *Nierówności społeczne a Wzrost Gospodarczy, Vol. 61, No. 1,* pp. 138-155.
32. Micek, G., Pietrzko, M., Fiedeń, Ł. (2022). Czasowo-przestrzenna ewolucja i czynniki kształtujące rozmieszczenie przemysłu wysokiej techniki w polskich gminach. *Prace Geograficzne, Vol. 167,* pp. 91-117. https://doi.org/10.4467/20833113PG.22.009.16222
33. Myrdal, G. (1957). *Economic theory and under-developed regions*. London: Gerald Duckworth & Co.
34. Naisbitt, J. (1997). *Megatrendy. Dziesięć nowych kierunków zmieniających nasze życie*. Poznań: Zysk i S-ka.
35. Petrakos, G., Saratis, Y. (2000). Regional inequalities in Greece. *Paper in Regional Science, Vol. 79,* pp. 57-74.
36. Rostow, W.W. (1971). *The Stages of Economic Growth*. Cambridge: University Pres.
37. Rowthorn, R., Coutts, K. (2004). De-industrialization and the balance of payments in advanced economies. *Cambridge Journal of Economics, Vol. 28. No. 5,* 767-790.
38. Rowthorn, R., Ramaswamy, R. (1997). Deindustrialization: Causes and Implications. *IMF Working Paper.* Available on: https://www.imf.org/ external/pubs/ft/wp/wp9742.pdf
39. Rowthorn, R., Wells, J.R. (1987). *De-industrialisation and Foreign Trade*. Cambridge: Cambridge University Press. University of Marburg Working Paper.
40. Schwab, K. (2018). *Czwarta rewolucja przemysłowa*. Warszawa: Studio Emka
41. Singh, A. (1977). UK Industry and the World Economy: A Case of Deindustrialization? *Cambridge Journal of Economics, Vol. 1, No. 2,* pp. 113-36.
42. Smętkowski, M. (2015). Zróżnicowanie i dynamika rozwoju regionów Europy Środkowo-Wschodniej. *Prace Komisji Geografii Przemysłu Polskiego Towarzystwa Geograficznego, Vol. 29, No. 2,* pp. 37-52.
43. Storper, M. (1997). *The regional world: Territorial development in a global economy*. New York: Guilford Press.

44. Sutcliffe, R.B. (1971). *Industry and Underdevelopment*. Boston: Addison Wesley Longman.
45. Swadźba, S. (1994). *Zmiany w strukturze gospodarczej Wspólnoty Europejskiej*. Katowice: AE w Katowicach.
46. Toffler, A. (2003). *Zmiana władzy. Wiedza, bogactwo i przemoc u progu XXI stulecia*. Poznań: Zysk i S-ka.
47. *Traktat o funkcjonowaniu Unii Europejskiej* (2012). Available online: https://eur-lex.europa.eu/legal-content/PL/TXT/PDF/?uri=CELEX:12012E/TXT,DziennikUrzędowyUniiEuropejskiej
48. Valaskakis, K. (2010). The case for global governance. *Technological Forecasting and Social Change, Vol. 77, No. 9,* pp. 1595-1598.
49. Whittlesey, D. (1954). A critique for critique. *The Professional Geographer, Vol. 6, No. 4,* pp. 3-4, DOI: 10.1111/j.0033-0124.1954.064_3.x.
50. Williamson, J.G. (1965). Regional inequalities and the process of national development. *Economic Development and Cultural Change, Vol. 13, No. 4, part 2.*

Appendix

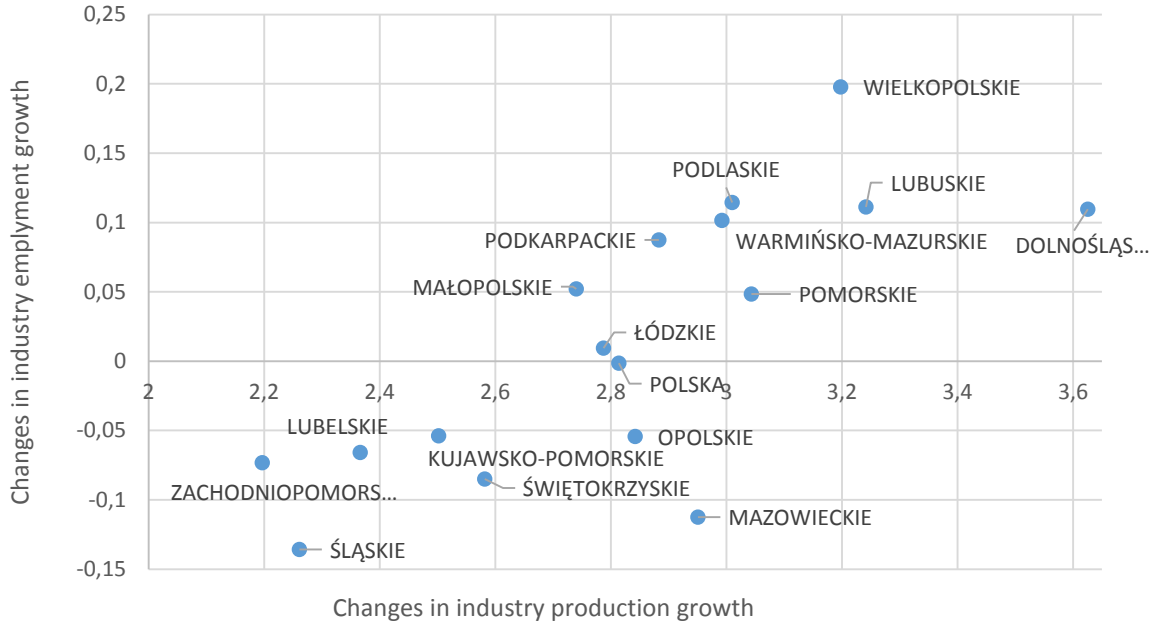

Figure 1. Changes in industry production and employment growth in 2000-2021.

Source: Own elaboration.

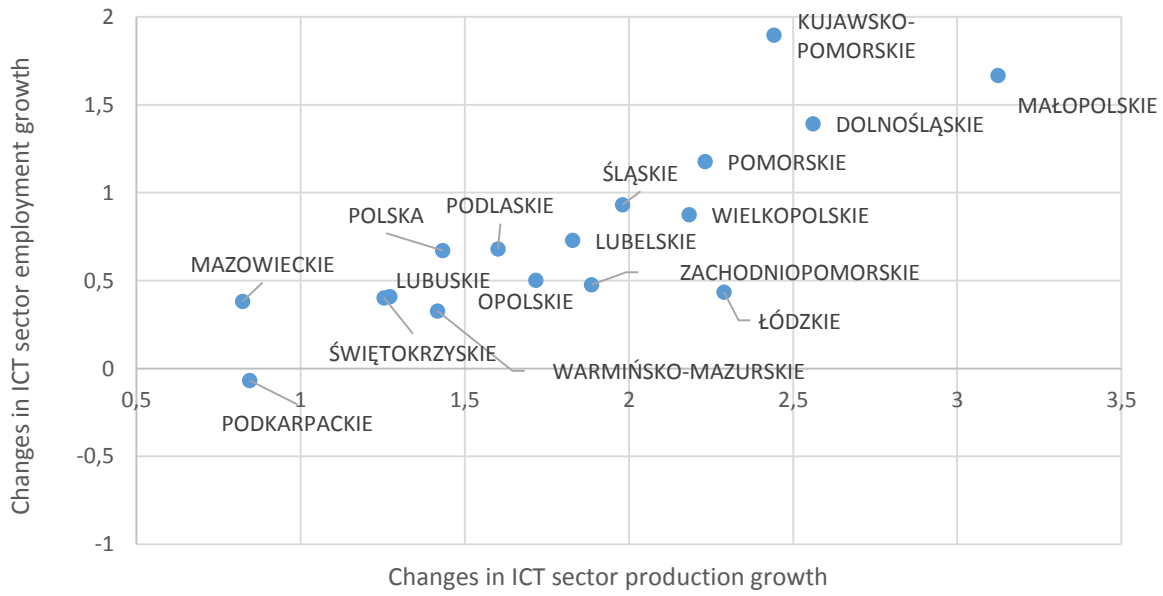

Figure 2. Changes in production and employment of ICT sector in 2000-2021.

Source: Own elaboration.

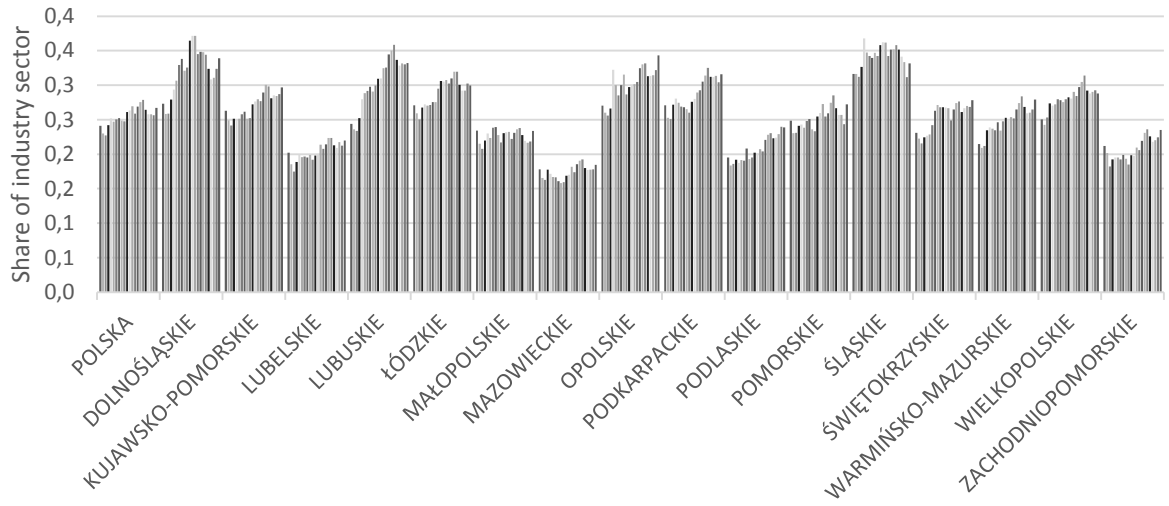

Figure 3. Changes in share of industry sector in value added in 2000-2021.

Source: Own elaboration.

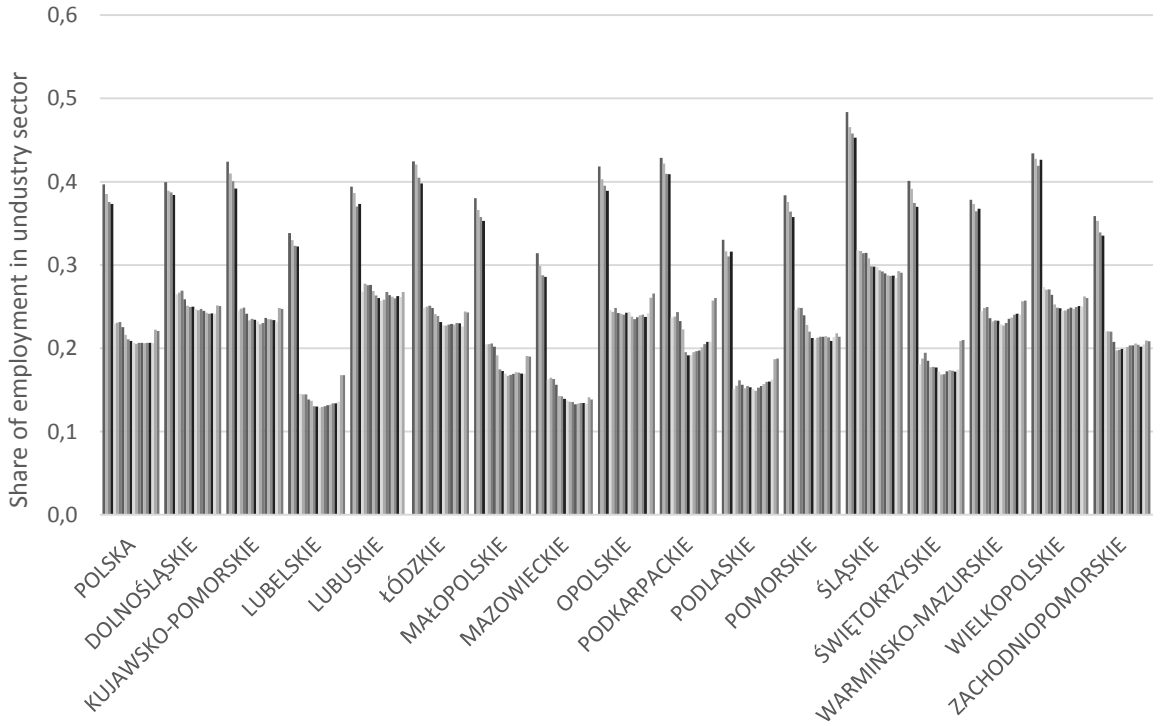

Figure 4. Changes in share of employment in industry sector in total employment in 2000-2021.

Source: Own elaboration.

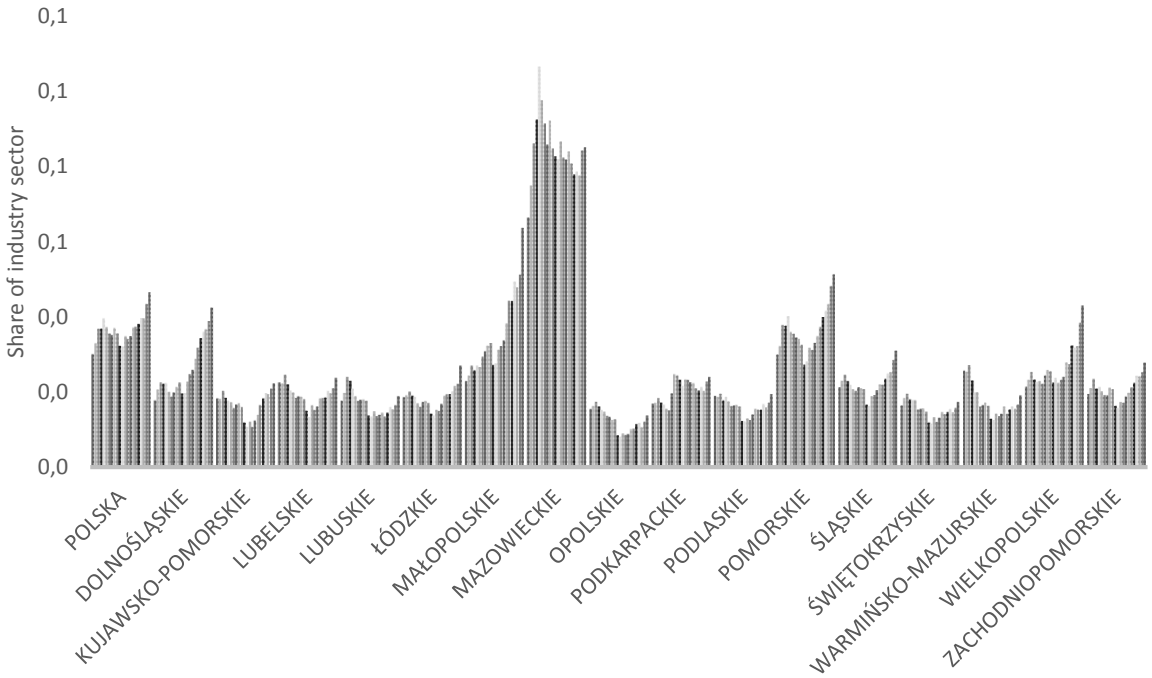

Figure 5. Changes in share of ICT sector in value added in 2000-2021.

Source: Own elaboration.

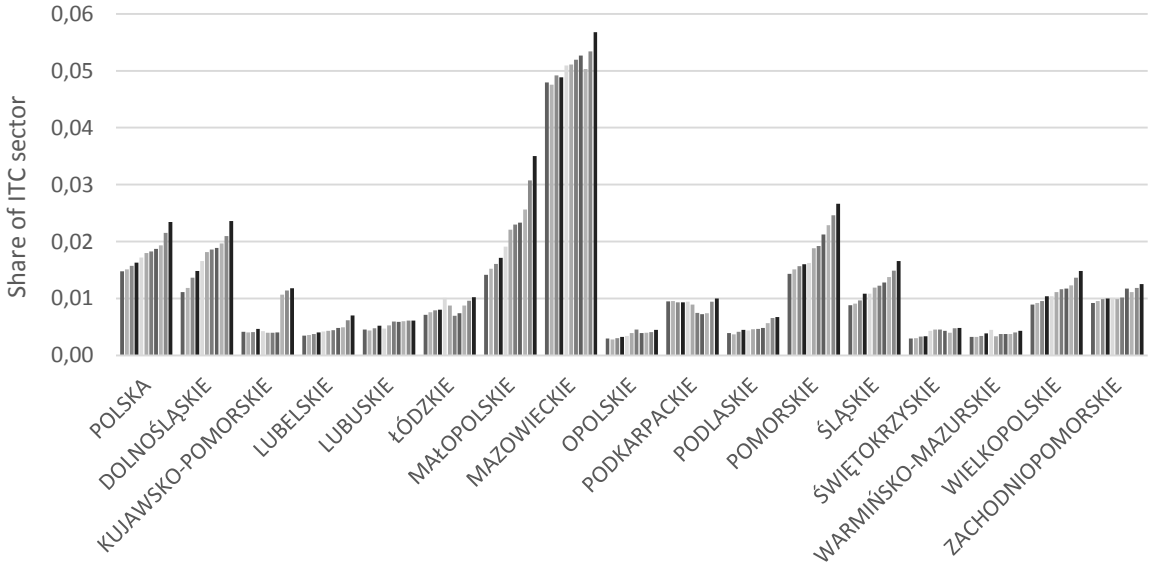

Figure 6. Changes in share of employment in ICT sector in total employment in 2011-2021.

Source: Own elaboration.

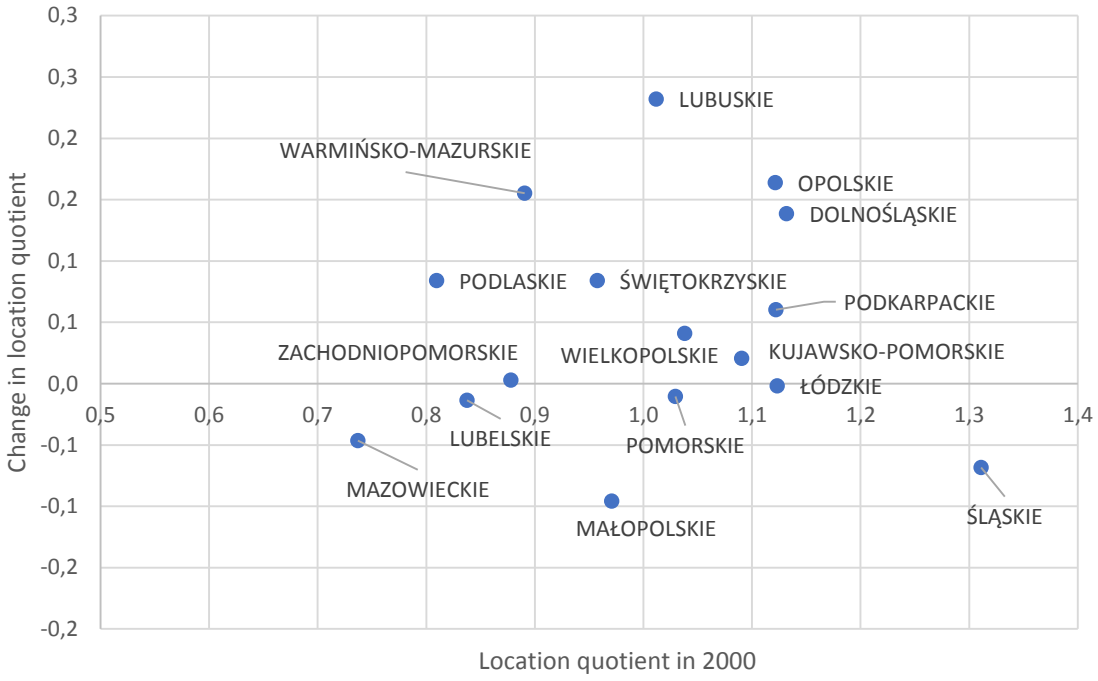

Figure 7. Location quotient in 2000 and its change between 2000- 2021 for industry sector production.

Source: Own elaboration.

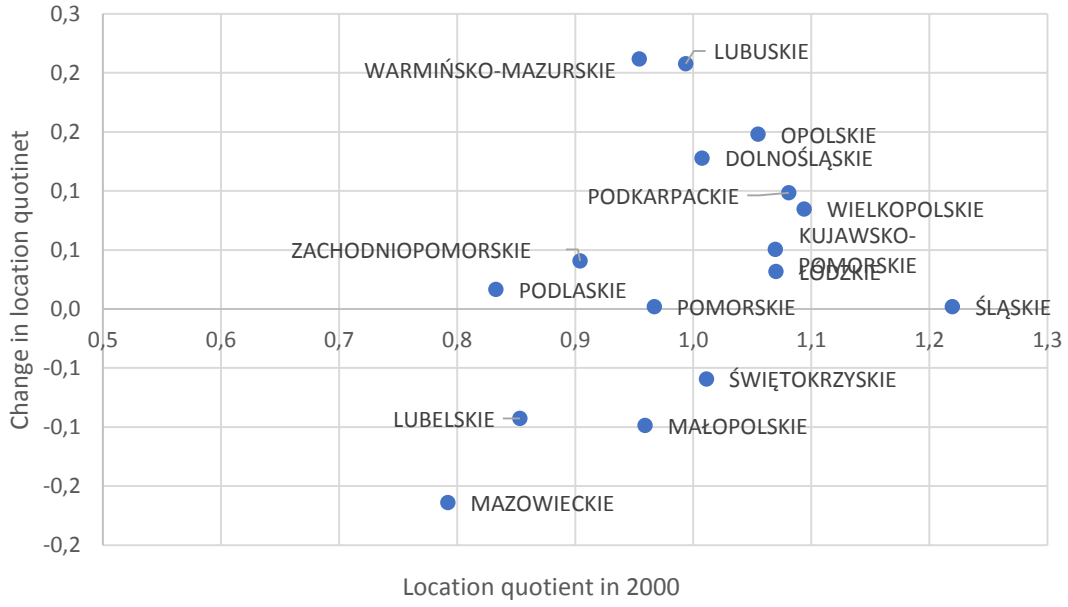

Figure 8. Location quotient in 2000 and its change between 2000- 2021 for employment in industry sector.

Source: Own elaboration.

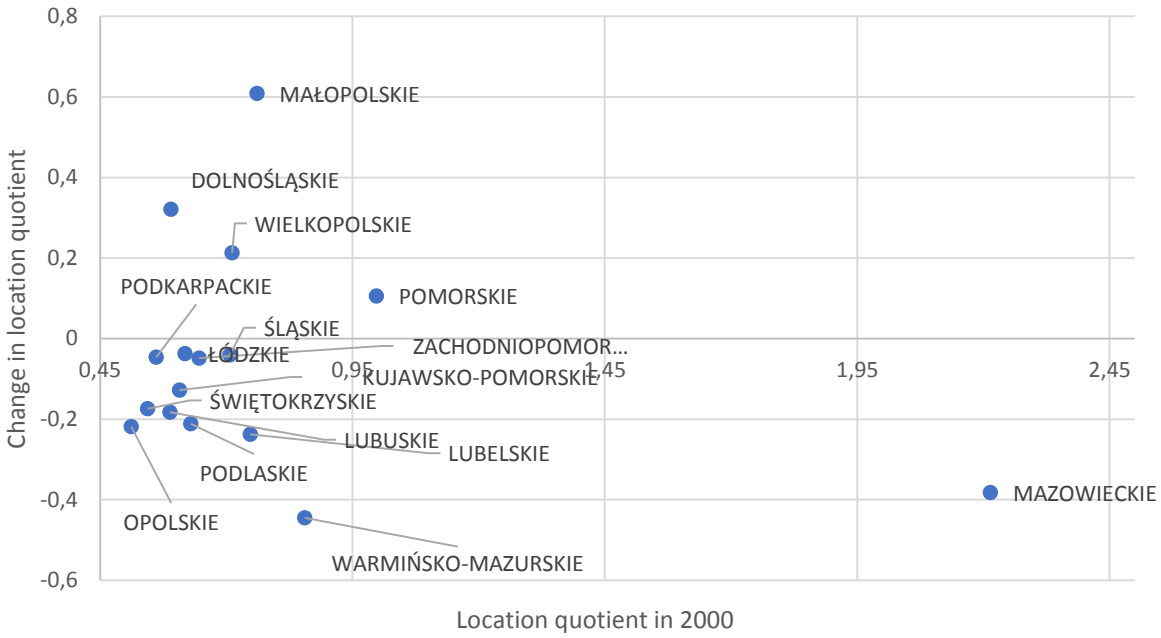

Figure 9. Location quotient in 2000 and its change between 2000- 2021 in production of ICT sector. Source: Own elaboration.

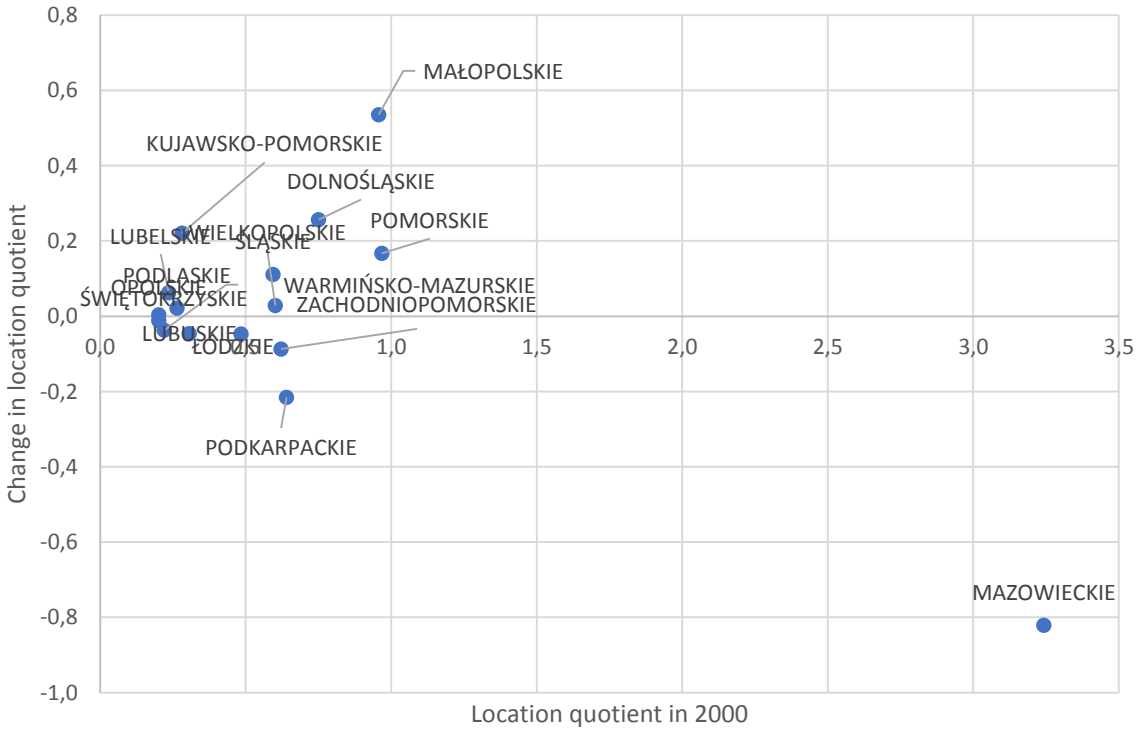

Figure 10. Location quotient in 2000 and its change between 2000- 2021 in production of ICT sector. Source: Own elaboration.

Table 1.
Classification of regions in Poland in terms of industrialization intensity in 2021

		Location quotient of employment in industry				
		> 1.5	1.0-1.5	0.5-1.0	0.25-0.5	< 0.25
Location quotient of industry production	> 1,5					
	1.0-1.5		Dolnośląskie Kujawsko-Pomorskie Lubuskie Łódzkie Opolskie Podkarpackie Śląskie Warmińsko-Mazurskie Wielkopolskie	Pomorskie Świętokrzyskie		
	0.5-1.0			Lubelskie Małopolskie Mazowieckie Podlaskie Zachodniopomorskie		
	0.25-0.5					
	< 0.25					

Source: Own elaboration.

Table 2.
Classification of regions in Poland in terms of industrialization intensity in ICT sector 2021

		Location quotient of employment in ITC industry				
		> 1.5	1.0-1.5	0.5-1.0	0.25-0.5	< 0.25
Location quotient of ITC production	> 1,5	Mazowieckie				
	1.0-1.5		Małopolskie Pomorskie			
	0.5-1.0		Dolnośląskie	Podkarpackie Śląskie Wielkopolskie Zachodniopomorskie	Lubelskie Łódzkie	Warmińsko-Mazurskie
	0.25-0.5			Kujawsko-Pomorskie	Lubuskie Podlaskie	Opolskie Świętokrzyskie
	< 0.25					

Source: Own elaboration.

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TOTAL COST OF OWNERSHIP OF FUEL CELL (FCEV) AND ELECTRIC (EV) BUSES IN DELIVERY OF PUBLIC TRANSPORTATION SERVICES ON THE EXAMPLE OF UPPER-SILESIAN AND ZAGLEBIE METROPOLIS

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Purpose: The purpose of the article is to determine and compare Total Cost of Ownership (TCO) metrics of buses operating in public transportation system depending on their powertrain. TCO is widely used method supporting decision making in purchases, taking into account all operational and extraordinary costs of delivery, operations, maintenance and liquidation of an asset in its lifecycle. It will provide answer to the question of sustainability of the business in the time horizon reflecting economic life on an asset, in this case – the vehicle.
Design/methodology/approach: Main methods used in the paper are critical literature review concerning TCO models and its application for rolling stock, case study research conducted in the Upper Silesian and Zagłębie Metropolis aimed at collection of financial data. Gathered figures were used to develop comparative calculations of TCO for electric (EV) and fuel cell (FCEV) buses.
Findings: In course of the research and analyses it was confirmed that the Total Cost of Ownership of the EV is significantly lower, comparing to FCEV, and only political decisions and significant public support of investments in FCEV buses may equalize TCO values for both types of powertrain. Sensitivity of TCO calculated against fuel and electricity prices is very low, and such depreciation of hydrogen fuel is very unlikely to take place.
Research limitations/implications: Data gathered for EVs are real life, as carriers have long term experience in their use, whereas the data for FCEVs comes primarily from test drives and road tests carried out by the suppliers and carriers.
Practical implications: Development of hydrogen technology still requires massive public financial support, otherwise the costs of bus operations with this type of powertrain is uncompetitive comparing to battery (EV) powertrain. Decarbonisation of the economy is then highly dependent on political priorities, since the businesses may not demonstrate sufficient interest in participation in this process, primarily due to higher costs and lack of attractive incentives.
Originality/value: Originality of this approach results from rather infrequent use of this method, comparing to other, i.e. NPV. Use of TCO may facilitate decision making process as it does not require differential approach, comparing to NPV, however, for comparing different possible choices, such comparison of values may be also applied.

Keywords: total cost of ownership, economic performance, public transportation, FCEV, EV.
Category of the paper: conceptual paper, case study.

1. Introduction

Delivery of high quality public services meeting the standards of smart and resilient cities requires outlay of funds, the source of which is primarily local or metropolitan government's budget. However, growing costs of rendering services meeting the preferences of their users, requires higher spending. Upper Silesian and Zagłębie Metropolis is a sound example of the public organization and territorial unit, whose annual spending on public transportation services exceeds 1 billion złoty, which is the equivalent of roughly 200 millions Euros (MFF, 2023). Income sources of the Metropolis are insufficient to cover these costs, so it is necessary to move some part of the on the users of public transport. The system is built on three pillars: users, the Metropolis and operators of public transport (carriers). It is the Metropolis' legal obligation to deliver the services uninterruptedly, with the use of operators possessing buses, tramways and trolleybuses. According to the EU level regulations (Regulation 1370/2007), operators are entitled to have covered all the operating costs of delivery of transportation services, excluding extraordinary revenues, so that their net profit does not exceed the level of so called reasonable profit, calculated as a fair rate of return on equity capital multiplied by the value of equity capital for given year. In case of reporting loss on transportation services, the operators are entitled to receive additional compensation of the value making it possible to reach reasonable net profit. In the opposite situation, operators are obliged to return excessive revenues to the Metropolis, so that their net profit is reasonable.

In order to predict the operating costs, generate different scenarios of revenues from public transportation services, taken into account the investment outlay on rolling stock or other necessary assets, it is needed to develop a method facilitating the aforementioned. Widely used discounted cash-flow methods (DCF) has a significant deficit. It always requires differential approach, comparing different investment options, resulting in different choices. The authors of the paper propose to use total cost of ownership approach (TCO) closely related to life-cycle costing. TCO uses similar positions of the financial forecasts, but may refer to single investment option. Its application enables decision makers to calculate all costs and investment outlay (incl. replacement expenditures), assign them to proper periods, depending on time horizon of calculations, as well as determine potential deficit or surplus generated by delivery of transportation services. This type of financial information will stabilize decisions of both operators and the Metropolis, as well as facilitate and support creation of fair tariff policy, which is one of the most sensitive factors, considered the passengers, final consumers of the services. In order to keep abreast to the latest technologies, more and more operators decide to

replace their vehicles with direct ignition powertrain with electric ones or hydrogen-powered fuel-cell electric vehicles. The question of ability to generate reasonable profit by them, however, still remains unanswered. Similar dilemmas touch the financing of the whole system. Undoubtedly, it is necessary to determine future requirements of public co-financing of the services, as well as future tariffs, since the costs of use of public transportation must reflect its quality and must be competitive, comparing to private means of transport, mainly cars, the growing number of which deteriorates the condition of the environment and contributes to growth of traffic congestion.

2. Total Cost of Ownership concept – literature review

Total cost of ownership (TCO) is one of the methods of evaluating investments (Palmer, 2018; Rusich, 2015; Hurkens et al., 2006; Vora et al., 2017). This method takes into account not only the purchase, but also all other costs of maintaining and using a given resource. (Originally, the method was used to estimate the costs of purchasing and maintaining IT systems, but is currently used in the assessment of investments in various types of fixed assets (e.g. devices, machines) and services. The method has been used since 1990 and has gained recognition around the world (Korpi, Ala-Risku, 2008) due to its main advantages:

- indicates a precise result, which provides justification for the decision,
- covers the entire life cycle of a product or service,
- builds awareness of the costs of purchasing and using a given fixed asset,
- enables the presentation of results in an aggregated and individual manner.

The TCO method assumes taking into account all costs throughout the entire life cycle or the assumed analysis horizon. As a consequence, a person making a decision to purchase a product or service can compare values between variants. The main cost drivers include: operational cost, quality, logistics, technological advantage, supplier reliability and capability, maintenance, inventory cost, transaction cost, life cycle, initial price, customer-related, opportunity cost (Ferrin, Plank, 2002). The entity making the purchasing decision should determine which costs it considers to be the most important or significant in the process of acquiring, owning, using and subsequently selling a product or service (Ellram, 1995). Estimating so many values allows you to build awareness of the level of costs, but also to indicate potential areas for cost reduction. The wide range of variables included in the TCO model can also be seen as a disadvantage of this method. Forecasting the value of many variables over a period of, for example, several years increases the risk of making an estimation error. The limitations of using this method include the need to update calculations, especially during an extended decision-making process or variant investment implementation, due to changes in, among others, macroeconomic indicators, interest rates, exchange rates, etc.

The TCO method has been successfully applied to vehicle purchase decisions. Analyzes of vehicle maintenance costs are becoming more and more important due to the dynamic development of alternative drives. The subject of research is both passenger vehicles (Al-Alawi, Bradley, 2013) and public transport (Szumska, Pawełczyk, Jurecki, 2022). In recent years, many studies have been published on the comparison of TCO for vehicles with different drives. However, these results are most often regional in nature due to specific conditions (Falcao et al., 2017), e.g. technologies used (battery capacity), availability of charging/refueling infrastructure (limitations, e.g. in hydrogen refueling infrastructure and the availability of the power grid), the possibility of obtaining subsidies from public funds for the purchase of vehicles (Szulc, Krawczyk, Tchórzewski, 2021), and even cultural conditions (fear of change, education and training of employees) (Hurkens et al., 2006). The implementation of innovative drives causes many cost components to differ significantly, e.g. purchase costs, conditions related to refueling/charging infrastructure, unit cost of energy/fuel. There are also different forecasts regarding the costs of individual energy carriers, which is influenced by global policies aimed at, among others, to move away from fossil fuels (Palmer et al., 2018).

Due to its comprehensive approach to costs, the TCO method should be used more often in the public sector. The use of TCO may be one of the criteria for evaluating offers in tender procedures, including for the purchase of buses or public transport services (Jagiełło, Wołek, Bizon, 2023).

The most comprehensive identification of cost drivers which may be applied for TCO calculations are provided by Ferrin and Planck.

They proposed the following groups of costs:

- operations costs,
- quality costs,
- logistics costs,
- costs of technological advantage,
- maintenance costs,
- inventory costs,
- customer-related costs,
- life cycle costs,
- miscellaneous costs (Ferrin, Planck, 2002).

Topal and Nakir proposed a comprehensive approach of Zero-Emissions Bus Purchase and Operation Model provided in the figure (Figure 1.)

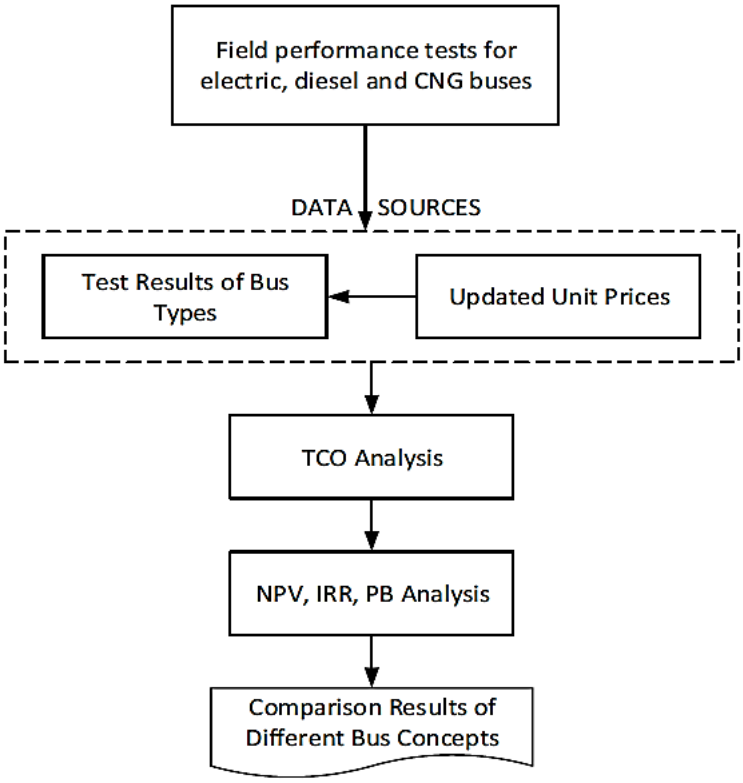

Figure 1. Zero Emissions Bus Purchase and Operation Model flowchart.

Source: Topal, Nakir, 2018, p. 4.

TCO analysis is performed in the third stage of the proposed model. The proposed TCO method takes into account the bus purchases and operational investment costs depends on the variables of transportation operators. The cost components considered in this model are the following:

Maintenance and Operating costs

- Preventive maintenance costs,
- Vehicle body cost,
- Engine renewal costs,
- Damage & repair payments costs,
- Material cost,
- Cost of emergency response team,
- General administrative management costs,
- Depot's energy costs (electricity, water, natural gas for heating),
- Traffic insurance and vehicle inspection expenses costs,
- Taxes.

Fuels

It should be underlined that no personnel related costs are included in this model. However direct and indirect labour costs are explicitly listed by Ferrin and Planck.

The authors of the paper decided to use the most universal approach to calculate respective TCOs, using the following formula:

$$TCO = I_0 + \sum_{t=0}^{n} \frac{POC + PRC}{(1 + r_d)^n} \quad (1)$$

where:

POC – period operating costs,

PRC – period replacement costs (where applicable),

I_0 – initial investment outlay,

r_d – discounting rate.

3. Total Cost of Ownership of EV and FCEV buses – case study

Calculations of TCO for both investment options are based on average operating costs reported by the public transportation operators (carriers) commissioned by Upper Silesian and Zagłębie Metropolis. All of them are presented as unit costs referred to kilometer of operational work. Detailed analytics is provided in the (Table 1). To reflect their forecasted annual change, there was applied the nominal growth rate published by the Ministry of Finance in October 2023 (Guidelines, 2023). Operational costs were divided into 3 groups: EV specific, FCEV specific and common for both types of powertrain, including costs of functioning of the depot.

Table 1.
Unit operating costs in current prices

Analytics of operating costs per km (current prices)	**Unit**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Growth rate of costs on non-consumer markets	%		12,00	6,60	4,10	3,10	2,50	2,50	2,50	2,50	2,50
EV											
External services and outsourcing	PLN/ km	0,960	1,075	1,146	1,193	1,230	1,261	1,292	1,325	1,358	1,392
Taxes and fees	PLN/ km	0,090	0,101	0,107	0,112	0,115	0,118	0,121	0,124	0,127	0,130
Wages (incl. costs management and administrative cost)	PLN/ km	2,577	2,886	3,077	3,203	3,302	3,385	3,469	3,556	3,645	3,736
Social security and other HR costs	PLN/ km	0,634	0,710	0,757	0,788	0,813	0,833	0,854	0,875	0,897	0,920
Other costs	PLN/ km	0,146	0,164	0,174	0,182	0,187	0,192	0,197	0,202	0,207	0,212
FCEV											
External services and outsourcing	PLN/ km	0,860	0,963	1,027	1,069	1,102	1,130	1,158	1,187	1,216	1,247
Taxes and fees	PLN/ km	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Wages (incl. costs management and administrative cost)	PLN/ km	2,577	2,886	3,077	3,203	3,302	3,385	3,469	3,556	3,645	3,736
Social security and other HR costs	PLN/ km	0,634	0,710	0,757	0,788	0,813	0,833	0,854	0,875	0,897	0,920

Cont. table 1.

Other costs	PLN/ km	0,200	0,224	0,239	0,249	0,256	0,263	0,269	0,276	0,283	0,290
Depot costs of materials, additional fuels and energy											
Oils and lubricants	PLN/ km	0,018	0,020	0,021	0,022	0,023	0,023	0,024	0,025	0,025	0,026
Depot energy costs	PLN/ km	0,014	0,015	0,016	0,017	0,017	0,018	0,018	0,019	0,019	0,020
Other use of materials and energy	PLN/ km	0,359	0,402	0,429	0,446	0,460	0,471	0,483	0,495	0,508	0,520
Natural gas (heating)	PLN/ km	0,018	0,020	0,021	0,022	0,023	0,023	0,024	0,025	0,025	0,026
Tyres	PLN/ km	0,025	0,028	0,030	0,031	0,032	0,033	0,033	0,034	0,035	0,036
Water and wastewater	PLN/ km	0,004	0,004	0,005	0,005	0,005	0,005	0,005	0,005	0,005	0,005

Source: own elaboration based on financial reports and forecasts provided by the carriers.

In order to compare periodically the aforementioned values and finally aggregate them to calculate the ultimate value of TCO, it is necessary to determine the interest rate which will be used to find the present values of respective items as for year 2023. According to the rules of financial engineering, definition of the discount rate is the duty of the owners of capital engaged in the business. To determine the overall rate covering both equity capital and liabilities, excluding non-interest bearing current liabilities, weighted average cost of capital is used. Since the operators deliver public service, the authors of the paper decided to choose the minimum acceptable rate of return, which bears no risk. For the EU market it is the rate of return of German national bonds and for year 2023 it is 2,6% (Eurostat). Operating unit costs in constant prices are presented in the table (Table 2).

Table 2.
Unit operating costs in constant prices

Analytics of operating costs per km (constant prices)	**Unit**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
EV											
External services and outsourcing	PLN/ km	0,960	1,048	1,089	1,105	1,110	1,109	1,108	1,107	1,106	1,105
Taxes and fees	PLN/ km	0,090	0,098	0,102	0,104	0,104	0,104	0,104	0,104	0,104	0,104
Wages (incl. costs management and administrative cost)	PLN/ km	2,577	2,813	2,923	2,965	2,980	2,977	2,974	2,971	2,968	2,965
Social security and other HR costs	PLN/ km	0,634	0,692	0,719	0,730	0,734	0,733	0,732	0,731	0,731	0,730
Other costs	PLN/ km	0,146	0,159	0,166	0,168	0,169	0,169	0,169	0,168	0,168	0,168
FCEV											
External services and outsourcing	PLN/ km	0,860	0,939	0,975	0,990	0,994	0,994	0,993	0,992	0,991	0,990
Taxes and fees	PLN/ km	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000	0,000
Wages (incl. costs management and administrative cost)	PLN/ km	2,577	2,813	2,923	2,965	2,980	2,977	2,974	2,971	2,968	2,965
Social security and other HR costs	PLN/ km	0,634	0,692	0,719	0,730	0,734	0,733	0,732	0,731	0,731	0,730
Other costs	PLN/ km	0,200	0,218	0,227	0,230	0,231	0,231	0,231	0,231	0,230	0,230

Cont. table 2.

Depot costs of materials, additional fuels and energy											
Oils and lubricants	PLN/ km	0,018	0,019	0,020	0,020	0,021	0,021	0,020	0,020	0,020	0,020
Depot energy costs	PLN/ km	0,014	0,015	0,015	0,016	0,016	0,016	0,016	0,016	0,016	0,016
Other use of materials and energy	PLN/ km	0,359	0,392	0,407	0,413	0,415	0,415	0,414	0,414	0,413	0,413
Natural gas (heating)	PLN/ km	0,018	0,020	0,020	0,021	0,021	0,021	0,021	0,021	0,021	0,021
Tyres	PLN/ km	0,025	0,027	0,028	0,029	0,029	0,029	0,029	0,029	0,029	0,029
Water and wastewater	PLN/ km	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004	0,004

Source: own elaboration.

One of the most important factors affecting TCO is consumption and cost of energy. According to the experience of the carriers, average consumption of energy for EV buses equals 120 kWh per 100 kilometers. Deviations are minor and depend basically on the shape of terrain and weather conditions of operations. For FCEV buses, according to significantly shorter experience and test drives provided by their suppliers, average consumption of hydrogen equals 6 kg per 100 kilometers. It may be observed that net energy demand for FCEVs is significantly higher as the energy density for hydrogen is ca. 33kWh/kg. In order to compare the costs of consumption it was calculated that typical vehicle's annual operational work in the transportation network of the Metropolis is about 75 000 km.

Considering the costs of hydrogen fuel and electricity, there was provided a forecast of their future costs in current and constant prices. Initial values of prices of 1kg of H_2 and electricity were provided by the carriers. These are the real prices offered by the suppliers of these media in 2023 and are subject to indexation by the nominal average growth rate of costs on non-consumer markets. The forecast is provided in the table below (Table 3).

Table 3.
Forecast of prices of electricity and hydrogen

Fuels and Energy (current prices)	**Unit**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
Hydrogen	PLN/kg	51,600	57,792	61,606	64,132	66,120	67,773	69,468	71,204	72,984	74,809
Electricity	PLN/kWh	0,750	0,840	0,895	0,932	0,961	0,985	1,010	1,035	1,061	1,087

Source: own elaboration.

Given the aforementioned data, annual cost of consumption of direct fuels and electricity in current and constant prices was provided in the table (Table 4).

Table 4.
Forecast of annual cost of hydrogen fuel and electricity in current and constant prices

Cost	**Unit**	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**	**2032**
(current prices)											
Hydrogen	PLN	309 600	346 752	369 638	384 793	396 721	406 639	416 805	427 226	437 906	448 854
Electricity	PLN	67 500	75 600	80 590	83 894	86 494	88 657	90 873	93 145	95 474	97 861
(constant prices)											
Hydrogen	PLN	309600	337965	351141	356275	358011	357662	357313	356965	356617	356270
Electricity	PLN	67500	73684	76557	77676	78055	77979	77903	77827	77751	77675

Source: own elaboration.

One of the factors affecting the ultimate value of TCO is the investment outlay, as it takes place mainly in the first periods of analysis. In this case it takes place in the first year. As it was reported by the operators who completed their tender procedures for deliveries of both types of vehicles, the prices of EV bus equals roughly 2 250 000 PLN net, and FCEV bus appropriately 3 750 000 PLN net. According to the experience in operating EVs, after 7 years of exploitation it is required to modernize the bus by replacing the battery due to loss of capacity and decline of its range without additional intra-day charging. Average cost of modernization stands for 40% of the value of a new vehicle. This fact was covered in the study and the value of this modernization in current and constant price was included in the calculations.

One of the components of TCO approach is depreciation reflecting moral wear of assets. According to the accounting law, depreciation rate that must be applied to commercial vehicles incl. buses and coaches equals 10%. In the presented case for given time horizon the assets do not get fully depreciated, so for the last year of analysis there must be taken into account their residual value which is the net present value of non-depreciated part of the assets for last year of analysis. Residual value must be included in TCO calculations as a benefit, so it must be deducted from all identified costs. Depreciation, residual value in current and constant prices are provided in the table (Table 5).

Table 5.
Forecast of depreciation and residual value in current and constant prices

Item	Unit	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032
(current prices)											
D(EV)	PLN	0	225000	225000	225000	225000	225000	225000	225000	225000	225000
D(FCEV)	PLN	0	375000	375000	375000	375000	375000	375000	375000	375000	375000
RV(EV)	PLN										219298,25
RV(FCEV)	PLN										365497,08
(constant prices)											
D(EV)	PLN	0	219298,25	213740,98	208324,54	203045,36	197899,96	192884,95	187997,03	183232,97	178589,64
D(FCEV)	PLN	0	365497,08	356234,97	347207,57	338408,94	329833,27	321474,92	313328,39	305388,29	297649,41
RV(EV)	PLN										174063,98
RV(FCEV)	PLN										290106,63

Source: own elaboration.

Having analyzed all the costs it was determined that:

- Present value (PV) of all operational costs incl. battery retrofitting for EVs, adjusted by residual value equals: 7 211 078,02 PLN net,
- Present value (PV) of all operational costs for FCEVs, adjusted by residual value equals: 10 172 013,73 PLN net.

The last element of the TCO calculation is inclusion in the calculations of the respective investment outlays.

The ultimate values of TCO for respective options are the following:

- TCO(EV) = 9 461 078,02 PLN net,
- TCO(FCEV) = 13 922 013,63 PLN net.

TCO per kilometer referred to respective years of analysis are presented in the graph (Figure 1). The first year of analysis was intentionally skipped, for the values include the investment outlay. It distorts the meaning of the numbers provided below. In the penultimate year of analysis there is a peak for EVs. It is the result of retrofitting of new batteries, which does not take place for FCEVs.

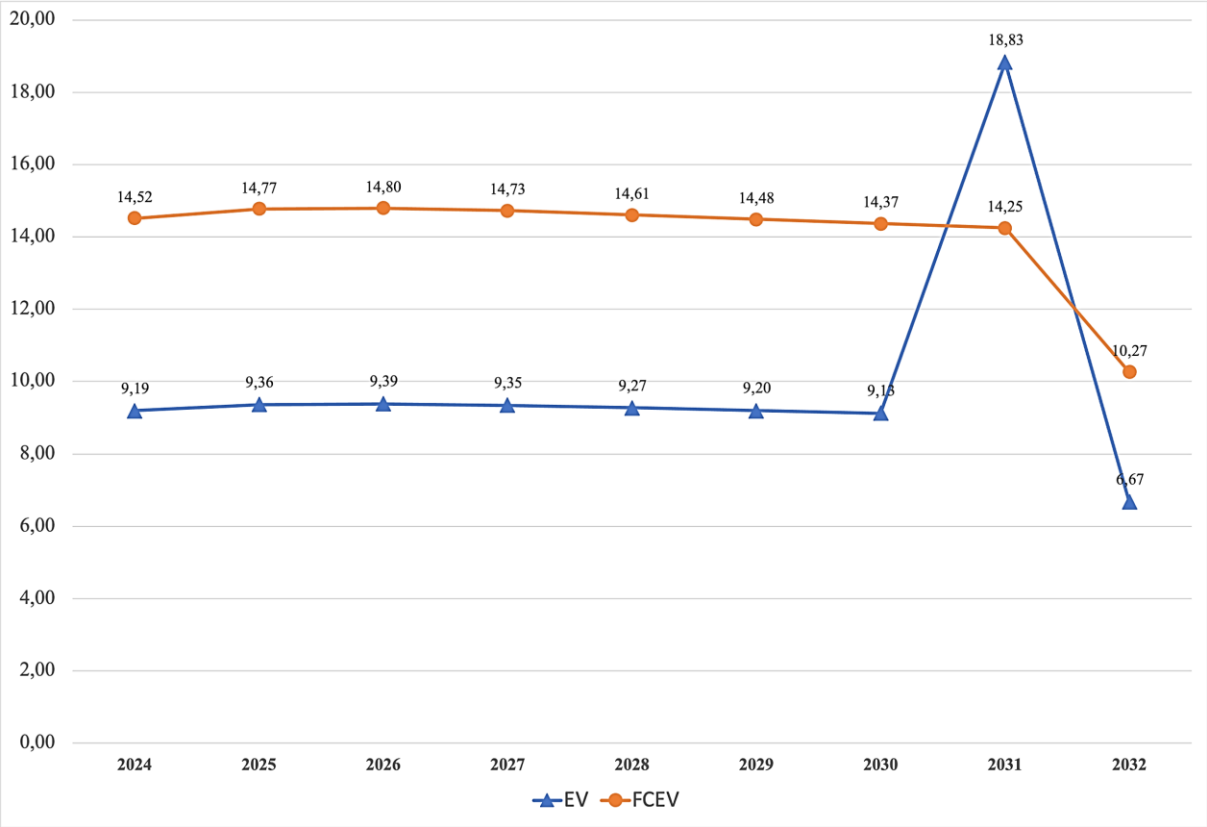

Figure 1. TCO per kilometer for EVs and FCEVs.

Source: own elaboration.

The first year of analysis was intentionally skipped, for the values include the investment outlay. It distorts the meaning of the numbers provided below. In the penultimate year of analysis there is a peak for EVs. It is the result of retrofitting of new batteries, which does not take place for FCEVs.

4. Sensitivity analysis, future research lines and conclusions

Critical factors affecting significant difference between these options are: investment outlay for new buses and costs of fuel and electricity. It should be also indicated that energy demand of EVs and FCEVs is significantly different. It was measured that EV bus needs 120 kWh to run 100 kms, whereas FCEV bus consuming 8 kgs of H_2, uses 264 kWh to run 100 kms.

Since the hydrogen technology for powertrain is rather immature, its cost of purchase is significantly higher than the mature technology used in EV buses.

Having calculated both TCO values, the authors decided to conduct the sensitivity analysis. In this approach there were indicated four variables which may affect TCO: investment outlay for FCEV and EV, and unit cost of fuel or electricity.

In the first scenario the independent variable was the unit price of hydrogen. In order to equalize TCO of EVs with TCO of FCEVs, the cost of H_2 fuel should have negative value, which is simply impossible.

In the second scenario the independent variable was the unit price of electricity. If TCO values for EVs and FCEVs are supposed to be the same, the cost of energy should increase from 0,75 PLN net to 5,14 PLN net. This scenario is also extremely unlikely and the result is rather ridiculous.

In the third scenario, the independent variable was the price of the FCEV bus. In such case the purchase cost of a new vehicle should not exceed 30% of its current price (approx. 1 150 000,00 PLN net). That is why investments in FCEV buses is strongly supported by the European Union, as it stays in line with its decarbonization policy. However, taking into account market game only (excl. EU grants), use of FCEVs becomes costly and uncompetitive, comparing to other sources of powertrain of the buses.

In the fourth scenario, the independent variable was the price of the EV bus. In such case the purchase cost of a new vehicle should increase almost twice to 4 450 000 PLN net, which also seems rather unlikely, since it does not reflect current market values.

Concluding, in order to get more and more comprehensive values of TCO, regardless of the type of vehicle, it is necessary to indicate or determine more specific costs, as proposed by Ferrin and Plank (Ferrin, Plank, 2002). Many of them are not calculated by the businesses, since they are not required for financial reporting. The same refers to environmental and social costs or benefits, as it was proposed by Moreira Falcão et al. and Rusich and Danielis (Moreira Falcão et al., 2017; Rusich, Danielis, 2015). Lack of legal obligation of their reporting results in practical lack of data do acquire from the businesses.

References

1. Al-Alawi, B.M., Bradley, T.H. (2013). Total cost of ownership, payback, and consumer preference modeling of plug-in hybrid electric vehicles. *Applied Energy, Vol. 103*, pp. 488-506, doi: 10.1016/j.apenergy.2012.10.009
2. Ellram, L.M. (1995). Total cost of ownership. An analysis approach for purchasing. *International Journal of Physical Distribution & Logistics Management, Vol. 25, Iss. 8*, pp. 4-23, doi: 10.1108/09600039510099928.

3. Falcao, E.A.M., Teixeira, A.C.R., Sodre, J.R. (2017). Analysis of CO_2 emissions and techno-economic feasibility of an electric commercial. *Applied Energy, Vol. 193,* pp. 297-307, doi: 10.1016/j.apenergy.2017.02.050.
4. Ferrin, B.G., Plank, R.E. (2002). Total Cost of Ownership Models: An Exploratory Study, *Journal of Supply Chain Management, 38(3),* pp. 18-29, doi: DOI: 10.1111/j.1745-493X.2002.tb00132.x.
5. Hurkens, K., van der Valk, W., Wynstra, F. (2006). Total Cost of Ownership in the Services Sector: a case study. *Journal of Supply Chain Management, Vol. 42, Iss. 1,* pp. 27-37, doi: 10.1111/j.1745-493X.2006.04201004.x.
6. Jagiełło, A., Wołek, M., Bizon, W. (2023). Comparison of Tender Criteria for Electric and Diesel Buses in Poland—Has the Ongoing Revolution in Urban Transport Been Overlooked? *Energies, Vol. 16, Iss. 11,* doi: 10.3390/en16114280
7. Korpi, E., Ala-Risku, T., (2018). Life cycle coasting. A review of published case studies. *Managerial Auditing Journal, Vol. 23(3),* pp. 240-261, doi: 10.1108/02686900810857703.
8. Ministry of Finance (October 2023). *Guidelines for the use of uniform macroeconomic indicators as a basis for estimation of the financial effects of proposed laws*, https://www.gov.pl/web/finanse/wytyczne-sytuacja-makroekonomiczna, 11/2023.
9. Moreira Falcão, E.A., Rodrigues Teixeira, A.C., Sodré, J.R. (2017). Analysis of CO_2 emissions and techno-economic feasibility of an electric commercial vehicle. *Applied Energy, vol. 193,* pp. 297-307, doi: 10.1016/j.apenergy.2017.02.050
10. Palmer, K. et al. (2018). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Applied Energy, 209*, pp. 108-119, doi: 10.1016/j.apenergy.2017.10.089
11. Palmer, K., Tate J.A., Wadud Z., Nellthorp, J. (2018). Total cost of ownership and market share for hybrid and electric vehicles in the UK, US and Japan. *Applied Energy, Vol. 209,* pp. 108-119, doi: 10.1016/j.apenergy.2017.10.089.
12. Regulation (EC) No 1370/2007 of the European Parliament and of the Council of 23 October 2007 on public passenger transport services by rail and by road and repealing Council Regulations (EEC) Nos 1191/69 and 1107/70; OJ L 315, 3.12.2007, pp. 1-13, https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=celex%3A32007R1370, 11/2023.
13. Resolution No. XLIX/359/2022 of the Assembly of the Upper Silesia and Zagłębie Metropolis of 16 December 2022 on adopting the Multiannual Financial Forecast for years 2023-2032, https://bip.metropoliagzm.pl/artykul/34656/129566/uchwala-nr-307-2022-zarzadu-gornoslasko-zaglebiowskiej-metropolii-z-dnia-15-listopada-2022-r-w-sprawie-projektu-wpf-2023-2032, 11/2023.
14. Rusich, A., Danielis, R. (2015). Total cost of ownership, social lifecycle cost and energy consumption of various automotive technologies in Italy. *Research in Transportation Economics*, doi:10.1016/j.retrec.2015.06.002

15. Szulc, T., Krawczyk G., Tchórzewski, S. (2021). Models of Delivery of Sustainable Public Transportation Services in Metropolitan Areas–Comparison of Conventional, Battery Powered and Hydrogen Fuel-Cell Drives. *Energies, Vol. 14, Iss. 22,* doi: 10.3390/en14227725
16. Topal, O., Nakir, I. (2018). Total Cost of Ownership Based Economic Analysis of Diesel, CNG and Electric Bus Concepts for the Public Transport in Istanbul City. *Energies, 11, 2369,* doi:10.3390/en11092369
17. Vora, A. et al. (2017). Design-space exploration of series plug-in hybrid electric vehicles for medium-duty truck applications in a total cost-of-ownership framework. *Applied Energy, vol. 202,* pp. 662-672, doi: 10.1016/j.apenergy.2017.05.090

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THE RESTRUCTURING NATURE

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Purpose: This article aims to systematize the concept of restructuring and its types.
Design/methodology/approach: The article uses literature analysis as a research tool. The issue covers domestic and foreign publications of the last quarter of a century.
Findings: The activities carried out as part of the restructuring process are unique and unrepeatable. They cannot be directly copied or mapped in another organization. The concept of restructuring has been and is currently considered by authors in four approaches as a market phenomenon resulting from changes in the environment, as a microeconomic phenomenon, as a result of the systemic-industrial restructuring of the national economy and in meso- and macro-economic approach.
Research limitations/implications: An article from a literature review is limited by its subjective selection.
Originality/value: The article updates contemporary knowledge about the restructuring process. Its value is the diagrammatic representation of overlapping approaches to restructuring.

Keywords: restructuring, definition, classification.

Category of the paper: Literature review.

1. Introduction

Restructuring is a "natural" need, the causes of which can be traced to weaknesses in the organization's management system and control area, as well as changes in the environment. In some economic sectors, such as education, mining, and hospitality, restructuring is a continuous process going from reform to reform. As early as a quarter of a century ago, the causes of restructuring were identified, among other things (Gabrusiewicz, 1999):

- transformations of system assumptions and economic changes;
- the high dependence of enterprise development on relations with the environment;
- the need to transform the organization model from a closed to an open system;
- competition affecting the functioning of the organization;
- the organization's constant striving for development.

J. Stoner and H. Wankel believe that the main reason for restructuring is the threat of bankruptcy, liquidation or takeover by other entities (Stoner, Wankel, 1994). Changes in organizations are the result of phenomena that need to be recognized. These phenomena (causes) affect the type of changes implemented in restructuring and can be classified differently depending on the extent, type of change, duration, effect, or cost (Famielec, Kożuch, 2018). This article aims to systematize the concept of restructuring and its types.

2. Restructuring in theoretical terms

Companies have continuously operated in complex and changing conditions, forcing them to adapt to environmental changes constantly. In domestic and foreign literature on management, one can find a number of definitions of the restructuring concept, which emphasize various aspects of the concept. The following table presents selected definitions showing the diversity of approaches in terminology over the years.

Table 1.
Selected definitions of the restructuring concept.

Autor	Definition		Autor
	in domestic terms	**in foreign terms**	
A. Stabryła, 1995	Restructuring is a set of diagnostic and design activities aimed at improving the management and operating enterprise system. Implemented changes mainly concern the transformation of the organizational form, decision-making systems and human resources	Restructuring is all major changes in the organization's strategy that force transformation of rules and principles in the way the company operates, but also involves changes in the area of human resources (employment structure and qualifications).	D. Thierry, 1995
J. Stachowicz, 2001	Restructuring includes activities involving the reconstruction of the existing economic structure of the enterprise in order to modernize it, improve its flexibility, innovation and adaptability to changes in the environment. Its result should be an increase in the efficiency of the organization's management.	Restructuring applies to companies that have generated a negative financial result indicating the need to take corrective measures in the structure of the organization, otherwise the company faces bankruptcy.	S. Slatter, D. Lovett, 2001
R. Borowiecki, 2006	Restructuring is a fundamental reconstruction of an enterprise relating to the main areas of its operation, and its application results in numerous changes relating to modernization and adaptation of the organizational structure and operating principles to the current requirements of the economy.	Restructuring is a radical and fundamental change in all areas of a company's operations.	J.M. Brett, A.H. Reilly, L.H. Stroh, 2006

Source: own elaboration based on: Thierry, 1995; Slatter, Lovett, 2001; Brett, Reilly, Stroh, 2006; Stabryła, 1995; Stachowicz, 2001; Borowiecki.

Restructuring is seen as a change of a special, unique nature. Its specificity is evidenced by such features as (Głód, 2011; Chmielewski, Płoska, 2018):

- radicality: restructuring involves solutions that have not been applied in the company before, requiring the rejection of an old approach and the adoption of a new one;
- global: often the implemented changes include all areas of the organization's functioning, making the process multifaceted, complex and requiring consistency between activities;
- long-term: the design and implementation of the activities covered by the restructuring is a long-term process, so the evaluation of the results itself may only occur after several years;
- orientation to the environment: restructuring results from the need to adapt the organization to changes in the environment, by which it should lead to the adaptation of the organization's structure and operating principles to the current and future environmental conditions;
- cost-intensity: restructuring changes are expensive from both a social and financial point of view;
- planning: the implementation of restructuring changes is carried out in a planned manner, by a previously developed action plan.

A common feature is the perception of restructuring as a change of a radical nature involving fundamental areas of the organization. According to R. A. Weber, a change is a transformation of policy, organizational structure or the employee approach to increase the enterprise's efficiency level (Szplit, Fudaliński, 2002). Inherent in the economy is change, which makes it necessary to find newer and newer management solutions that allow companies to achieve their goals (Jaki, 2014).

3. Restructuring areas

The restructuring process can concern the economic, organizational, technical or social areas (Miłkowska, 2011). In the literature, there is a division of restructuring due to various criteria. The purpose of implementing restructuring activities is the most common criterion for the division of restructuring. The breakdown of restructuring according to the criterion adopted is shown in the figure below.

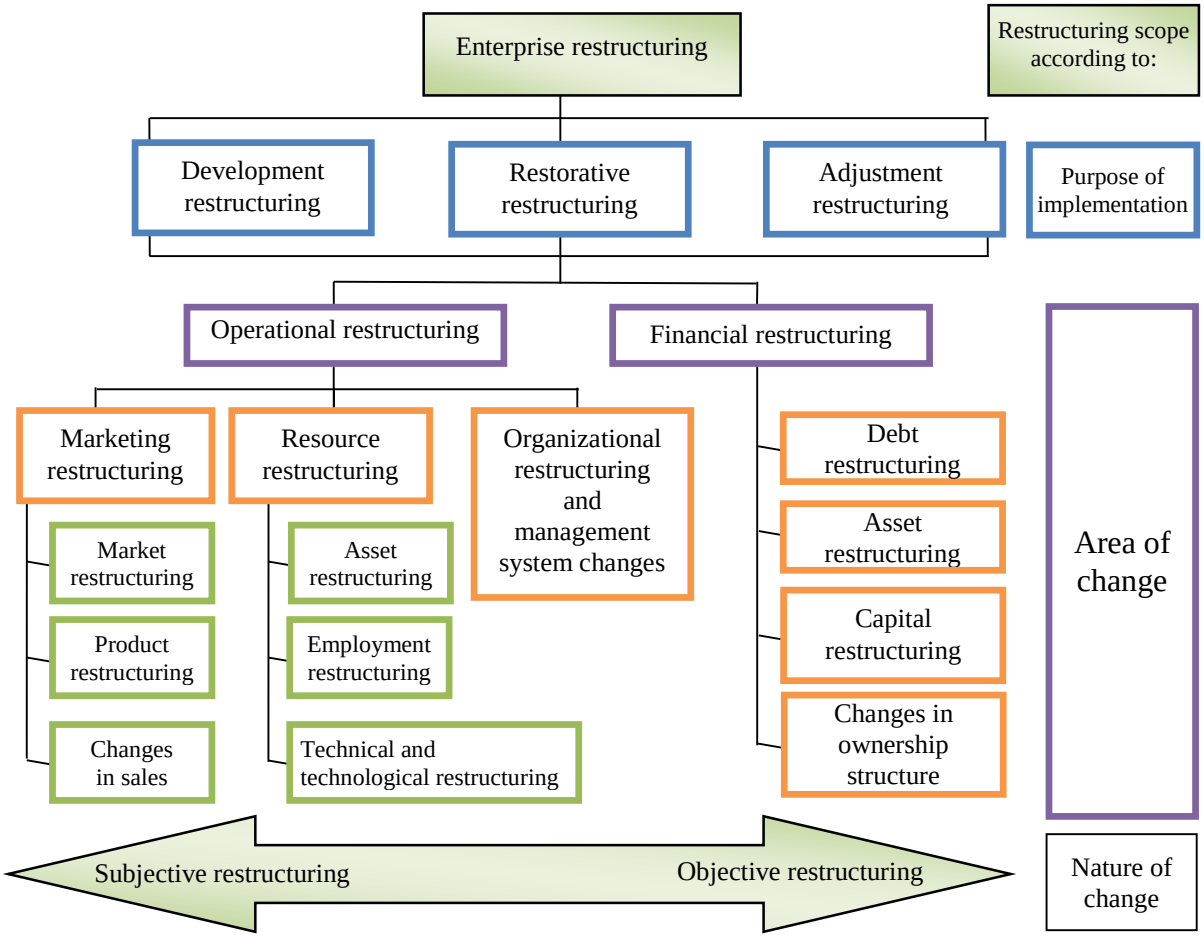

Figure 1. Types of restructuring.

Source: own elaboration based on: Kaczmarek, 2018; Romanowska, 2011; Cabała, Bartusik, 2006; Dźwigoł, 2010; Stabryła, 2000; Suszyński, 2003.

Restructuring is viewed differently depending on the enterprise's size, the problem's scale and the purpose it is intended to serve. As a result of the company's restructuring process, changes of various sizes, types and directions take place, shaping its current and future property, capital or organizational structure. According to the criterion of purpose, restructuring can be divided into corrective and development and adjustment. Another division (according to the criterion of the nature of the changes) divides restructuring into object and entity restructuring (Stabryła, 2010). The essence of restructuring cited division of restructuring by its scope (macro, meso and micro). Areas of activity can also classify restructuring. In such a view, organizational, asset, financial and operational restructuring are specified.

Developmental restructuring (dynamic, creative restructuring) is a period of long-term changes (from 2 to 5 years) relating to the area of the organization's strategy. The restructuring measures aim to guarantee the company's future development (in the sense of innovation). It is implemented by setting ambitious, exorbitant strategic goals. It may concern the acquisition of a new market, the implementation of innovative technology, carrying out fundamental modernization and upgrading, or increasing the quality of the organization of work, the products offered, the technologies used and the entire management system (Lachiewicz, 2007;

Walkowiak, Mietlewski, 2007). Developmental restructuring should lead to consolidation of the organization's position in the domestic and foreign markets (Brzeziński, 2007).

Restorative restructuring occurs when the business is threatened (Dźwigoł, 2007). It consists of restoring the initial state, before the "complications" began to occur (Stabryła, 2009). Mostly, it results from a long-term crisis or unfavorable economic situation of the company, so often its purpose is to ensure liquidity and financial stability (Penc, 2007). The result of corrective restructuring is to save the organization from the threat of liquidation or bankruptcy.

Adjustment (adaptive) restructuring means ongoing and effective implementation of designed changes in response to identified changes in the organization's environment. Speed and precision in defining changes can help the company not to allow the occupied market position to deteriorate (Borowiecki, Kwieciński, 2001). A successive (phased) course characterizes it. It has a medium-term time horizon (Trocki, 2002). Its purpose is (as in the case of the previous types of restructuring) to adapt the organization to new conditions in the environment, and thus ensure or restore its good position in the market (Gabrusiewicz, 1999).

Employment restructuring is a process aimed at adjusting the employment structure to the organization's conduct strategy (Lachiewicz, 2005). The reason for implementing employment restructuring should be the need to adapt the potential of employees to the current and future needs of the organization (Gębczyński, 2004). The restructuring process can be implemented through outplacement (Kaloshina, Galimova, 2003), downsizing (Dlouhy, Casper, 2021), social reconversion (Gruchelski, 2022) or employee retraining.

Financial restructuring distinguishes between debt, asset and capital restructuring. The most common variety of financial restructuring is debt restructuring, which seeks an agreement between creditors and the debtor (hospital). The task of asset restructuring is to increase the profitability of the organization as a result of sales, leases and the use of strategic alliances concerning the permanent transfer of resources between strategic partners. In turn, the task of capital restructuring is to increase the efficiency of capital use (Garstka, 2006).

Organizational restructuring is used to adjust the organizational structure and procedures to implement the adopted strategy (Wąsowicz, 2023). Its scope encompasses various areas of the organization's functioning, starting with the liquidation of unprofitable departments, through their merger, and ending with the modernization. The assumptions of lean management and reengineering concepts can be considered as the basis for changes in the organizational area.

From a systemic perspective, restructuring can be considered by subject and object. The objective of subjective restructuring is to increase the efficiency of operations in the technical-technological and product area. In contrast, the subjective one refers to changes in the form of ownership and legal form, legal and economic transformations and changes in the organizational structure, e.g. in sales or separation of organizational units from the structure as independent entities (Lis, Kotelska, 2022).

According to J. Sapijaszko, the critical factor affecting the success of restructuring is the time in which problems are noticed. The sooner the difficulties are noticed, the greater the chances of achieving the planned result and the smaller the losses (Sapijaszka, 1997). Identification of the cause/need for restructuring activities includes identifying problem areas and identifying the causes of the unfavorable situation. This is coupled with an assessment of the organization's current position and conducting a strategic analysis. The purpose of this activity is to thoroughly diagnose the current state of the organization and its environment and identify external conditions that allow the organization to develop (Tabaszewska, 2007). The restructuring process ends with an assessment of the implementation of the designed program. The success of the entire project depends on the method of implementation. Implementation of the restructuring program requires (Głód, 2011):

- determining how the tasks defined within the restructuring program will be implemented;
- determine the budget needed to carry out the restructuring and monitor deviations during the implementation of the program;
- allocating resources to implement specific activities;
- "adjusting the organization's systems, procedures and policies".

The restructuring process is initiated by conducting a thorough analysis of the organization, which leads to identifying the causes of the unfavourable situation within the company. In addition, the authors recommend conducting an analysis of the organization's environment to identify current and future opportunities and threats. The second element is the scope of the proposed restructuring. The authors point out the need to restore the company's competitiveness and improve its efficiency in the use of financial resources, referring to corrective and developmental restructuring.

4. Summary

The restructuring process is carried out in a complex and changing environment, the various elements of which form the basis for restructuring activities. In addition to changes in the environment, the restructuring process can be dictated by the internal needs of the company (Zakrzewska-Bielawska, 2005). In each case, restructuring will require a systemic approach that divides the organization into different areas of operation. The systemic approach, in effect, should lead to a more efficient way of finding a solution to the organization's specific problem. Important with such an approach are the relationships linking the various subsystems, for example, the relationship between competence and information flow (Dźwigoł, 2009).

The concept of restructuring has been and is currently considered by authors in four approaches (Borowiecki, 2003):

- restructuring as a market phenomenon resulting from changes in the environment, which are characterized by global scope and unpredictability (the changes are abrupt and related to the various phases of the cycles of economic processes);
- microeconomic restructuring: restructuring activities taking place in one or more areas of the company are conscious, planned and purposeful, their undertaking is the result of changes in the environment or management decisions;
- systemic-industrial restructuring of the national economy: in this case, the outcome of restructuring activities depends on the effectiveness and efficiency of the market mechanism. In this view, restructuring includes the privatization of enterprises, an increase in competitiveness as a result of the relaxation of pricing policies, the leveling of barriers to the movement of capital, etc.;
- meso- and macro-economic restructuring: the former involves transformations in selected sectors, industries, and economic regions, and the latter - transformations in the economy of the whole country.

The activities carried out as part of the restructuring process are unique and unrepeatable, as they cannot be directly copied or mapped in another organization. Each enterprise has its different conditions in which it operates and thus has a wide range of possibilities for shaping the relationship between it and the turbulent environment.

References

1. Borowiecki, R. (2003). *Zarządzanie restrukturyzacją procesów gospodarczych. Aspekty techniczno-praktyczne*. Warszawa: Difin, pp. 76-77.
2. Borowiecki, R. (2006). Zarządzanie restrukturyzacją procesów gospodarczych. In: M. Rochoń, *Efektywność restrukturyzacji finansowej przedsiębiorstw* (p. 15). Szczecin: Walkowska.
3. Borowiecki, R., Kwieciński, M. (2001). *Zarządzanie zasobami informacji w przedsiębiorstwie. Ku przedsiębiorstwu przyszłości*. Warszawa: WNT, pp. 25-26.
4. Brett, J.M., Reilly, A.H., Stroh, L.M. (2006) The impact of corporate turbulence on management journal. In: M. Rochoń, *Efektywność restrukturyzacji finansowej przedsiębiorstw* (p. 16). Szczecin: Walkowska.
5. Brzeziński, M. (2007). *Wprowadzenie do nauk o przedsiębiorstwie*. Warszawa: Difin, p. 132.
6. Cabała, P., Bartusik, K. (2006). *Restrukturyzacja w jednostkach gospodarczych*. Kraków: Akademia Ekonomiczna w Krakowie, p. 19.

7. Chmielewski, M., Płoska, R. (2018). Przydatność narzędzi z zakresu społecznej odpowiedzialności przedsiębiorstw w procesach restrukturyzacji. *Zeszyty Naukowe Politechniki Śląskiej, Seria: Organizacja i Zarządzanie, Vol. 132*, pp. 135-136.
8. Dlouhy, K., Casper, A. (2021). Downsizing and surviving employees' engagement and strain: The role of job resources and job demands. *Hum. Resour. Manage., Vol. 60, Iss. 3,* p. 435, doi: 10.1002/hrm.22032
9. Dźwigoł, H. (2007). *Model restrukturyzacji organizacyjnej przedsiębiorstwa górnictwa węgla kamiennego*. Warszawa: Difin, p. 20.
10. Dźwigoł, H. (2009). Model restrukturyzacji organizacyjnej przedsiębiorstwa górniczego. *Organizacja i Zarządzanie, no. 2(6)*, p. 27.
11. Dźwigoł, H. (2010). *Podejście systemowe w procesie restrukturyzacji przedsiębiorstwa*. Gliwice: Wydawnictwo Politechniki Śląskiej, pp. 47-51.
12. Gabrusiewicz, W. (1999). Restrukturyzacja przedsiębiorstw i metody oceny jej efektów. *Przegląd Organizacji, no. 3*, p. 26.
13. Garstka, M. (2006). *Restrukturyzacja przedsiębiorstwa. Podział przez wydzielenie*. Warszawa: CeDeWu, p. 19.
14. Gębczyński, M. (2004). Analiza i ocena restrukturyzacji zatrudnienia w przedsiębiorstwie przemysłu tradycyjnego. *Zeszyty Naukowe Politechniki Śląskiej. Organizacja i Zarządzanie, Z. 21*, p. 333.
15. Głód, G. (2011). *Zarządzanie zmianą w jednostce ochrony zdrowia*. Katowice: Wydawnictwo Uniwersytetu Ekonomicznego w Katowicach, pp. 58-59.
16. Gruchelski, M. (2022). Etyczne zwolnienia a społeczna odpowiedzialność biznesu. *Studia społeczne, Vol. 1(36)*, pp. 162-163.
17. Jaki, A. (2014). Przejawy ryzyka w zarządzaniu wartością. *Zeszyty Naukowe Uniwersytety Szczecińskiego. Finanse, Rynki Finansowe, Ubezpieczenia, no.* 66, p. 747.
18. Kaczmarek, P. (2018). Rola zarządzania ryzykiem w restrukturyzacji przedsiębiorstwa. *Zarządzanie i Finanse, Uniwersytet Gdański, vol. 16, no. 4/1*, pp. 107-108.
19. Kaloshina, T., Galimova, A. (2023). *Outplacement: current practice of a responsible employer for transport and logistics companies*. International Scientific and Practical Conference "Environmental Risks and Safety in Mechanical Engineering" (ERSME-2023), pp. 1-2
20. Lachiewicz, S. (2007). *Menedżerowie w strukturach władzy organizacji gospodarczych*. Warszawa: PWE, pp. 17, 49.
21. Lachiewicz, S., Zakrzewska-Bielawska, A. (2005). *Restrukturyzacja organizacji i zasobów kadrowych przedsiębiorstwa*. Kraków: Oficyna Ekonomiczna, p. 214.
22. Lis, M., Kotelska, J. (2022). *Restrukturyzacja górnictwa węgla kamiennego w Polsce w perspektywie oceny interesariuszy*. Dąbrowa Górnicza: Akademia WSB, p. 35.

23. Miłkowska, E. (2011). Restrukturyzacja przedsiębiorstwa w sądowym postępowaniu naprawczym. In: B. Dembowska, J. Gonicka (ed.), *Zarządzanie przedsiębiorstwem w kryzysie*. Łódź: Akademia Humanistyczno-Ekonomiczna, p. 28.
24. Penc, J. (2007). *Nowoczesne kierowanie ludźmi. Wywieranie wpływu i współdziałanie w organizacji*. Warszawa: Difin, p. 221.
25. Romanowska, M. (2011). Restrukturyzacja jako reakcja na zmiany (na przykładzie Grupy Kapitałowej Zakładów Chemicznych "Police" SA. *Zeszyty Naukowe Uniwersytetu Szczecińskiego, Studia i Prace Wydziału Nauk Ekonomicznych i Zarządzania, no. 21*, p. 209.
26. Sapijaszka, Z. (1997). *Restrukturyzacja przedsiębiorstwa. Szanse i ograniczenia*. Warszawa: PWN, p. 184.
27. Slatter, S., Lovett, D. (2001). *Corporate turnaroiund managing companies in distress. Edycja Polska.* Warszawa: WiG-Press, p. 273.
28. Stabryła, A. (2009.). *Doskonalenie struktur organizacyjnych przedsiębiorstw w gospodarce opartej na wiedzy*. Warszawa: C.H. Beck, p. 318.
29. Stabryła, A. (2010). *Zarządzanie strategiczne w teorii i praktyce firmy*. Warszawa/Kraków: PWN, p. 251.
30. Stachowicz, J. (2001). *Zarządzanie procesami reorientacji strategicznej w przedsiębiorstwie przemysłów tradycyjnych*. Warszawa: PWN, p. 16.
31. Strybała, A. (1995). *Zarządzanie rozwojem firmy*. Kraków: Księgarnia Akademicka, p. 16.
32. Suszyński, C. (2003). *Restrukturyzacja, konsolidacja, globalizacja przedsiębiorstw*. Warszawa: PWE, p. 128.
33. Szplit, A., Fudaliński, J., Markiweicz, P., Smutek, H. (2002). *Strategie rozwoju organizacji*. Kraków: Antykwa, p. 21.
34. Tabaszewska, E. (2007). *Nowoczesne koncepcje zarządzania - wyniki badań*. Wrocław: Wydawnictwo Akademii Ekonomicznej, p. 81.
35. Thierry, D. (1995). *Restrukturyzacja przedsiębiorstw. Adaptacja pracowników do zmian*. Warszawa: Poltext, p. 18.
36. Trocki, M. (2002). *Nowoczesne zarządzanie w opiece medycznej. Zarządzanie w zakładach opieki zdrowotnej*. Warszawa: Instytut Przedsiębiorczości i Samorządności, p. 85.
37. Walkowiak, R., Mietlewski, Z. (2007). *Oblicza restrukturyzacji w świetle badań*. Olsztyn: Wydawnictwo Olsztyńskiej Wyższej Szkoły Informatyki i Zarządzania im. prof. T. Kotarbińskiego, p. 17.
38. Wąsowicz, K. (2023). *Zarządzanie rozwojem organizacji przedsiębiorstwa lokalnego transport zbiorowego na przykładzie MPK S.A. w Krakowie*. Kraków: Attyka s.c. J. Jagła, W. Skrzypiec, p. 119
39. Zakrzewska-Bielawska, A. (2005). Uwarunkowania restrukturyzacji przedsiębiorstw. In: S. Lachiewicz, A. Zakrzewska-Bielawska (eds.), *Restrukturyzacja organizacji i zasobów kadrowych przedsiębiorstwa*. Kraków: Oficyna Ekonomiczna, p. 46.

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THE USAGE OF ROOT CAUSE ANALYSIS (RCA) IN INDUSTRY 4.0 CONDITIONS

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Purpose: The purpose of this publication is to present the usage of Root Cause Analysis (RCA) 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 Root Cause Analysis (RCA) within Industry 4.0 emerges as a strategic imperative, offering a systematic and holistic approach to problem-solving in the dynamic landscape of advanced technologies and interconnected systems. RCA serves as a powerful tool for dissecting multifaceted issues arising from the convergence of physical and digital systems, crucial in understanding and mitigating problems linked to smart technologies, automation, and data-driven processes. In the context of Industry 4.0's complexities, RCA facilitates a comprehensive examination of events, enabling organizations to identify the fundamental causes of disruptions or inefficiencies. The systematic investigative approach of RCA proves indispensable for navigating the intricate web of factors influencing the performance of smart manufacturing processes, cyber-physical systems, and the Internet of Things (IoT). As industries prioritize real-time data collection and analysis, RCA becomes instrumental in deciphering patterns and correlations within the data deluge, guiding informed decision-making and proactive problem resolution. Overall, RCA's integration into Industry 4.0 signifies a strategic method for fostering resilience, continuous improvement, and sustainable success within this dynamic and technologically-driven landscape.
Originality/Value: Detailed analysis of all subjects related to the problems connected with the usage of Root Cause Analysis in Industry 4.0 conditions.

Keywords: Industry 4.0; Quality 4.0, quality management; quality methods, RCA, Root Cause Analysis.

Category of the paper: literature review.

1. Introduction

Root Cause Analysis in Industry 4.0 conditions involves the application of this systematic investigative approach to understand and mitigate problems arising from the integration of smart technologies, automation, and data-driven processes. With the complexity and interconnectedness inherent in Industry 4.0 systems, the identification of root causes becomes even more challenging yet crucial.

In this context, RCA serves as a powerful tool for dissecting multifaceted issues that may arise in the convergence of physical and digital systems. It enables organizations to delve into the intricate web of factors influencing the performance of smart manufacturing processes, cyber-physical systems, and the Internet of Things (IoT). By identifying the fundamental causes of disruptions or inefficiencies, Industry 4.0 enterprises can develop targeted solutions that address the heart of the problem. Moreover, as Industry 4.0 emphasizes the real-time collection and analysis of vast amounts of data, Root Cause Analysis becomes instrumental in deciphering patterns and correlations within this data deluge. Whether it's a glitch in a production line, a cybersecurity breach, or a malfunction in an IoT device, RCA facilitates a comprehensive examination of events, leading to more informed decision-making and proactive problem resolution (Barsalou, 2023; Maganga, Taifa, 2023).

The purpose of this publication is to present the usage of Root Cause Analysis (RCA) approach in Industry 4.0 condition.

2. The basics of Root Cause Analysis (RCA) approach

Root Cause Analysis (RCA) is a systematic process employed to identify the underlying factors that contribute to an issue or problem within an organization. This analytical approach is crucial for addressing problems at their source rather than merely treating the symptoms. The ultimate goal of Root Cause Analysis is to prevent the recurrence of issues by understanding and addressing the fundamental reasons behind them (Singh et al., 2023).

The RCA methodology involves a thorough investigation into the events and circumstances leading up to a problem. It goes beyond surface-level symptoms and delves into the deeper layers of causation. By examining the entire chain of events, RCA seeks to identify the primary cause or causes responsible for the observed issues. A key aspect of Root Cause Analysis is the recognition that problems are often the result of a combination of factors rather than a single isolated incident. Therefore, it requires a comprehensive examination of various contributing elements, including processes, systems, human factors, and external influences. This holistic approach enables organizations to develop more effective solutions that target the root of the problem (Gajdzik et al., 2023).

The RCA process typically involves the collection and analysis of data, interviews with relevant stakeholders, and a careful examination of documentation. It may also incorporate tools such as Fishbone diagrams, 5 Whys, or Fault Tree Analysis to facilitate a structured and methodical investigation. One of the critical benefits of Root Cause Analysis is its ability to foster a culture of continuous improvement within an organization. By identifying and addressing the root causes of problems, organizations can implement preventive measures and enhance their overall operational efficiency. This proactive approach not only mitigates current issues but also helps prevent similar problems from arising in the future (Yanamandra et al., 2023).

The integration of RCA into Industry 4.0 practices aligns with the overarching goal of achieving predictive maintenance and minimizing downtime. By understanding the root causes of equipment failures or system malfunctions, organizations can implement predictive analytics and preventive measures, optimizing operational efficiency and reducing the risk of costly disruptions (Jokovic et al., 2023).

In conclusion, the usage of Root Cause Analysis in Industry 4.0 conditions signifies a strategic approach to problem-solving in the face of advanced technologies and interconnected systems. As industries continue to embrace the transformative capabilities of the fourth industrial revolution, the application of RCA becomes indispensable for fostering resilience, continuous improvement, and the sustainable success of organizations operating in this dynamic and technologically-driven landscape.

Table 1 contains description of Root Cause Analysis (RCA) key principles. These principles collectively form the foundation for an effective Root Cause Analysis process, providing a systematic and proactive approach to problem-solving in various industries and contexts.

Table 1.
Key principles of Root Cause Analysis (RCA)

Key principle	Description
Systematic Approach	Root Cause Analysis involves a methodical and structured examination of events, considering the entire system rather than focusing solely on isolated incidents or symptoms.
Holistic Investigation	It emphasizes a comprehensive exploration of various contributing factors, including processes, systems, human elements, and external influences, to identify the primary causes of an issue.
Data-Driven Analysis	Root Cause Analysis relies on the collection and analysis of relevant data to uncover patterns, trends, and correlations that contribute to a deeper understanding of the problem.
Multidisciplinary Perspective	It encourages collaboration and input from diverse stakeholders, incorporating insights from different disciplines to gain a well-rounded understanding of the factors influencing the issue.
Proactive Problem-Solving	The focus is on preventing the recurrence of problems by addressing the root causes rather than merely treating the symptoms, fostering a proactive approach to continuous improvement.
Iterative Process	Root Cause Analysis may involve an iterative process, revisiting and refining the analysis as new information becomes available, ensuring a thorough and evolving understanding of the issue.

Cont. table 1.

Use of Analytical Tools	Various tools, such as Fishbone diagrams, 5 Whys, Fault Tree Analysis, or statistical methods, may be employed to facilitate a structured and effective investigation into the root causes.
Continuous Improvement	It contributes to a culture of continuous improvement by identifying and rectifying the fundamental causes of problems, promoting a learning environment within the organization.

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 Root Cause Analysis (RCA) method can be integrated with Industry 4.0 and Quality 4.0 concept

Root Cause Analysis (RCA) is becoming increasingly integral to the landscape of Industry 4.0, where digitalization and advanced technologies are reshaping industrial processes. In this era of interconnected systems and smart manufacturing, the integration of RCA plays a crucial role in identifying and mitigating issues at their core (Alrabadi et al., 2023).

One key aspect of this integration lies in the digitalization of processes and the use of advanced data analytics. RCA leverages technologies such as the Internet of Things (IoT) sensors and machine learning algorithms to collect and analyze real-time data. This digital approach enables a more comprehensive understanding of complex systems and facilitates the identification of root causes by uncovering patterns and anomalies. Within smart manufacturing systems characteristic of Industry 4.0, RCA addresses issues related to cyber-physical systems and the automation of production processes. As machines become more intelligent and interconnected, RCA provides a systematic approach to dissecting complex problems, ensuring a thorough examination of interconnected elements to pinpoint root causes effectively (Bousdekis et al., 2023).

Moreover, the integration of RCA supports the shift towards predictive maintenance strategies. By analyzing historical data and identifying root causes, organizations can anticipate equipment failures and proactively address issues before they lead to disruptions. This proactive maintenance approach optimizes equipment performance, reduces downtime, and enhances overall operational efficiency.

In the context of the interconnected supply chain in Industry 4.0, RCA extends its application to address disruptions or inefficiencies that may arise from the integration of suppliers, logistics, and production processes. This ensures a holistic examination of the supply chain, identifying root causes that may impact the flow of materials, information, and products across the entire value chain.

Additionally, RCA is crucial in addressing cybersecurity incidents within the digital ecosystems of Industry 4.0. As organizations embrace digitalization, the risk of cyber threats increases. RCA helps in understanding the root causes of cybersecurity breaches, enabling the development of robust measures to safeguard critical assets and maintain the integrity of digital systems (Maganga, Taifa, 2023).

The integration of Root Cause Analysis with Industry 4.0 reflects a strategic approach to problem-solving in the context of digital transformation (Jonek Kowalska, Wolniak, 2021, 2022). By leveraging advanced technologies and a systematic analytical approach, RCA becomes an essential tool for organizations aiming to optimize processes, enhance efficiency, and ensure the resilience of interconnected systems in the evolving landscape of Industry 4.0 (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

Table 2 is listing examples of integration of Root Cause Analysis (RCA) method with Iindustry 4.0. This table provides a concise overview of how Root Cause Analysis is integrated into various aspects of Industry 4.0, showcasing its relevance in addressing challenges and optimizing processes in the evolving landscape of smart and interconnected industries.

Table 2.
Root Cause Analysis (RCA) integration with industry 4.0

Aspect	Description
Digitalization and Data Analytics	Integration involves leveraging digital technologies like IoT sensors and machine learning for real-time data collection and analysis. This enables a comprehensive understanding of complex systems and facilitates the identification of root causes by uncovering patterns and anomalies.
Smart Manufacturing Systems	RCA is applied within smart manufacturing systems to address issues related to cyber-physical systems and the automation of production processes. It provides a systematic approach to dissecting complex problems in interconnected and intelligent manufacturing environments.
Predictive Maintenance	Integration supports predictive maintenance strategies by analyzing historical data and identifying root causes, allowing organizations to anticipate equipment failures and proactively address issues before disruptions occur. Proactive maintenance optimizes equipment performance and reduces downtime.
Interconnected Supply Chain	RCA extends to the interconnected supply chain, addressing disruptions or inefficiencies arising from the integration of suppliers, logistics, and production processes. It ensures a holistic examination of the supply chain, identifying root causes that may impact the flow of materials, information, and products.
Cybersecurity Incidents	Integration involves applying RCA to investigate and mitigate cybersecurity incidents within digital ecosystems. It addresses the vulnerabilities and root causes of cyber threats, allowing organizations to understand breaches and develop robust measures to safeguard critical assets.
Digital Twin Technology	Integration involves leveraging digital twin technology to create virtual replicas of physical systems. This enables a real-time comparison between the expected and actual performance, aiding in the identification of root causes by simulating and analyzing different scenarios.
Real-Time Monitoring and Control	RCA is integrated with real-time monitoring and control systems to identify deviations from expected performance immediately. This proactive approach ensures quick detection of issues, allowing organizations to analyze root causes promptly and implement corrective measures in real time.

Cont. table 2.

Cross-Functional Collaboration	Integration encourages cross-functional collaboration, involving stakeholders from various departments such as engineering, operations, and IT. This collaboration ensures a holistic analysis, combining diverse perspectives to identify and address root causes comprehensively.
Supply Chain Traceability	RCA extends to supply chain traceability, utilizing technologies like blockchain to track and trace products throughout the supply chain. This aspect ensures transparency and aids in identifying root causes of issues related to quality, delays, or disruptions in the supply chain.
Human-Machine Interaction	Integration considers the human-machine interaction aspects, recognizing that human errors or interactions with automated systems can contribute to issues. RCA in Industry 4.0 includes an analysis of human factors to identify root causes related to training, communication, or decision-making.
Advanced Sensor Integration	RCA leverages the integration of advanced sensors in manufacturing equipment and processes. These sensors provide detailed data on performance, allowing for a more granular analysis of root causes related to equipment malfunctions, wear and tear, or environmental conditions.
Machine Learning and AI Applications	Integration involves the application of machine learning and artificial intelligence algorithms to analyze vast datasets. These technologies enhance the depth of root cause analysis by identifying complex patterns and correlations that may not be immediately apparent through traditional methods.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Amat-Lefort et al., 2023; Alrabadi et al., 2023; Singh et al., 2023; Barsalou, 2023; Antony et al., 2023; Saihi et al., 2023; Sureshchandar, 2023; Swarnakar et al., 2023; Gimerska et al., 2023; Salimbeni, Redchuk, 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

Table 3 is describe the advantages Root Cause Analysis (RCA) approach usage in industry 4.0. This table provides an overview of the various advantages of integrating Root Cause Analysis with Industry 4.0, emphasizing the positive impact on proactive issue resolution, operational efficiency, cost reduction, and overall organizational performance.

Table 3.
The advantages of Root Cause Analysis (RCA) integration with industry 4.0

Advantage	Description
Proactive Issue Resolution	Integration enables organizations to proactively identify and resolve issues at their root causes before they escalate. By leveraging real-time data and advanced analytics, RCA in Industry 4.0 allows for predictive problem-solving, reducing the impact of disruptions and minimizing downtime.
Enhanced Operational Efficiency	The systematic approach of RCA integration optimizes operational efficiency within Industry 4.0. By addressing root causes, organizations can streamline processes, identify bottlenecks, and implement targeted improvements. This leads to increased productivity, reduced waste, and a more efficient utilization of resources.
Cost Reduction through Predictive Maintenance	Integration with predictive maintenance strategies results in cost savings. By identifying and addressing root causes before equipment failures occur, organizations can reduce maintenance costs, minimize unplanned downtime, and extend the lifespan of machinery and assets. This contributes to overall cost efficiency in Industry 4.0 environments.
Improved Quality and Productivity	RCA integration contributes to improved product quality and increased productivity. By identifying and rectifying root causes of quality issues, organizations can enhance the overall product quality. Additionally, addressing efficiency-related root causes leads to increased productivity and throughput in manufacturing processes.
Data-Driven Decision Making	The integration of RCA with Industry 4.0 leverages data-driven decision-making. By analyzing vast amounts of real-time data, organizations gain valuable insights into the factors influencing operations. This informed decision-making enhances overall strategic planning, resource allocation, and continuous improvement initiatives.

Cont. table 3.

Prevention of Recurring Issues	RCA integration helps prevent the recurrence of issues by addressing root causes. Organizations can implement corrective actions based on a thorough understanding of the underlying problems, reducing the likelihood of similar issues arising in the future. This preventive approach contributes to the stability and reliability of processes in Industry 4.0.
Cross-Functional Collaboration	Integration fosters cross-functional collaboration. By involving stakeholders from various departments in the RCA process, organizations benefit from diverse perspectives. This collaboration enhances problem-solving capabilities, encourages knowledge-sharing, and promotes a culture of continuous improvement across different functional areas in the Industry 4.0 environment.
Optimized Supply Chain Performance	RCA integration extends to the supply chain, optimizing its performance. By identifying and addressing root causes of disruptions, delays, or quality issues in the supply chain, organizations can enhance overall supply chain efficiency. This leads to improved on-time delivery, customer satisfaction, and resilience in Industry 4.0's interconnected and dynamic supply chain ecosystems.
Enhanced Cybersecurity Resilience	Integration with RCA strengthens cybersecurity resilience in Industry 4.0. By identifying root causes of cybersecurity incidents, organizations can implement robust measures to safeguard digital systems, protect sensitive data, and mitigate the risks associated with cyber threats. This proactive approach contributes to the overall cybersecurity posture of Industry 4.0 environments.

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 describes the problems of Root Cause Analysis (RCA) approach usage in Industry 4.0 and methods to overcome them. Addressing these problems requires a strategic and thoughtful approach, involving a combination of technological solutions, organizational change management, and ongoing adaptation to evolving industry standards and practices.

Table 4.
The problems of Root Cause Analysis (RCA) integration with industry 4.0

Problems	Description of Problem	Overcoming Strategies
Data Overload and Complexity	The integration of RCA with Industry 4.0 often involves dealing with vast amounts of complex and diverse data from interconnected systems, making it challenging to extract meaningful insights.	Implement advanced analytics and machine learning algorithms to automate data analysis. Use data visualization tools to simplify complex data sets. Prioritize relevant data sources and focus on key performance indicators (KPIs). Ensure data quality and accuracy through proper validation and cleansing processes.
Interconnected Systems Challenges	The interconnected nature of Industry 4.0 systems introduces challenges in identifying and isolating root causes due to the intricate relationships between various components and processes.	Develop a comprehensive understanding of system interdependencies through system modeling and digital twin technology. Utilize simulation tools to analyze the impact of changes or disruptions. Foster collaboration between different departments and teams to gain diverse perspectives on interconnected challenges.
Human-Technology Interaction Issues	As Industry 4.0 involves increased human-technology interaction, root causes may stem from factors such as inadequate training, communication gaps, or human errors in interacting with advanced technologies.	Implement comprehensive training programs for personnel interacting with advanced technologies. Emphasize a culture of continuous learning and improvement. Conduct usability studies to identify and address challenges in human-technology interfaces. Establish clear communication channels and protocols for reporting and addressing issues arising from human-technology interactions.

Cont. table 4.

Integration Costs and Resource Allocation Challenges	Integrating RCA with Industry 4.0 may incur substantial costs, including investments in technology, training, and system integration. Resource allocation challenges may arise due to competing priorities.	Conduct a cost-benefit analysis to justify integration investments. Prioritize critical areas for integration based on their impact on overall operational efficiency. Explore collaboration with technology partners and vendors for cost-effective solutions. Implement a phased approach to integration to manage costs and resource allocation effectively. Consider leveraging open-source solutions and industry best practices for cost-effective integration.
Lack of Standardization and Compatibility	Lack of standardization in data formats, communication protocols, and technology interfaces across Industry 4.0 systems can hinder seamless integration and complicate RCA efforts.	Advocate for industry-wide standardization efforts and adopt common protocols. Ensure compatibility by selecting technologies that adhere to widely accepted standards. Collaborate with industry partners to establish interoperability standards. Work closely with vendors to ensure that solutions are compatible with existing systems and can support the desired level of integration.
Cybersecurity Risks	The integration of RCA with Industry 4.0 introduces cybersecurity risks, as increased connectivity may expose systems to potential vulnerabilities and cyber threats.	Implement robust cybersecurity measures, including encryption, authentication, and access controls. Regularly update and patch software to address known vulnerabilities. Conduct thorough risk assessments and penetration testing. Foster a cybersecurity-aware culture through training and awareness programs. Collaborate with cybersecurity experts and stay informed about emerging threats and best practices in the rapidly evolving landscape of cybersecurity.
Expertise and Skill Gap	Integrating RCA with Industry 4.0 may face challenges due to a lack of expertise and a skill gap among personnel in handling advanced technologies and data analytics.	Invest in training programs to upskill existing personnel. Recruit or collaborate with experts in data analytics, machine learning, and Industry 4.0 technologies. Foster a culture of continuous learning and knowledge-sharing within the organization. Consider partnerships with educational institutions or external consultants to bring in specialized expertise.
Resistance to Change	Employees may resist the changes introduced by RCA integration, such as new technologies, altered workflows, or a shift in organizational culture.	Develop a comprehensive change management plan to communicate the benefits of RCA integration. Involve employees in the decision-making process to address concerns and garner support. Provide training and support during the transition period. Highlight success stories and quick wins to demonstrate the positive impact of RCA integration. Foster a culture that values innovation, adaptability, and continuous improvement.
Data Privacy and Compliance Concerns	The integration of RCA with Industry 4.0 involves handling sensitive data, raising concerns about data privacy and compliance with regulations such as GDPR.	Implement robust data privacy policies and compliance measures. Conduct regular audits to ensure adherence to data protection regulations. Employ encryption and anonymization techniques to protect sensitive information. Collaborate with legal and compliance experts to stay updated on relevant regulations. Educate personnel about data privacy best practices and compliance requirements. Consider adopting privacy-enhancing technologies to minimize the risk of data breaches.

Cont. table 4.

Complex Supply Chain Dynamics	Root causes of issues within the supply chain can be complex, involving multiple stakeholders, global logistics, and dynamic market conditions.	Employ advanced supply chain analytics to gain visibility into complex dynamics. Collaborate closely with suppliers and partners to share information and address challenges collectively. Utilize blockchain or other traceability technologies to enhance transparency and trace root causes through the supply chain. Develop contingency plans for supply chain disruptions and build resilience through diversified sourcing and flexible logistics strategies.
Legacy System Integration Challenges	Legacy systems in Industry 4.0 environments may pose challenges in integrating with modern RCA technologies, leading to compatibility issues and data silos.	Develop a phased approach to legacy system integration, starting with essential components. Explore middleware solutions that facilitate communication between legacy and modern systems. Prioritize updates or replacements for legacy systems that pose significant integration challenges. Leverage APIs and standard data formats to improve compatibility between legacy and new systems. Engage with vendors that specialize in retrofitting or upgrading legacy systems for Industry 4.0 compatibility.
Overemphasis on Technology Solutions	There might be an overemphasis on adopting new technologies without addressing underlying organizational or process-related issues that contribute to root causes.	Conduct thorough organizational assessments to identify systemic issues beyond technological considerations. Implement a holistic approach that includes organizational restructuring, process optimization, and cultural change alongside technology adoption. Prioritize addressing fundamental issues in workflows, communication, and collaboration to ensure the effectiveness of RCA integration beyond technology alone.
Limited Scalability and Flexibility	RCA solutions may face limitations in scalability and adaptability to evolving Industry 4.0 requirements, hindering their effectiveness in dynamic environments.	Choose RCA solutions that are scalable and adaptable to changing business needs. Regularly review and update RCA processes to align with evolving technologies and industry standards. Implement modular and flexible solutions that can be easily integrated with new technologies and accommodate future expansions. Stay informed about emerging technologies and trends to proactively address scalability challenges.

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 Root Cause Analysis (RCA) in Industry 4.0 conditions represents a strategic and indispensable approach to problem-solving within the dynamic landscape of advanced technologies and interconnected systems. Root Cause Analysis serves as a powerful tool, allowing organizations to dissect multifaceted issues that may arise in the convergence of physical and digital systems. Its systematic investigative approach is crucial for understanding

and mitigating problems stemming from the integration of smart technologies, automation, and data-driven processes.

The complexities and interconnectedness inherent in Industry 4.0 systems elevate the significance of Root Cause Analysis. In this context, RCA enables organizations to navigate the intricate web of factors influencing the performance of smart manufacturing processes, cyber-physical systems, and the Internet of Things (IoT). By identifying the fundamental causes of disruptions or inefficiencies, Industry 4.0 enterprises can develop targeted solutions that address the heart of the problem. Moreover, as Industry 4.0 emphasizes real-time data collection and analysis, Root Cause Analysis becomes instrumental in deciphering patterns and correlations within the data deluge. Whether addressing glitches in production lines, cybersecurity breaches, or malfunctions in IoT devices, RCA facilitates a comprehensive examination of events, leading to more informed decision-making and proactive problem resolution.

The purpose of this publication is to underscore the usage of the Root Cause Analysis approach in Industry 4.0 conditions, highlighting its role as a strategic method for problem-solving. The fundamentals of Root Cause Analysis involve a systematic and holistic investigation into the underlying factors contributing to an issue. This method aims not only to address surface-level symptoms but to prevent the recurrence of problems by understanding and rectifying their fundamental reasons. The integration of RCA into Industry 4.0 practices aligns with the overarching goal of achieving predictive maintenance and minimizing downtime. By understanding the root causes of equipment failures or system malfunctions, organizations can implement predictive analytics and preventive measures, optimizing operational efficiency and reducing the risk of costly disruptions.

In the landscape of Industry 4.0, RCA is increasingly integral, leveraging digitalization and advanced technologies to reshape industrial processes. The integration of RCA plays a crucial role in identifying and mitigating issues at their core, using technologies like IoT sensors, machine learning, and digital twin technology. This integration extends to various aspects of Industry 4.0, including smart manufacturing systems, predictive maintenance, interconnected supply chains, and addressing cybersecurity incidents. Table 1 outlines the key principles of Root Cause Analysis, forming the foundation for an effective problem-solving process. These principles include a systematic approach, holistic investigation, data-driven analysis, multidisciplinary perspective, proactive problem-solving, iterative process, use of analytical tools, and a focus on continuous improvement.

Table 2 provides examples of how Root Cause Analysis is integrated into Industry 4.0, illustrating its relevance in addressing challenges and optimizing processes. This integration encompasses digitalization and data analytics, smart manufacturing systems, predictive maintenance, interconnected supply chains, cybersecurity incidents, digital twin technology, real-time monitoring, cross-functional collaboration, supply chain traceability, human-machine interaction, advanced sensor integration, and machine learning applications. Table 3

enumerates the advantages of Root Cause Analysis integration with Industry 4.0, emphasizing proactive issue resolution, enhanced operational efficiency, cost reduction through predictive maintenance, improved quality and productivity, data-driven decision-making, prevention of recurring issues, cross-functional collaboration, optimized supply chain performance, and enhanced cybersecurity resilience.

Table 4 delves into the challenges associated with Root Cause Analysis integration with Industry 4.0, offering a comprehensive view of the problems and suggested overcoming strategies. These challenges include data overload and complexity, interconnected systems challenges, human-technology interaction issues, integration costs and resource allocation challenges, lack of standardization and compatibility, cybersecurity risks, expertise and skill gap, resistance to change, data privacy and compliance concerns, complex supply chain dynamics, legacy system integration challenges, overemphasis on technology solutions, and limited scalability and flexibility.

The usage of Root Cause Analysis in Industry 4.0 conditions signifies a strategic approach to problem-solving in the face of advanced technologies and interconnected systems. As industries continue to embrace the transformative capabilities of the fourth industrial revolution, the application of RCA becomes indispensable for fostering resilience, continuous improvement, and the sustainable success of organizations operating in this dynamic and technologically-driven landscape.

References

1. Almeida, S., Abreu, L.P.M. (2024). The Quality Manager in the Industry 4.0 Era. *Lecture Notes in Mechanical Engineering*, 468–474.
2. Alrabadi, T.D.S., Talib, Z.M., Abdullah, N.A.B. (2023). The role of Quality 4.0 in supporting digital transformation: Evidence from telecommunication industry. *International Journal of Data and Network Science, 7(2)*, 717–728.
3. Amat-Lefort, N., Barravecchia, F., Mastrogiacomo, L. (2023). Quality 4.0: big data analytics to explore service quality attributes and their relation to user sentiment in Airbnb reviews. *International Journal of Quality and Reliability Management*, *40(4)*, 990–1008.
4. Antony, J., McDermott, O., Sony, M., Cudney, E.A., Doulatabadi, M. (2023). Benefits, challenges, critical success factors and motivations of Quality 4.0 – A qualitative global study. *Total Quality Management and Business Excellence*, *34(7-8)*, 827–846.
5. Antony, J., Sony, M., McDermott, O., Jayaraman, R., Flynn, D. (2023). An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions. *International Journal of Quality and Reliability Management*, *40(2)*, 582–606.

6. Antony, J., Swarnakar, V., Sony, M., McDermott, O., Jayaraman, R. (2023). How do organizational performances vary between early adopters and late adopters of Quality 4.0? An exploratory qualitative study. *TQM Journal*.
7. Barsalou, M. (2023). Root Cause Analysis in Quality 4.0: A Scoping Review of Current State and Perspectives. *TEM Journal, 12(1),* 73–79.
8. Bousdekis, A., Lepenioti, K., Apostolou, D., Mentzas, G. (2023). Data analytics in quality 4.0: literature review and future research directions. *International Journal of Computer Integrated Manufacturing, 36(5),* 678–701.
9. Escobar, C.A., Macias-Arregoyta, D., Morales-Menendez, R. (2023). The decay of Six Sigma and the rise of Quality 4.0 in manufacturing innovation. *Quality Engineering*.
10. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny R., Grebski, W.W. (2023). Energy Behaviors of Prosumers in Example of Polish Households. *Energies, 16(7), 3186*; https://doi.org/10.3390/en16073186.
11. Gimerská, V., Šoltés, M., Mirdala, R. (2023). Improving Operational Efficiency through Quality 4.0 Tool: Blockchain Implementation and Subsequent Market Reaction. *Quality Innovation Prosperity, 27(2),* 16–32.
12. Jokovic, Z., Jankovic, G., Jankovic, S., Supurovic, A., Majstorović, V. (2023). Quality 4.0 in Digital Manufacturing – Example of Good Practice. *Quality Innovation Prosperity, 27(2),* 177–207.
13. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114*, 1-6.
14. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability, 14(4),* 1-23.
15. Khourshed, N., Gouhar, N. (2023). Developing a Systematic and Practical Road Map for Implementing Quality 4.0. *Quality Innovation Prosperity, 27(2),* 96–121.
16. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies, 14(13),* 1-22.
17. Liu, H.-C., Liu, R., Gu, X., Yang, M. (2023). From total quality management to Quality 4.0: A systematic literature review and future research agenda. *Frontiers of Engineering Management, 10(2),* 191–205
18. Maganga, D.P., Taifa, I.W.R. (2023). Quality 4.0 conceptualisation: an emerging quality management concept for manufacturing industries. *TQM Journal, 35(2),* 389–413.
19. Olsen, C. (2023). Toward a Digital Sustainability Reporting Framework in Organizations in the Industry 5.0 Era: An Accounting Perspective. *Lecture Notes in Networks and Systems, 557,* 463-473.

20. Saihi, A., Awad, M., Ben-Daya, M. (2023). Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices – a systematic review. *International Journal of Quality and Reliability Management*, *40(2),* 628–650.
21. Salimbeni, S., Redchuk, A. (2023). Quality 4.0 and Smart Product Development. *Lecture Notes in Networks and Systems, 614*, LNNS, 581–592.
22. Singh, J., Ahuja, I.S., Singh, H., Singh, A. (2023). Application of Quality 4.0 (Q4.0) and Industrial Internet of Things (IIoT) in Agricultural Manufacturing Industry. *AgriEngineering*, *5(1),* 537–565.
23. Sureshchandar, G.S. (2023). Quality 4.0 – a measurement model using the confirmatory factor analysis (CFA) approach. *International Journal of Quality and Reliability Management, 40(1),* 280–303.
24. Wang, Y., Mo, D.Y., Ma, H.L. (2023). Perception of time in the online product customization process. *Industrial Management and Data Systems, 123(2),* pp. 369–385.
25. Yanamandra, R., Abidi, N., Srivastava, R., Kukunuru, S., Alzoubi, H.M. (2023). *Approaching Quality 4.0: The Digital Process Management as a Competitive Advantage*. 2nd International Conference on Business Analytics for Technology and Security, ICBATS 2023.

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THE USAGE OF SMART DOORBELLS IN SMART HOME

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Purpose: The purpose of this publication is to present the usage of smart doorbells in smart homes.
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 smart doorbells into the fabric of smart homes signifies a substantial leap forward in the realms of home automation and security. Originally conceived as a means to alert homeowners to visitors, smart doorbells have undergone a remarkable evolution, emerging as sophisticated devices that significantly contribute to heightened security, convenience, and overall peace of mind. These vigilant guardians offer real-time video surveillance, incorporating features like two-way audio communication, motion detection, and night vision for comprehensive security coverage. Beyond security functions, smart doorbells extend unparalleled convenience through remote access and seamless integration with other smart home devices, allowing users to engage in remote communication, manage settings, and automate various tasks. The incorporation of artificial intelligence and machine learning further enhances their capabilities, introducing features like facial recognition and adaptive learning. Table 1 details the key features, highlighting their diverse contributions to modern smart home environments. The multifaceted advantages of smart doorbells, encompassing security enhancements, convenience, and increased property value, are outlined in Table 2. While acknowledging potential challenges outlined in Table 3, such as privacy concerns and dependence on internet connection, practical solutions are presented, underscoring the ongoing potential for smart doorbells to redefine the management of living spaces as they become increasingly interconnected, secure, and intelligent.

Originality/Value: Detailed analysis of all subjects related to the problems connected with the usage of smart doorbells in smart home.

Keywords: Smart City, energy efficiency, smart home, smart house, digitalization, smart doorbells.

Category of the paper: literature review.

1. Introduction

The integration of smart technology into the fabric of our daily lives has transformed the way we interact with and manage our homes. One such innovation that has gained significant prominence in the realm of smart homes is the smart doorbell. This seemingly unassuming device has evolved beyond its traditional role of merely alerting homeowners to the presence of a visitor at the door. Instead, smart doorbells have become integral components of sophisticated home automation systems, offering a plethora of features and benefits that enhance both security and convenience (Chaudhari et al., 2023).

At its core, a smart doorbell is a connected device equipped with a camera and various sensors that allow it to capture and transmit real-time video and audio feeds to the homeowner's smartphone or other connected devices. This live streaming capability enables homeowners to remotely monitor their front door, providing a layer of security and peace of mind, especially when away from home. The visual verification of visitors and package deliveries empowers homeowners to make informed decisions about whether to answer the door, communicate with the visitor, or take appropriate action, all from the convenience of their mobile devices (Raff et al., 2024).

The purpose of this publication is to present the usage of smart window blinds in smart doorbells.

2. Smart doorbells in smart home

Security is a paramount concern for homeowners, and smart doorbells play a pivotal role in bolstering the protective layers of a smart home. With features such as motion detection and night vision, these devices provide round-the-clock surveillance, ensuring that any suspicious activity or unexpected visitors are promptly brought to the homeowner's attention. The ability to record and store video footage locally or in the cloud further contributes to a comprehensive security strategy, serving as a valuable resource in the event of a security incident or the need for evidence (Wu et al., 2023, Ameur et al., 2023).

The convenience offered by smart doorbells extends beyond security concerns. Homeowners can benefit from features like two-way audio communication, allowing them to interact with visitors without physically opening the door. Whether it's instructing a delivery person on where to leave a package or letting a friend know they'll be right down, the ability to communicate remotely enhances overall convenience. Additionally, smart doorbells often integrate with other smart home devices, such as smart locks and lighting systems, creating a seamless and

interconnected ecosystem that can be controlled through a centralized platform or smartphone app (Patheja et al., 2023).

Furthermore, the integration of artificial intelligence (AI) and machine learning technologies in smart doorbells enhances their functionality. Advanced facial recognition algorithms can distinguish between familiar faces and unknown individuals, providing personalized alerts and contributing to a more tailored and efficient user experience. This level of intelligence also enables the device to learn and adapt to the homeowner's preferences over time, refining its ability to filter out false alarms and irrelevant notifications (Douha et al., 2023).

The usage of smart doorbells in smart homes represents a significant leap forward in home automation and security. These devices go beyond the basic function of a traditional doorbell, offering a sophisticated array of features that contribute to enhanced security, convenience, and peace of mind (Raff et al., 2024). As technology continues to advance, the integration of smart doorbells into the broader ecosystem of smart home devices is likely to further redefine the way we experience and manage our living spaces, creating homes that are not only secure but also seamlessly connected and intelligent (Afroz et al., 2024; Sobhani et al., 2023; Ramanujam et al., 2024).

Table 1 contains descriptions of key features of smart doorbells usage. This table provides an overview of the diverse features that contribute to the utility and functionality of smart doorbells in modern smart home environments.

Table 1.
Key features of smart doorbells usage

Key Features of smart doorbells	Description
Video Surveillance	Smart doorbells are equipped with high-definition cameras that provide real-time video feeds of the front door area. This feature enables homeowners to visually verify visitors, monitor deliveries, and enhance overall security.
Two-Way Audio Communication	The inclusion of microphones and speakers allows for seamless two-way communication between homeowners and visitors. This feature facilitates remote conversations, enabling homeowners to instruct delivery personnel, communicate with guests, or deter potential intruders.
Motion Detection	Smart doorbells utilize motion sensors to detect movement in the vicinity of the front door. This feature triggers alerts and recordings, providing homeowners with notifications about activity, even if the doorbell is not pressed.
Night Vision	Equipped with infrared LEDs, smart doorbells offer night vision capabilities, ensuring clear visibility in low-light or nighttime conditions. This enhances security and surveillance round the clock.
Cloud Storage	Many smart doorbells offer cloud storage options for recorded video footage. This allows homeowners to access and review past events remotely, providing a valuable resource for security purposes or in the event of a dispute or incident.
Integration with Smart Home Systems	Smart doorbells often integrate seamlessly with other smart home devices and ecosystems. This integration allows users to create automation scenarios, such as turning on lights or unlocking doors when the doorbell is pressed, enhancing the overall smart home experience.

Cont. table 1.

Facial Recognition	Advanced smart doorbells may feature facial recognition technology, allowing the device to identify and differentiate between familiar faces and unknown individuals. This enhances security and enables personalized notifications based on recognized faces.
Mobile App Control	Homeowners can control and monitor their smart doorbell through dedicated mobile applications. These apps provide a user-friendly interface for accessing live video feeds, adjusting settings, receiving notifications, and managing other aspects of the smart doorbell's functionality.
Wireless Connectivity	Smart doorbells typically connect to home networks via Wi-Fi, eliminating the need for complex wiring. This wireless connectivity not only simplifies installation but also allows for remote access and control through mobile devices, enhancing user convenience.
Artificial Intelligence (AI) Features	Some smart doorbells leverage AI capabilities, such as machine learning algorithms, to improve performance. This includes the ability to learn and adapt to user preferences, refine motion detection accuracy, and provide more intelligent and personalized alerts over time.
Wide-Angle Lens	Wide-angle lenses provide a broader field of view, reducing blind spots and ensuring comprehensive coverage of the front door area. This feature enhances surveillance capabilities, capturing more details in the camera's field of vision.
Multiple User Access	Support for multiple user accounts allows various household members to access and control the smart doorbell through individual smartphones. This collaborative access facilitates shared monitoring and management among family members.
Customizable Motion Zones	Users can define specific areas for motion detection, avoiding unnecessary alerts from passing objects. This customization enhances the precision of the smart doorbell's motion-sensing capabilities, tailoring it to the unique layout of the home.
Weather Resistance	Smart doorbells are designed to withstand various weather conditions, ensuring durability and functionality in rain, snow, or extreme temperatures. Weather-resistant materials contribute to the device's reliability and longevity.
Battery or Wired Options	Smart doorbells offer flexibility in power sources, with options for rechargeable batteries or connection to existing doorbell wiring. Battery-powered models are suitable for homes without wiring, providing versatile installation choices.
Siren or Chime Integration	Integration with additional security features, such as sirens or chimes, enhances the smart doorbell's capabilities. Users can remotely activate a siren for security purposes or customize chime alerts for different scenarios, adding an audible layer to the device's functionality.
Visitor History and Timestamps	Smart doorbells maintain logs of visitor history with timestamps, allowing homeowners to review past events. This comprehensive timeline includes doorbell presses, motion detections, and interactions, providing a detailed record of front-door activity.
Package Detection	Advanced smart doorbells can recognize packages left at the doorstep, sending specific notifications to homeowners about deliveries. This feature enhances convenience for online shoppers, ensuring they are promptly informed about package arrivals.
Third-Party Integration (APIs)	Support for third-party integration through APIs enables connectivity with a broader ecosystem of smart home devices and services. This interoperability expands the functionality of the smart doorbell, allowing users to create more comprehensive and customized smart home setups.
Tamper Detection	Built-in sensors can detect tampering or interference with the smart doorbell, providing alerts if someone attempts to disable or damage the device. Tamper detection adds an extra layer of security, ensuring the device remains operational and effective.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

3. The advantages and problems of using smart doorbells

The utilization of smart doorbells introduces a multitude of advantages that collectively contribute to an elevated level of security, convenience, and overall home management. Foremost among these benefits is the enhancement of home security (Tong et al., 2023; Rhode et al., 2023). Smart doorbells serve as vigilant guardians, offering real-time video surveillance and monitoring of the front door. This capability allows homeowners to visually confirm the identity of visitors, monitor deliveries, and promptly receive alerts regarding any suspicious activity. The integration of two-way audio communication adds an extra layer of control, enabling remote interactions with visitors and acting as a deterrent to potential intruders (Valencia-Arias et al., 2023).

Beyond security, smart doorbells bring a notable degree of convenience and remote access. Through dedicated mobile applications, users can remotely access and manage their smart doorbells from anywhere (Hussain et al., 2023). This functionality facilitates live video streaming, empowering homeowners to stay connected to their residences, make informed decisions about answering the door, and ensure the security of their property even when away. The ability to monitor package deliveries in real time further adds to the convenience, preventing theft and ensuring the timely retrieval of valuable deliveries (Dhaou, 2023).

Smart doorbells seamlessly integrate with other smart home devices, fostering a cohesive and interconnected ecosystem. This integration allows for the automation of various functions, such as adjusting lights or unlocking doors when the doorbell is pressed, enhancing overall smart home efficiency. Additionally, users gain valuable insights into visitor history, timestamps, and recorded interactions, providing a comprehensive record of front-door activity.

Customizable motion detection zones mitigate false alarms, ensuring that users receive relevant alerts tailored to their specific security needs. The weather-resistant design of smart doorbells ensures reliable performance in diverse weather conditions, maintaining functionality regardless of outdoor elements. These devices also contribute to energy efficiency by coordinating with other smart home devices to optimize energy resources (Hussain et al., 2023, Chen et al., 2023).

In addition to these features, smart doorbells offer benefits that extend to increased property value. Homes equipped with advanced security features and smart home technology tend to be more attractive to potential buyers or renters. For family caregivers, smart doorbells serve as a valuable tool for remote monitoring of elderly family members, offering video and audio features to check on their well-being.

Emergency response coordination is facilitated through two-way audio, enabling homeowners to communicate with emergency services or neighbors during critical situations. Some insurance providers offer premium discounts for properties equipped with smart security systems, leading to potential long-term financial benefits for homeowners. Facial recognition

capabilities in smart doorbells enhance safety by allowing homeowners to identify familiar faces and ensure authorized access to the home.

Moreover, smart doorbells foster community safety collaboration, allowing users to share alerts and information about suspicious activities with neighbors. This collective effort contributes to maintaining a secure neighborhood and promotes a sense of community and cooperation. In summary, the advantages of using smart doorbells extend far beyond traditional doorbell functionality, offering a comprehensive and intelligent approach to modern home living (Bsarir-Ozel et al., 2023; Olabode et al., 2023).

Table 2 highlighting the advantages of using smart doorbells in smart home.

Table 2.
Advantages of using smart doorbells

Advantage	Description
Enhanced Security	Smart doorbells significantly enhance home security by providing real-time video surveillance and monitoring of the front door. Homeowners can visually verify visitors, monitor deliveries, and receive instant alerts about suspicious activity, contributing to a proactive approach to home security. The ability to remotely communicate with visitors adds an extra layer of control and deterrence against potential intruders.
Convenience and Remote Access	Smart doorbells offer unparalleled convenience through remote access and control. Homeowners can view live video feeds, communicate with visitors, and manage doorbell settings from anywhere using a dedicated mobile app. This level of remote access enables users to stay connected to their home, make informed decisions about answering the door, and ensure the security of their property, even when away.
Package Monitoring	Smart doorbells provide the ability to monitor package deliveries in real time. Homeowners receive alerts when packages are delivered, preventing theft or ensuring timely retrieval. This feature adds an extra layer of convenience for online shoppers and helps safeguard valuable deliveries.
Deterrence of Intruders	The visible presence of a smart doorbell acts as a deterrent to potential intruders. Knowing that their actions are being recorded and monitored can discourage unauthorized individuals from attempting to breach the property, contributing to a safer living environment.
Integration with Smart Homes	Smart doorbells seamlessly integrate with other smart home devices, creating a cohesive and interconnected ecosystem. This integration allows users to automate various functions, such as turning on lights or unlocking doors when the doorbell is pressed, enhancing overall smart home efficiency.
Visitor Insights and History	Homeowners can access detailed visitor history and insights through smart doorbells. This includes timestamps and recorded interactions, providing a comprehensive record of front-door activity. Analyzing this data can offer valuable insights into daily routines, visitor patterns, and overall home dynamics.
Customizable Motion Detection	Smart doorbells often feature customizable motion detection zones, allowing users to define specific areas for monitoring. This customization minimizes false alarms triggered by unrelated motion, ensuring that users receive relevant alerts tailored to their specific security needs.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

Table 3 highlighting some of the common problems and challenges associated with the problems of using smart doorbells in smart homes.

Table 3.
Problems of using smart doorbells

Problem	Description	Methods of Overcoming
Privacy Concerns	The use of smart doorbells raises privacy concerns as they record and transmit video footage of the front door area. This can lead to potential invasions of privacy for both residents and visitors.	Opt for models with advanced privacy features, such as customizable motion zones, facial blurring, or geofencing. Clearly communicate the presence of a smart doorbell to visitors, and establish rules for when the camera is active or inactive.
Dependence on Internet Connection	Smart doorbells rely on a stable internet connection for proper functionality. In the event of network outages or disruptions, users may experience interruptions in video streaming, communication, and remote access.	Install a reliable and high-speed internet connection. Consider having a backup power source, such as a battery backup or alternative network options (e.g., cellular connectivity) to ensure continuous operation during internet outages.
Initial Cost and Installation	The upfront cost of purchasing and installing a smart doorbell can be relatively high compared to traditional doorbells. Additionally, installation may require technical expertise, potentially adding to the overall cost.	Research and choose budget-friendly models without compromising essential features. Installation costs can be minimized by opting for wireless models that do not require extensive wiring, and some users may choose to install the devices themselves.
Vulnerability to Hacking	Smart doorbells, like any connected device, are susceptible to hacking attempts. If not adequately secured, hackers may gain access to the device, compromising video footage and potentially breaching the homeowner's privacy.	Regularly update firmware and security settings. Use strong, unique passwords for device access. Choose models from reputable manufacturers with a track record of prioritizing security. Consider additional security measures, such as two-factor authentication.
Limited Field of View	Some smart doorbells may have a limited field of view, potentially missing important details or areas around the front door. This limitation could impact the device's effectiveness in providing comprehensive surveillance.	Select models with wider-angle lenses for a broader field of view. Consider additional devices, such as outdoor cameras, to complement the smart doorbell and ensure comprehensive coverage of the front door area.
Power Source Dependence	Smart doorbells are dependent on a power source, whether through hardwiring or rechargeable batteries. Power outages or battery depletion may render the device temporarily nonfunctional, leaving the front door unmonitored.	Choose a smart doorbell with alternative power options, such as battery backup or hardwiring to existing doorbell wiring. Regularly check and replace batteries if applicable, and consider installing backup power sources for added reliability.
Compatibility with Existing Systems	Compatibility issues may arise when integrating smart doorbells with existing home automation systems or other smart devices. This may result in limited functionality or the need for additional equipment to ensure seamless integration.	Prioritize smart doorbells designed to work with popular smart home platforms. Verify compatibility before purchase and consult user reviews or manufacturer support to address any potential compatibility issues.
Weather and Environmental Impact	Smart doorbells may be susceptible to adverse weather conditions, affecting performance and longevity. Exposure to extreme temperatures, rain, or direct sunlight can impact the device's functionality and durability over time.	Choose weather-resistant models designed to withstand various environmental conditions. Install the smart doorbell in a sheltered location, such as under an eave, to minimize exposure to direct sunlight, rain, or extreme temperatures.

Cont. table 3.

Limited Offline Functionality	Some smart doorbells may have limited offline functionality, particularly in the absence of an internet connection. This limitation can hinder basic functions such as remote access, live streaming, and alerts during network outages.	Prioritize smart doorbells with offline functionalities, such as local storage options for video footage. Consider models that can still perform essential functions, such as doorbell chimes, even when the internet connection is temporarily unavailable.
Data Storage Costs	Cloud storage for recorded video footage often incurs additional costs, especially for extended storage durations. This ongoing expense may contribute to the overall cost of ownership and may be a consideration for users on a tight budget.	Opt for smart doorbells with local storage options to minimize reliance on cloud storage. Adjust video storage settings to retain footage for a shorter duration or explore subscription plans that align with budget constraints.
False Alarms and Notifications	Smart doorbells with motion detection capabilities may generate false alarms or notifications triggered by unrelated movement, such as passing cars or animals. This can potentially lead to user frustration and decreased confidence in the device's reliability.	Adjust motion sensitivity settings to minimize false alarms. Utilize customizable motion zones to focus detection on specific areas. Regularly review and update settings based on environmental changes or feedback from false alerts.
Limited Facial Recognition Accuracy	Facial recognition features in smart doorbells may have limitations in accuracy, leading to potential misidentification of familiar or unfamiliar faces. This can impact the effectiveness of personalized notifications and security measures based on recognized individuals.	Understand the limitations of facial recognition technology and set realistic expectations. Regularly update firmware to benefit from improvements. Utilize additional security measures, such as secure access codes, to complement facial recognition.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

4. Conclusion

The integration of smart doorbells into the framework of smart homes represents a significant advancement in home automation and security. Originally designed to alert homeowners to visitors, smart doorbells have evolved into sophisticated devices with features that contribute to enhanced security, convenience, and peace of mind.

Smart doorbells serve as vigilant guardians, providing real-time video surveillance and monitoring of the front door area. The inclusion of features such as two-way audio communication, motion detection, and night vision contributes to comprehensive security coverage. These devices empower homeowners to visually verify visitors, monitor deliveries, and receive timely alerts about any suspicious activity, fostering a proactive approach to home security.

Beyond security, the convenience offered by smart doorbells extends to remote access and integration with other smart home devices. Homeowners can remotely communicate with visitors, manage doorbell settings, and even automate functions like unlocking doors or turning on lights. The seamless integration of artificial intelligence (AI) and machine learning enhances the functionality of smart doorbells, providing advanced features such as facial recognition and adaptive learning, further refining the user experience over time.

Table 1 highlights key features of smart doorbell usage, emphasizing the diverse capabilities that contribute to their utility in modern smart home environments. The advantages of using smart doorbells are multifaceted, encompassing enhanced security, convenience, and increased property value. These devices not only serve as a technological deterrent to intruders but also facilitate remote monitoring of elderly family members, emergency response coordination, and potential insurance premium discounts. Table 2 provides a detailed overview of these advantages, showcasing how smart doorbells contribute to a safer, more connected, and intelligent home environment. However, it's essential to acknowledge the potential challenges associated with smart doorbell usage, as outlined in Table 3. Privacy concerns, dependence on internet connection, installation costs, and vulnerability to hacking are among the challenges users may face.

Despite these challenges, methods of overcoming each problem are presented, offering practical solutions to ensure a secure and effective smart doorbell experience. As technology continues to advance, smart doorbells are poised to redefine the way we manage our living spaces, creating homes that are not only secure but also seamlessly connected and intelligent.

References

1. Afroz, A., Khamari, S.S., Behera, R.K. (2024). Solar Powered Smart Home Automation and Smart Health Monitoring with IoT. *Lecture Notes in Networks and Systems, 728*. LNNS, 169–182.
2. Alsaedi, M.K., Riccio, R.E., Sharma, A., Romero, L.M., Sonkusale, S. (2023). Smart sensing flexible sutures for glucose monitoring in house sparrows. *The Analyst, 148(22),* 5714–5723.
3. Ameur, A., Berrada, A., Emrani, A. (2023). Intelligent energy management system for smart home with grid-connected hybrid photovoltaic/gravity energy storage system. *Journal of Energy Storage, 72*, 108525.
4. Basarir-Ozel, B., Nasir, V.A., Turker, H.B. (2023). Determinants of smart home adoption and differences across technology readiness segments. *Technological Forecasting and Social Change, 197,* 122924.

5. Chaudhari, R.R., Joshi, K.K., Joshi, N., Pandey, A.K. (2023). *Smart and ecofriendly intelligent house based on iot and simulation using a Cisco networking simulator, Intelligent Sensor Node-Based Systems: Applications in Engineering and Science*, 259–273.
6. Chen, H., Zhang, Y., Wang, L. (2023). A study on the quality evaluation index system of smart home care for older adults in the community ——based on Delphi and AHP. *BMC Public Health, 23(1),* 411.
7. Dhaou, I.B. (2023). Design and Implementation of an Internet-of-Things-Enabled Smart Meter and Smart Plug for Home-Energy-Management System. *Electronics, 12(19),* 4041.
8. Douha, N.Y.-R., Renaud, K., Taenaka, Y., Kadobayashi, Y. (2023). Smart home cybersecurity awareness and behavioral incentives. *Information and Computer Security, 31(5),* 545–575.
9. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W., Romanyshyn, T. (2023). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies, 16(21),* 7364.
10. Gøthesen, S., Haddara, M., Kumar, K.N. (2023). Empowering homes with intelligence: An investigation of smart home technology adoption and usage. *Internet of Things (Netherlands), 24,* 100944.
11. Huda, N.U., Ahmed, I., Adnan, M., Ali, M., Naeem, F. (2024). Experts and intelligent systems for smart homes' Transformation to Sustainable Smart Cities: A comprehensive review. *Expert Systems with Applications, 238,* 122380.
12. Hussain, S., Azim, M.I., Lai, C., Eicker, U. (2023). New coordination framework for smart home peer-to-peer trading to reduce impact on distribution transformer. *Energy, 284,* 129297.
13. Hussain, S., Imran Azim, M., Lai, C., Eicker, U. (2023). Multi-stage optimization for energy management and trading for smart homes considering operational constraints of a distribution network. *Energy and Buildings, 301,* 113722.
14. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114,* 1-6.
15. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability, 14(4),* 1-23.
16. Olabode, S., Owens, R., Zhang, V.N., Shi, L., Chambers, D. (2023). Complex online harms and the smart home: A scoping review. *Future Generation Computer Systems, 149,* 664–678.
17. Patheja, P.S., Kalra, Y., Tyagi, A. Patheja, P.S., Kalra, Y., Tyagi, A. (2023). *Intelligent Sensor Node-Based Systems: Applications in Engineering and Science*, 155–175.

18. Raff, S., Rose, S., Huynh, T. (2024). Perceived creepiness in response to smart home assistants: A multi-method study. *International Journal of Information Management, 74,* 102720.
19. Ramanujam, E., Kalimuthu, S., Harshavardhan, B.V., Perumal, T. (2024). Improvement in Multi-resident Activity Recognition System in a Smart Home Using Activity Clustering. *IFIP Advances in Information and Communication Technology, 683*, AICT, 316–334.
20. Rohde, F., von Andrian, N., Lange, S. (2023). Threat, fixable or opportunity? Contested smart home futures in the German social media debate. *Energy Research and Social Science, 106,* 103306.
21. Sobhani, A., Khorshidi, F., Fakhredanesh, M. (2023). DeePLS: Personalize Lighting in Smart Home by Human Detection, Recognition, and Tracking. *SN Computer Science, 4(6),* 773.
22. Tong, Z., Mansouri, S.A., Huang, S., Rezaee Jordehi, A., Tostado-Véliz, M. (2023). The role of smart communities integrated with renewable energy resources, smart homes and electric vehicles in providing ancillary services: A tri-stage optimization mechanism. *Applied Energy, 351,* 121897.
23. Valencia-Arias, A., Cardona-Acevedo, S., Gómez-Molina, S., Gonzalez-Ruiz, J.D., Valencia, J. (2023). Smart home adoption factors: A systematic literature review and research agenda, *PLoS ONE, 18(10 October),* e0292558.
24. Wu, D., Feng, W., Li, T., Yang, Z. (2023). Evaluating the intelligence capability of smart homes: A conceptual modeling approach. *Data and Knowledge Engineering, 148*, 102218.

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THE USAGE OF SMART WINDOW BLINDS IN SMART HOME

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Purpose: The purpose of this publication is to present the usage of smart window blinds in smart homes.
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 smart window blinds into the realm of smart homes signifies a significant technological advancement, elevating traditional window treatments to sophisticated components that redefine the modern living space. The fusion of automation and connectivity within smart window blinds yields a plethora of benefits, turning homes into intelligent and responsive environments. The seamless incorporation of these blinds into various smart home ecosystems grants users unprecedented control over natural light, privacy, and energy consumption. Automated features, including scheduled programming and sensor-based adjustments, introduce unparalleled convenience by eliminating the need for constant manual intervention. Energy efficiency takes center stage as the blinds intelligently regulate sunlight, contributing to effective temperature control and reducing reliance on heating and cooling systems. Privacy and security concerns are effectively addressed through customizable settings, while safety features cater to households with children and pets. The integration with smart lighting systems enhances overall ambiance, creating a cohesive and aesthetically pleasing living space. Data-driven insights into energy consumption patterns empower homeowners to make informed decisions, fostering a more conscious and efficient approach to home management. Despite challenges, such as initial costs and technological dependencies, the transformative evolution of smart window blinds positions them as a testament to the seamless integration of intelligence and automation, shaping connected, efficient, and responsive living environments for homeowners.
Originality/Value: Detailed analysis of all subjects related to the problems connected with the usage of smart window blinds in smart home.

Keywords: Smart City, energy efficiency, smart home, smart house, digitalization, smart window blinds.

Category of the paper: literature review.

1. Introduction

The integration of smart window blinds into the realm of smart homes has emerged as a significant advancement, transforming traditional window treatments into technologically sophisticated components. Smart window blinds leverage automation and connectivity to enhance convenience, energy efficiency, and overall home management. This innovative solution goes beyond mere aesthetics, offering a range of benefits that contribute to a more intelligent and responsive living environment.

One of the primary advantages of smart window blinds lies in their ability to seamlessly integrate with various smart home ecosystems. These blinds can be easily connected to central home automation systems, allowing users to control them remotely through dedicated applications or voice commands. This connectivity fosters a holistic approach to managing the home environment, offering users unprecedented control over natural light, privacy, and energy consumption (Olabode et al., 2023).

The purpose of this publication is to present the usage of smart window blinds in smart home.

2. Smart window blinds in smart home

The automated functionality of smart window blinds brings about a new level of convenience for homeowners. Through scheduled programming or sensor-based automation, these blinds can adjust themselves based on factors such as time of day, weather conditions, or even the user's preferences (Dhaou, 2023). This hands-free operation eliminates the need for manual adjustments and ensures that the blinds respond dynamically to the changing environment, creating an optimal living space (Chen et al., 2023).

Energy efficiency is a key focal point in the deployment of smart window blinds. By intelligently regulating the amount of sunlight entering a room, these blinds contribute to effective temperature control. During hot summer days, the blinds can automatically tilt to block out excessive sunlight, reducing the need for air conditioning and consequently lowering energy consumption. Conversely, in colder seasons, the blinds can be programmed to maximize sunlight penetration, harnessing natural warmth and minimizing reliance on heating systems (Gajdzik et al., 2023; Jonek-Kowalska, Wolniak, 2021, 2022).

Privacy and security are paramount concerns for homeowners, and smart window blinds address these by offering customizable settings for different times of the day or night. Residents can remotely adjust the blinds to create a secure and private atmosphere, deterring potential intruders while maintaining a comfortable living environment. This level of control enhances the overall safety and peace of mind within the smart home ecosystem (Patheja et al., 2023).

Additionally, the integration of sensors in smart window blinds allows them to respond to environmental changes in real-time (Valencia-Arias et al., 2023). For instance, the blinds can be programmed to close automatically during inclement weather to protect the interior from rain or snow. This responsiveness adds an extra layer of protection to the home, safeguarding it against potential weather-related damages (Tong et al., 2023).

In conclusion, the incorporation of smart window blinds into smart homes signifies a leap forward in home automation technology. Beyond their aesthetic appeal, these blinds offer a myriad of practical benefits, from enhanced convenience and energy efficiency to increased privacy and security. As technology continues to evolve, smart window blinds stand as a testament to the seamless integration of intelligence and automation, shaping a more connected, efficient, and responsive living environment for homeowners (Ameur et al., 2023; Basarir-Ozel et al., 2023).

Table 1 contains descriptions of key features of smart window blinds usage.

Table 1.
Key features of smart window blinds usage

Key Features of window blind usage	Description
Automation and Remote Control	Smart window blinds can be automated and controlled remotely through dedicated applications or voice commands, allowing users to adjust them without manual intervention. This feature enhances convenience and accessibility.
Integration with Smart Home Ecosystems	These blinds seamlessly integrate with various smart home ecosystems, enabling users to incorporate them into centralized home automation systems. This integration promotes a cohesive and interconnected smart home environment.
Scheduled Programming	Users can program the blinds to operate on a schedule, adjusting themselves based on specific times of the day or night. This feature eliminates the need for constant manual adjustments and ensures optimal use of natural light.
Sensor-Based Automation	Smart window blinds can respond to environmental changes through sensors. For example, they can adjust based on factors such as sunlight intensity, weather conditions, or temperature, providing real-time adaptability.
Energy Efficiency	By regulating sunlight and temperature, smart window blinds contribute to energy efficiency. They can automatically block out excessive sunlight during hot days, reducing the need for air conditioning, and maximize sunlight penetration in colder seasons to minimize heating requirements.
Privacy and Security Settings	Users can customize privacy and security settings for different times of the day or night. This feature enhances security by deterring potential intruders and ensures privacy when needed, contributing to a safe and comfortable living environment.
Real-Time Responsiveness	The inclusion of sensors enables smart window blinds to respond in real-time to environmental changes, such as closing automatically during inclement weather. This feature adds an extra layer of protection to the home, safeguarding it against potential damages.
Voice Control Integration	Smart window blinds often support voice control, allowing users to adjust them using popular virtual assistants like Amazon Alexa or Google Assistant. This hands-free control further enhances the user experience and accessibility.
App-Based Customization	Dedicated applications enable users to customize various settings, such as blind tilt, height, and scheduling. This level of personalization ensures that the blinds cater to individual preferences and specific room requirements.

Cont. table 1.

Energy Monitoring and Reporting	Some smart window blinds come equipped with energy monitoring features, providing users with insights into their energy consumption patterns. This data empowers homeowners to make informed decisions about energy usage.
Integration with Weather Forecasts	By integrating with weather forecasts, smart window blinds can proactively adjust based on predicted weather conditions. This feature anticipates changes and ensures that the blinds respond accordingly to maintain comfort and protection.
Child and Pet Safety Features	Smart window blinds often include safety features, such as cordless designs or motorized mechanisms, to prevent accidents involving children or pets. This prioritizes the well-being of household members.
Adaptive Learning Algorithms	Some advanced smart window blinds leverage adaptive learning algorithms to understand user preferences over time. The blinds can then autonomously adjust based on historical data, optimizing their operation to suit user habits.
Integration with Smart Lighting	Integration with smart lighting systems allows for synchronized control. Smart window blinds can work in tandem with smart lights, creating harmonized lighting conditions that enhance the overall ambiance of the room.
Manual Override and Manual Control	Despite the automation, smart window blinds typically offer manual override options. Users can manually adjust the blinds when needed, providing flexibility and control in situations where manual intervention is preferred.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

3. The advantages and problems of using smart window blinds

The utilization of smart window blinds in modern homes presents a multitude of advantages that extend beyond mere aesthetic enhancements. One of the primary benefits lies in the realm of energy efficiency, as these blinds are equipped to intelligently regulate natural light ingress. By automatically adjusting themselves based on environmental conditions, smart window blinds contribute significantly to energy conservation, reducing the reliance on heating and cooling systems and subsequently lowering utility costs. In terms of convenience and automation, the integration of smart window blinds allows for effortless control (Huda et al., 2024). Through remote operation via dedicated applications or voice commands, users can seamlessly adjust the blinds, eliminating the need for manual intervention and enhancing the overall ease of daily living (Douha et al., 2023). The customization and personalization options afforded by these blinds further enhance their appeal, enabling users to tailor settings to suit individual preferences for tilt, height, and scheduling, ensuring a harmonious fit with the unique requirements of each room (Chaudhari et al., 2023).

Privacy and security are paramount concerns for homeowners, and smart window blinds address these by offering scheduled adjustments that not only deter potential intruders but also provide a convenient means of maintaining privacy. Real-time responsiveness, facilitated by sensors integrated into the blinds, ensures adaptive reactions to sudden changes in environmental conditions, adding an extra layer of protection to the home (Ramanujam et al.,

2024). The seamless integration of smart window blinds into broader smart home systems fosters a holistic home automation experience. This interconnectedness allows users to manage these blinds alongside other smart devices, creating a unified and cohesive environment (Alsaedi et al., 2023).

Safety features are another noteworthy advantage, with many smart window blinds designed to prioritize the well-being of household members (Raff et al., 2024). Cordless designs and motorized mechanisms reduce potential hazards, particularly for children and pets. Furthermore, the integration of smart window blinds with smart lighting systems enhances the overall ambiance of a room. Synchronized control between blinds and lights creates a cohesive atmosphere, contributing to a more comfortable and aesthetically pleasing living space (Wu et al., 2023).

Lastly, some smart window blinds offer data-driven insights into energy consumption patterns. This information empowers homeowners to make informed decisions about energy usage, fostering a more conscious and efficient approach to home management. In conclusion, the adoption of smart window blinds goes beyond convenience and aesthetics, presenting a comprehensive solution that addresses energy efficiency, security, customization, and overall home automation (Sobhani et al., 2023).

Table 2 highlighting the advantages of using smart window blinds in smart home.

Table 2.
Advantages of using smart window blinds

Advantage	Description
Energy Efficiency	Smart window blinds contribute to energy efficiency by automatically regulating the amount of sunlight entering a room. This helps in reducing reliance on heating and cooling systems, leading to lower energy consumption and utility costs.
Convenience and Automation	The automation and remote control capabilities of smart window blinds add a high level of convenience to daily life. Users can effortlessly adjust the blinds with the touch of a button or through voice commands, eliminating the need for manual operation.
Customization and Personalization	Smart window blinds offer extensive customization options, allowing users to tailor settings such as tilt, height, and scheduling according to individual preferences. This level of personalization ensures that the blinds align with the specific needs of each room.
Improved Privacy and Security	With the ability to set privacy and security schedules, smart window blinds enhance home security by creating a deterrent for potential intruders. They also offer a convenient way to maintain privacy by automatically adjusting based on the time of day or night.
Real-Time Responsiveness	Equipped with sensors, smart window blinds respond in real-time to environmental changes. Whether it's adjusting to sudden changes in sunlight intensity or closing during inclement weather, this responsiveness adds an extra layer of protection to the home.
Integration with Smart Home Systems	Smart window blinds seamlessly integrate with broader smart home ecosystems, allowing users to manage them alongside other smart devices. This integration creates a unified and interconnected home automation experience.
Safety Features	Many smart window blinds incorporate safety features such as cordless designs or motorized mechanisms, reducing potential hazards for children and pets. These safety measures prioritize the well-being of household members.

Cont. table 2.

Enhanced Ambiance with Lighting Integration	Integration with smart lighting systems enables synchronized control, creating a cohesive ambiance. Smart window blinds can adjust in tandem with smart lights, enhancing the overall atmosphere of a room.
Data-Driven Insights	Some smart window blinds offer energy monitoring features, providing users with valuable insights into their energy consumption patterns. This data empowers homeowners to make informed decisions about energy usage and efficiency.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

Table 3 highlighting some of the common problems and challenges associated with the problems of using smart window blinds in smart homes.

Table 3.
Problems of using smart window blinds

Problem	Description	Methods of Overcoming
Initial Cost	The upfront cost of acquiring and installing smart window blinds can be higher compared to traditional blinds. This initial investment may pose a financial barrier for some homeowners.	Consider exploring budget-friendly options, waiting for sales or discounts, or gradually implementing smart blinds in specific rooms rather than the entire house. As technology advances, costs may decrease over time.
Dependence on Technology	Smart window blinds rely on technology for operation, and in the event of a technological malfunction, power outage, or connectivity issues, manual operation may be compromised.	Ensure the blinds have a manual override option for situations where technology may fail. Additionally, investing in reliable backup power sources, such as uninterruptible power supplies (UPS), can mitigate issues during power outages.
Compatibility Challenges	Compatibility issues may arise when integrating smart window blinds with existing home automation systems or when using blinds from different manufacturers. Incompatibility can lead to functionality limitations.	Prioritize selecting smart blinds that are compatible with your existing smart home ecosystem. Choose products from reputable manufacturers that adhere to widely accepted communication standards, such as Zigbee or Z-Wave, to ensure seamless integration.
Maintenance and Upkeep	Smart window blinds, like any technology, may require regular maintenance, software updates, or troubleshooting. Failure to address maintenance needs can result in decreased performance or malfunction.	Stay informed about software updates provided by the manufacturer and perform regular checks on the blinds. Opt for products with a user-friendly interface and reliable customer support for assistance in case of issues.
Limited Design Options	The selection of smart window blinds may be limited compared to traditional blinds, especially in terms of design, colors, and materials. This limitation may impact the aesthetic choices available to homeowners.	Research and choose smart blinds from manufacturers that prioritize a diverse range of design options. Alternatively, consider integrating smart blind systems with traditional blinds for greater design flexibility.
Privacy and Security Concerns	As with any connected device, smart window blinds pose potential privacy and security risks if not adequately secured. Unauthorized access to the blinds' controls could compromise the privacy of the occupants.	Implement strong, unique passwords for smart home devices, enable two-factor authentication when available, and regularly update device passwords. Regularly review and update the security settings on the connected smart home hub to enhance overall security.

Cont. table 3.

Learning Curve for Users	Some users may find the transition to operating smart window blinds less intuitive, especially if they are not familiar with smart home technology. The learning curve may impact the overall user experience.	Manufacturers should provide comprehensive user manuals and support materials. Additionally, offering user-friendly mobile applications with intuitive interfaces and providing customer support can help users adapt more easily to the technology.

Source: (Gøthesen et al., 2023; Alsaedi et al., 2023; Chaudhari et al., 2023; Huda et al., 2024; Husain et al., 2023; Rhode et al., 2023; Basarir-Ozel et al., 2023; Tong et al., 2023; Chen et al., 2023; Douha et al., 2023; Sobhani et al., 2023).

4. Conclusion

In conclusion, the integration of smart window blinds into the domain of smart homes represents a notable technological leap, transcending traditional window treatments into sophisticated components. The marriage of automation and connectivity in smart window blinds offers a myriad of advantages, transforming homes into intelligent and responsive environments.

The seamless integration of smart window blinds with various smart home ecosystems allows for unprecedented control over natural light, privacy, and energy consumption. The automated features, such as scheduled programming and sensor-based adjustments, introduce a new level of convenience for homeowners, eliminating the need for constant manual intervention. Energy efficiency takes center stage as these blinds intelligently regulate sunlight, contributing to effective temperature control and reducing reliance on heating and cooling systems.

Privacy and security concerns are effectively addressed through customizable settings, allowing residents to create a secure and private atmosphere at different times of the day or night. The inclusion of sensors ensures real-time responsiveness, adding an extra layer of protection against environmental changes.

The advantages of smart window blinds extend beyond functionality, encompassing safety features for households with children and pets. Furthermore, the integration with smart lighting systems enhances the overall ambiance of a room, creating a cohesive and aesthetically pleasing living space. The provision of data-driven insights into energy consumption patterns empowers homeowners to make informed decisions, promoting a more conscious and efficient approach to home management.

While the benefits are compelling, it's essential to acknowledge the challenges associated with smart window blinds. The initial cost may be a barrier for some homeowners, but this can be mitigated by exploring budget-friendly options or gradually implementing smart blinds in specific rooms. Dependence on technology poses a risk in case of malfunctions or power outages, emphasizing the importance of manual override options and backup power sources.

Compatibility challenges can be addressed by selecting smart blinds that adhere to widely accepted communication standards. Regular maintenance and software updates are crucial for optimal performance, and the learning curve for users can be eased through comprehensive user manuals and user-friendly interfaces provided by manufacturers.

The usage of smart window blinds in smart homes represents a transformative evolution in home automation. Despite challenges, the numerous advantages, ranging from energy efficiency to enhanced security and ambiance, position smart window blinds as a testament to the seamless integration of intelligence and automation in shaping connected, efficient, and responsive living environments for homeowners.

References

1. Afroz, A., Khamari, S.S., Behera, R.K. (2024). Solar Powered Smart Home Automation and Smart Health Monitoring with IoT. *Lecture Notes in Networks and Systems, 728*. LNNS, 169–182.
2. Alsaedi, M.K., Riccio, R.E., Sharma, A., Romero, L.M., Sonkusale, S. (2023). Smart sensing flexible sutures for glucose monitoring in house sparrows. *The Analyst, 148(22),* 5714–5723.
3. Ameur, A., Berrada, A., Emrani, A. (2023). Intelligent energy management system for smart home with grid-connected hybrid photovoltaic/gravity energy storage system. *Journal of Energy Storage, 72*, 108525.
4. Basarir-Ozel, B., Nasir, V.A., Turker, H.B. (2023). Determinants of smart home adoption and differences across technology readiness segments. *Technological Forecasting and Social Change, 197,* 122924.
5. Chaudhari, R.R., Joshi, K.K., Joshi, N., Pandey, A.K. (2023). *Smart and ecofriendly intelligent house based on iot and simulation using a Cisco networking simulator, Intelligent Sensor Node-Based Systems: Applications in Engineering and Science*, 259–273.
6. Chen, H., Zhang, Y., Wang, L. (2023). A study on the quality evaluation index system of smart home care for older adults in the community ——based on Delphi and AHP. *BMC Public Health, 23(1),* 411.
7. Dhaou, I.B. (2023). Design and Implementation of an Internet-of-Things-Enabled Smart Meter and Smart Plug for Home-Energy-Management System. *Electronics, 12(19),* 4041.
8. Douha, N.Y.-R., Renaud, K., Taenaka, Y., Kadobayashi, Y. (2023). Smart home cybersecurity awareness and behavioral incentives. *Information and Computer Security, 31(5),* 545–575.

9. Gajdzik, B., Wolniak, R., Nagaj, R., Grebski, W., Romanyshyn, T. (2023). Barriers to Renewable Energy Source (RES) Installations as Determinants of Energy Consumption in EU Countries. *Energies, 16(21),* 7364.
10. Gøthesen, S., Haddara, M., Kumar, K.N. (2023). Empowering homes with intelligence: An investigation of smart home technology adoption and usage. *Internet of Things (Netherlands), 24*, 100944.
11. Huda, N.U., Ahmed, I., Adnan, M., Ali, M., Naeem, F. (2024). Experts and intelligent systems for smart homes' Transformation to Sustainable Smart Cities: A comprehensive review. *Expert Systems with Applications, 238*, 122380.
12. Hussain, S., Azim, M.I., Lai, C., Eicker, U. (2023). New coordination framework for smart home peer-to-peer trading to reduce impact on distribution transformer. *Energy, 284,* 129297.
13. Hussain, S., Imran Azim, M., Lai, C., Eicker, U. (2023). Multi-stage optimization for energy management and trading for smart homes considering operational constraints of a distribution network. *Energy and Buildings, 301*, 113722.
14. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114*, 1-6.
15. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability, 14(4),* 1-23.
16. Olabode, S., Owens, R., Zhang, V.N., Shi, L., Chambers, D. (2023). Complex online harms and the smart home: A scoping review. *Future Generation Computer Systems, 14*9, 664–678.
17. Patheja, P.S., Kalra, Y., Tyagi, A. Patheja, P.S., Kalra, Y., Tyagi, A. (2023). *Intelligent Sensor Node-Based Systems: Applications in Engineering and Science*, 155–175.
18. Raff, S., Rose, S., Huynh, T. (2024). Perceived creepiness in response to smart home assistants: A multi-method study. *International Journal of Information Management, 74,* 102720.
19. Ramanujam, E., Kalimuthu, S., Harshavardhan, B.V., Perumal, T. (2024). Improvement in Multi-resident Activity Recognition System in a Smart Home Using Activity Clustering. *IFIP Advances in Information and Communication Technology, 683*, AICT, 316–334.
20. Rohde, F., von Andrian, N., Lange, S. (2023). Threat, fixable or opportunity? Contested smart home futures in the German social media debate. *Energy Research and Social Science, 106,* 103306.
21. Sobhani, A., Khorshidi, F., Fakhredanesh, M. (2023). DeePLS: Personalize Lighting in Smart Home by Human Detection, Recognition, and Tracking. *SN Computer Science, 4(6),* 773.
22. Tong, Z., Mansouri, S.A., Huang, S., Rezaee Jordehi, A., Tostado-Véliz, M. (2023). The role of smart communities integrated with renewable energy resources, smart homes

and electric vehicles in providing ancillary services: A tri-stage optimization mechanism. *Applied Energy, 351,* 121897.

23. Valencia-Arias, A., Cardona-Acevedo, S., Gómez-Molina, S., Gonzalez-Ruiz, J.D., Valencia, J. (2023). Smart home adoption factors: A systematic literature review and research agenda, *PLoS ONE, 18(10 October),* e0292558.
24. Wu, D., Feng, W., Li, T., Yang, Z. (2023). Evaluating the intelligence capability of smart homes: A conceptual modeling approach. *Data and Knowledge Engineering, 148,* 102218.

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THE USAGE OF STATISTICAL PROCESS CONTROL (SPC) IN INDUSTRY 4.0 CONDITIONS

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Purpose: The purpose of this publication is to present the usage of Statistical Process Control (SPC) 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 Statistical Process Control (SPC) with Industry 4.0 signifies a transformative shift in quality management, elevating SPC from a conventional monitoring tool to a proactive force in contemporary manufacturing. Originally employed for ensuring consistent quality through process monitoring, SPC's role has been redefined in the Industry 4.0 era, utilizing data analytics, real-time monitoring, and connectivity to offer a comprehensive understanding of the manufacturing ecosystem. Enabled by the Internet of Things (IoT), SPC gains real-time insights into production processes, crucial for swift anomaly identification and issue resolution. Advanced analytics and artificial intelligence enhance SPC's predictive capabilities, enabling proactive measures to maintain product quality. This publication underscores the significance of SPC in Industry 4.0 conditions, emphasizing its roots in statistical principles, systematic process control, and the distinction between common and special cause variations. The integration of SPC with Industry 4.0 and Quality 4.0 leverages technologies for enhanced quality management, emphasizing real-time data monitoring and collaborative, data-driven approaches. While Table 2 outlines specific aspects of SPC integration, highlighting its versatility, Table 3 enumerates the advantages, emphasizing improved visibility and predictive quality management. However, challenges such as data security concerns and technology integration complexity, outlined in Table 4, necessitate strategic solutions. In conclusion, this integration represents a pivotal advancement, positioning SPC as an indispensable asset for organizations seeking quality excellence, operational efficiency, and resilience in the dynamic landscape of modern manufacturing.
Originality/Value: Detailed analysis of all subjects related to the problems connected with the usage of Statistical process Control in Industry 4.0 conditions.

Keywords: Industry 4.0; Quality 4.0, quality management; quality methods, SPC, Statistical Process Control.

Category of the paper: literature review.

1. Introduction

In the traditional manufacturing paradigm, SPC was primarily implemented to monitor and control processes to ensure consistent quality. However, in the era of Industry 4.0, SPC takes on a more dynamic role by harnessing the power of data analytics, real-time monitoring, and connectivity. The advent of the Internet of Things (IoT) allows for the collection of vast amounts of data from sensors and devices throughout the production line.

SPC in Industry 4.0 leverages this data deluge to provide a deeper understanding of the entire manufacturing ecosystem. Real-time analytics enable quick identification of anomalies or deviations in the production process. This agility is crucial in addressing issues promptly, preventing defects, and maintaining overall process stability. Furthermore, the application of advanced analytics and artificial intelligence enhances the predictive capabilities of SPC. By analyzing historical data and identifying patterns, SPC can anticipate potential variations and recommend proactive measures to mitigate risks before they impact product quality. (Barsalou, 2023; Maganga, Taifa, 2023).

The purpose of this publication is to present the usage of Statistical Process Control (SPC) approach in industry 4.0 condition.

2. The basics of Statistical Process Control (SPC) approach

Statistical Process Control (SPC) is a powerful method employed in quality management to ensure that manufacturing processes consistently meet specified standards and produce products of high quality. Rooted in statistical principles, SPC involves the systematic monitoring and control of processes to identify and address variations that could lead to defects. The fundamental concept behind SPC is the recognition that any process will exhibit some degree of inherent variability. Instead of attempting to eliminate all variability, SPC focuses on distinguishing between common cause variation, which is inherent to the process and expected, and special cause variation, which arises sporadically and signals potential issues.

Key components of SPC include the collection and analysis of data, typically through the use of control charts. Control charts graphically display process data over time, allowing operators and managers to discern patterns and trends. The central line on the chart represents the process mean, while upper and lower control limits indicate acceptable variation. Points outside these limits suggest the presence of special cause variation, prompting further investigation and corrective action. Continuous monitoring through SPC not only aids in detecting deviations from the norm but also facilitates proactive adjustments to maintain process stability. By understanding the nature and sources of variation, organizations can enhance efficiency, reduce waste, and ultimately deliver consistent, high-quality products (Gajdzik et al., 2023).

SPC is widely applicable across various industries, including manufacturing, healthcare, and services, providing a robust framework for quality improvement. Embracing Statistical Process Control fosters a culture of continuous improvement, ensuring that processes remain in control and meet or exceed customer expectations. As organizations navigate the complexities of modern production, SPC stands as a valuable tool to optimize processes, enhance product quality, and ultimately drive overall operational excellence (Jokovic et al., 2023).

Collaboration and connectivity are integral aspects of Industry 4.0, and SPC aligns seamlessly with this paradigm. Information sharing across different stages of the supply chain and production network facilitates a holistic approach to quality management. SPC, in conjunction with smart manufacturing systems, fosters a more agile and responsive production environment (Singh et al., 2023).

The usage of Statistical Process Control in Industry 4.0 conditions represents a paradigm shift in quality management. The convergence of data analytics, real-time monitoring, and connectivity amplifies the capabilities of SPC, transforming it from a reactive tool to a proactive force in ensuring the highest levels of quality in the modern manufacturing landscape. As industries continue to evolve in the Industry 4.0 era, SPC stands as an indispensable asset for organizations aspiring to achieve not only quality excellence but also operational efficiency and resilience (Yanamandra et al., 2023).

Table 1 contains description of Statistical Process Control (SPC) key principles. This textual representation provides a description of each key principle of Statistical Process Control without using bullet points.

Table 1.
Key principles of Statistical Process Control (SPC)

Key principle	Description
Inherent Process Variation	Recognizes that every process exhibits natural variation, and distinguishes between common cause (inherent to the process) and special cause (sporadic) variations.
Data Collection and Analysis	Involves systematic gathering of process data, which is then analyzed statistically to identify trends, patterns, and variations over time.
Control Charts	Utilizes graphical representations (control charts) to visualize process data, with central lines indicating the mean and control limits showing acceptable variation.
Continuous Monitoring	Requires ongoing surveillance of the process through the use of control charts, allowing for the timely detection of deviations and potential issues.
Common Cause vs. Special Cause	Distinguishes between variation inherent to the process (common cause) and unexpected variations (special cause), aiding in targeted problem-solving strategies.
Process Stability	Aims to maintain the process in a stable state by identifying and eliminating special cause variations, ensuring consistent and predictable outcomes.
Statistical Analysis Tools	Utilizes statistical methods such as mean, standard deviation, and process capability indices to quantify and analyze process performance.
Proactive Problem Solving	Encourages a proactive approach to address potential issues before they affect product quality, minimizing defects and optimizing process efficiency.
Feedback and Improvement	Establishes a feedback loop for continuous improvement by using SPC data to implement corrective actions, enhance processes, and achieve higher quality standards.

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 Statistical Process Control (SPC) method can be integrated with Industry 4.0 and Quality 4.0 concept

The integration of Statistical Process Control (SPC) with Industry 4.0 and the Quality 4.0 concept represents a synergistic approach that harnesses the power of advanced technologies to enhance quality management in the modern industrial landscape (Maganga, Taifa, 2023).

In the context of Industry 4.0, which emphasizes the seamless integration of digital technologies and data-driven processes, SPC takes on a more dynamic role. The proliferation of sensors and connected devices throughout the manufacturing environment enables real-time data collection. SPC leverages this influx of data to provide a comprehensive and instantaneous view of the production process. By continuously monitoring key variables and utilizing advanced analytics, SPC can quickly identify patterns, trends, and variations, facilitating early detection of potential quality issues. Furthermore, the connectivity aspect of Industry 4.0 aligns seamlessly with the principles of SPC. The exchange of information across different stages of the production chain allows for a holistic and integrated quality management approach. SPC, in this context, becomes a collaborative tool that enables data-driven decision-making not only within the confines of a single facility but across the entire supply chain (Alrabadi et al., 2023).

Quality 4.0, an extension of Industry 4.0 in the realm of quality management, emphasizes the utilization of digital technologies to drive continuous improvement. SPC, with its focus on data analysis and process control, plays a pivotal role in achieving the objectives of Quality 4.0. The integration of SPC with advanced technologies, such as artificial intelligence and machine learning, enhances the predictive capabilities of quality management systems. This proactive approach allows organizations to anticipate potential quality issues, implement preventive measures, and optimize processes for sustained excellence (Bousdekis et al., 2023).

The integration of Statistical Process Control with Industry 4.0 and the Quality 4.0 concept creates a symbiotic relationship. SPC not only adapts to the digital transformation but also leverages the capabilities of Industry 4.0 technologies to reinforce its role in ensuring product quality. This integration facilitates a more agile, data-driven, and collaborative approach to quality management, aligning with the broader objectives of Industry 4.0 and Quality 4.0 in the pursuit of operational excellence (Antony et al., 2023; Escobar et al., 2023; Antony et al., 2023; Salimbeni, Redchuk, 2023).

Table 2 is listing examples of integration of Statistical Process Control (SPC) method with Iindustry 4.0. This table outlines various aspects of how Statistical Process Control integrates with Industry 4.0, providing a brief description of each aspect.

Table 2.
Statistical Process Control (SPC) integration with industry 4.0

Aspect	Description
Real-Time Data Monitoring	Integration with Industry 4.0 enables SPC to leverage real-time data from sensors and connected devices, allowing immediate monitoring of process variables for timely analysis and intervention.
Data Analytics and Predictive Modeling	SPC in Industry 4.0 utilizes advanced data analytics and predictive modeling to analyze historical and real-time data, enhancing its ability to identify patterns, trends, and potential variations in the production process.
Connectivity Across the Supply Chain	SPC becomes a collaborative tool by facilitating the exchange of information across different stages of the supply chain. This connectivity ensures a holistic approach to quality management, aligning with Industry 4.0 principles.
Integration with Smart Manufacturing	SPC aligns with smart manufacturing systems in Industry 4.0, enabling seamless integration with other digital technologies, automation, and intelligent control systems for a more cohesive and efficient production environment.
Proactive Problem Resolution	With Industry 4.0 technologies, SPC gains the capability for proactive problem resolution. By leveraging predictive analytics, it can anticipate potential issues and implement corrective actions before they impact product quality.
Utilization of Artificial Intelligence	Integration with Industry 4.0 allows SPC to harness the power of artificial intelligence for enhanced statistical analysis, decision-making, and process optimization, contributing to the overall efficiency and quality improvement.
IoT-enabled Process Visibility	SPC leverages the Internet of Things (IoT) to provide comprehensive visibility into the production process. This visibility extends to various manufacturing assets, enabling a deeper understanding of the entire operational ecosystem.
Adaptive Control Strategies	Industry 4.0 integration enables SPC to implement adaptive control strategies. By dynamically adjusting control parameters based on real-time data, SPC can optimize processes and respond to changing production conditions for continuous improvement.
Cloud-Based Data Storage and Access	SPC in Industry 4.0 benefits from cloud-based data storage, allowing for centralized and accessible data repositories. This facilitates data sharing, collaboration, and analysis across geographically distributed manufacturing sites.
Cyber-Physical System Integration	SPC integrates with cyber-physical systems, ensuring synergy between the digital and physical aspects of manufacturing. This integration enhances the coordination and synchronization of processes for improved efficiency and quality.
Automated Quality Control Processes	Integration with Industry 4.0 enables SPC to implement automated quality control processes. This includes the use of robotics, sensors, and automated inspection systems to enhance the accuracy and speed of quality assessments.
Blockchain for Traceability	SPC leverages blockchain technology for enhanced traceability of production data. This ensures a transparent and immutable record of quality-related information, supporting compliance and accountability throughout the supply 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; 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 Statistical Process Control (SPC) approach usage in industry 4.0. This table provides an overview of the various advantages of integrating Root Cause Analysis with Industry 4.0, emphasizing the positive impact on proactive issue resolution, operational efficiency, cost reduction, and overall organizational performance.

Table 3.
The advantages of Statistical Process Control (SPC) integration with industry 4.0

Advantage	Description
Enhanced Real-Time Visibility	Integration with Industry 4.0 provides SPC with enhanced real-time visibility into the manufacturing process. This allows for immediate identification of deviations and abnormalities, enabling quick responses to maintain quality standards and minimize disruptions.
Predictive Quality Management	Industry 4.0 integration empowers SPC with advanced analytics and predictive modeling capabilities. SPC can anticipate potential quality issues by analyzing historical and real-time data, facilitating proactive problem resolution and preventing defects before they occur.
Collaborative Supply Chain Quality	Connectivity across the supply chain in Industry 4.0 enables collaborative quality management. SPC can exchange information seamlessly with suppliers and other stakeholders, fostering a shared commitment to quality standards and facilitating a more integrated and responsive supply chain.
Optimized Smart Manufacturing	SPC aligns with smart manufacturing systems in Industry 4.0, contributing to optimized and intelligent production processes. The integration enables adaptive control strategies, automation, and synchronization of manufacturing operations, leading to increased efficiency, reduced waste, and enhanced overall productivity.
Proactive Problem Resolution	The combination of Industry 4.0 technologies and SPC allows for proactive problem resolution. By leveraging real-time data and analytics, SPC can identify and address issues before they escalate, minimizing the occurrence of defects and ensuring a more consistent and reliable production process.
Efficient Utilization of AI	Integration with Industry 4.0 enables SPC to efficiently utilize artificial intelligence (AI) for enhanced decision-making. AI algorithms can analyze complex data sets, identify patterns, and provide valuable insights for optimizing processes, improving quality, and supporting continuous improvement initiatives.
IoT-Driven Process Optimization	SPC leverages the Internet of Things (IoT) to drive process optimization. IoT-enabled sensors and devices collect real-time data from various manufacturing assets, allowing SPC to monitor, analyze, and optimize processes for improved efficiency, quality, and overall operational performance.
Cloud-Based Collaboration and Storage	Industry 4.0 integration facilitates cloud-based collaboration and data storage for SPC. This ensures centralized access to quality-related data, fostering collaboration among teams across different locations. Cloud-based storage also enhances data security, scalability, and accessibility, supporting effective quality management.
Adaptive Control in Dynamic Environments	SPC integrated with Industry 4.0 is capable of adaptive control in dynamic production environments. By adjusting control parameters based on real-time data, SPC can respond to changing conditions, fluctuations, and variations, ensuring that processes remain within specified control limits for sustained quality and efficiency.
Improved Traceability with Blockchain	SPC integrated with Industry 4.0 can utilize blockchain for improved traceability. Blockchain technology ensures a secure and transparent record of quality-related information, offering a tamper-proof audit trail. This enhances traceability across the supply chain, supporting compliance, quality assurance, and accountability.

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 Statistical Process Control (SPC) approach usage in Industry 4.0 and methods to overcome them. Addressing these problems requires a strategic and thoughtful approach, involving a combination of technological solutions, organizational change management, and ongoing adaptation to evolving industry standards and practices.

Table 4.
The problems of Statistical Process Control (SPC) integration with industry 4.0

Problems	Description of Problem	Overcoming Strategies
Data Security Concerns	The integration of SPC with Industry 4.0 involves the collection and sharing of sensitive production data, raising concerns about data security, privacy, and the risk of unauthorized access.	Implement robust cybersecurity measures, including encryption, secure data transmission protocols, and access controls. Ensure compliance with relevant data protection regulations.
Complexity in Technology Integration	The adoption of Industry 4.0 technologies can be complex, involving integration challenges with existing systems, legacy equipment, and diverse technological platforms.	Conduct a thorough technology assessment, invest in compatible and scalable technologies, and engage in phased integration to manage complexity. Collaborate with experienced technology partners for seamless implementation.
High Initial Costs	The implementation of Industry 4.0 technologies, including sensors, IoT devices, and data analytics platforms, can incur significant upfront costs, posing a financial challenge for some organizations.	Develop a cost-benefit analysis to justify investments. Consider scalable solutions and explore funding options, such as government incentives or partnerships, to alleviate the initial financial burden.
Resistance to Change	Employees may resist the adoption of new technologies and processes associated with Industry 4.0, leading to challenges in training, acceptance, and a potential slowdown in the integration process.	Implement comprehensive change management strategies, including training programs, communication plans, and fostering a culture of innovation. Involve employees in the decision-making process and highlight the benefits of the changes.
Interoperability Issues	Incompatibility between different technologies, devices, or systems may result in interoperability issues, hindering the seamless exchange of data and collaboration between various components in the production process.	Prioritize standardization and compatibility when selecting technologies. Utilize open standards and application programming interfaces (APIs) to enable communication between different systems.
Data Overload and Analysis Complexity	The abundance of real-time data generated by Industry 4.0 technologies can lead to information overload, making it challenging for organizations to extract meaningful insights and perform effective statistical analysis.	Implement advanced analytics tools and artificial intelligence for automated data processing and analysis. Define key performance indicators (KPIs) to focus on relevant data. Train personnel in data interpretation and analysis techniques.
Lack of Skilled Workforce	The successful integration of Industry 4.0 technologies requires a skilled workforce with expertise in data analytics, cybersecurity, and emerging technologies, which may be lacking in some organizations.	Invest in employee training and development programs to build the necessary skills. Collaborate with educational institutions and industry partners to create a pipeline of skilled professionals.
Overemphasis on Technology, Neglecting People	Focusing solely on technology implementation without considering the human element can result in dissatisfaction, disengagement, and resistance among employees, leading to suboptimal performance.	Prioritize a human-centric approach by involving employees in the decision-making process, providing adequate training, and fostering a culture that embraces technology while recognizing and valuing the contributions of the workforce.
Integration with Legacy Systems	Many organizations have existing legacy systems that may not seamlessly integrate with Industry 4.0 technologies, posing challenges in ensuring a smooth transition and coexistence of old and new systems.	Develop a phased integration plan that considers the compatibility of existing systems. Invest in middleware solutions or system upgrades to bridge the gap between legacy systems and Industry 4.0 technologies.

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 Statistical Process Control (SPC) with Industry 4.0 marks a paradigm shift in quality management, transforming SPC from a traditional monitoring tool into a dynamic and proactive force in the modern manufacturing landscape. In the traditional manufacturing paradigm, SPC was employed to ensure consistent quality through process monitoring and control. However, the advent of Industry 4.0 has redefined SPC's role, leveraging data analytics, real-time monitoring, and connectivity to provide a deeper understanding of the entire manufacturing ecosystem.

In Industry 4.0, the Internet of Things (IoT) facilitates the collection of vast amounts of data from sensors and devices, enabling SPC to gain real-time insights into the production process. This agility is crucial for quick identification of anomalies, deviation detection, and prompt issue resolution. Advanced analytics and artificial intelligence further enhance SPC's predictive capabilities, allowing organizations to anticipate potential variations and take proactive measures to ensure product quality.

This publication aims to present the usage of the Statistical Process Control (SPC) approach in Industry 4.0 conditions. SPC, deeply rooted in statistical principles, systematically monitors and controls processes, distinguishing between common cause and special cause variations. The principles of SPC, as outlined in Table 1, form a robust framework applicable across diverse industries, fostering a culture of continuous improvement and quality excellence.

The integration of SPC with Industry 4.0 and the Quality 4.0 concept signifies a synergistic approach that harnesses advanced technologies for enhanced quality management. SPC, in the context of Industry 4.0, benefits from real-time data monitoring, data analytics, and connectivity, fostering a collaborative and data-driven approach to quality management. Quality 4.0 emphasizes the use of digital technologies for continuous improvement, and SPC plays a pivotal role by enhancing predictive capabilities and facilitating proactive issue resolution.

Table 2 outlines specific aspects of SPC integration with Industry 4.0, showcasing its versatility across real-time data monitoring, predictive modeling, connectivity across the supply chain, and utilization of artificial intelligence, among others. These aspects collectively contribute to a more agile, efficient, and collaborative production environment. The advantages of SPC integration with Industry 4.0, detailed in Table 3, highlight the positive impact on real-time visibility, predictive quality management, collaborative supply chain quality, and overall process optimization. These advantages underscore the transformative potential of this integration for organizations aspiring to achieve operational excellence and sustained quality. However, challenges exist in the integration process, as outlined in Table 4. Issues such as data security concerns, technology integration complexity, and resistance to change require strategic approaches, including robust cybersecurity measures, comprehensive change management.

The integration of Statistical Process Control with Industry 4.0 represents a pivotal advancement in quality management. As industries evolve in the Industry 4.0 era, SPC stands as an indispensable asset for organizations striving not only for quality excellence but also operational efficiency and resilience. By addressing challenges and capitalizing on the advantages, organizations can unlock the full potential of this integration, ensuring a future-ready approach to quality management in the dynamic landscape of modern manufacturing.

References

1. Almeida, S., Abreu, L.P.M. (2024). The Quality Manager in the Industry 4.0 Era. *Lecture Notes in Mechanical Engineering*, 468–474.
2. Alrabadi, T.D.S., Talib, Z.M., Abdullah, N.A.B. (2023). The role of quality 4.0 in supporting digital transformation: Evidence from telecommunication industry. *International Journal of Data and Network Science, 7(2),* 717–728.
3. Amat-Lefort, N., Barravecchia, F., Mastrogiacomo, L. (2023). Quality 4.0: big data analytics to explore service quality attributes and their relation to user sentiment in Airbnb reviews. *International Journal of Quality and Reliability Management*, *40(4*), 990–1008.
4. Antony, J., McDermott, O., Sony, M., Cudney, E.A., Doulatabadi, M. (2023). Benefits, challenges, critical success factors and motivations of Quality 4.0–A qualitative global study. *Total Quality Management and Business Excellence*, *34(7-8)*, 827–846.
5. Antony, J., Sony, M., McDermott, O., Jayaraman, R., Flynn, D. (2023). An exploration of organizational readiness factors for Quality 4.0: an intercontinental study and future research directions. *International Journal of Quality and Reliability Management*, *40(2),* 582–606.
6. Antony, J., Swarnakar, V., Sony, M., McDermott, O., Jayaraman, R. (2023). How do organizational performances vary between early adopters and late adopters of Quality 4.0? An exploratory qualitative study. *TQM Journal*.
7. Barsalou, M. (2023). Root Cause Analysis in Quality 4.0: A Scoping Review of Current State and Perspectives. *TEM Journal, 12(1),* 73–79.
8. Bousdekis, A., Lepenioti, K., Apostolou, D., Mentzas, G. (2023). Data analytics in quality 4.0: literature review and future research directions. *International Journal of Computer Integrated Manufacturing, 36(5),* 678–701.
9. Escobar, C.A., Macias-Arregoyta, D., Morales-Menendez, R. (2023). The decay of Six Sigma and the rise of Quality 4.0 in manufacturing innovation. *Quality Engineering*.
10. Gajdzik, B., Jaciow, M., Wolniak, R., Wolny R., Grebski, W.W. (2023). Energy Behaviors of Prosumers in Example of Polish Households. *Energies, 16(7), 3186*; https://doi.org/10.3390/en16073186.

11. Gimerská, V., Šoltés, M., Mirdala, R. (2023). Improving Operational Efficiency through Quality 4.0 Tool: Blockchain Implementation and Subsequent Market Reaction. *Quality Innovation Prosperity, 27(2),* 16–32.
12. Jokovic, Z., Jankovic, G., Jankovic, S., Supurovic, A., Majstorović, V. (2023). Quality 4.0 in Digital Manufacturing – Example of Good Practice. *Quality Innovation Prosperity, 27(2),* 177–207.
13. Jonek-Kowalska, I., Wolniak, R. (2021). Economic opportunities for creating smart cities in Poland. Does wealth matter? *Cities, 114,* 1-6.
14. Jonek-Kowalska, I., Wolniak, R. (2022). Sharing economies' initiatives in municipal authorities' perspective: research evidence from Poland in the context of smart cities' development. *Sustainability, 14(4),* 1-23.
15. Khourshed, N., Gouhar, N. (2023). Developing a Systematic and Practical Road Map for Implementing Quality 4.0. *Quality Innovation Prosperity, 27(2),* 96–121.
16. Kordel, P., Wolniak, R. (2021). Technology entrepreneurship and the performance of enterprises in the conditions of Covid-19 pandemic: the fuzzy set analysis of waste to energy enterprises in Poland. *Energies, 14(13),* 1-22.
17. Liu, H.-C., Liu, R., Gu, X., Yang, M. (2023). From total quality management to Quality 4.0: A systematic literature review and future research agenda. *Frontiers of Engineering Management, 10(2),* 191–205
18. Maganga, D.P., Taifa, I.W.R. (2023). Quality 4.0 conceptualisation: an emerging quality management concept for manufacturing industries. *TQM Journal, 35(2),* 389–413.
19. Olsen, C. (2023). Toward a Digital Sustainability Reporting Framework in Organizations in the Industry 5.0 Era: An Accounting Perspective. *Lecture Notes in Networks and Systems, 557,* 463-473.
20. Saihi, A., Awad, M., Ben-Daya, M. (2023). Quality 4.0: leveraging Industry 4.0 technologies to improve quality management practices – a systematic review. *International Journal of Quality and Reliability Management, 40(2),* 628–650.
21. Salimbeni, S., Redchuk, A. (2023). Quality 4.0 and Smart Product Development. *Lecture Notes in Networks and Systems, 614.* LNNS, 581–592.
22. Singh, J., Ahuja, I.S., Singh, H., Singh, A. (2023). Application of Quality 4.0 (Q4.0) and Industrial Internet of Things (IIoT) in Agricultural Manufacturing Industry. *AgriEngineering, 5(1),* 537–565.
23. Sureshchandar, G.S. (2023). Quality 4.0 – a measurement model using the confirmatory factor analysis (CFA) approach. *International Journal of Quality and Reliability Management, 40(1),* 280–303.
24. Wang, Y., Mo, D.Y., Ma, H.L. (2023). Perception of time in the online product customization process. *Industrial Management and Data Systems, 123(2),* pp. 369–385.
25. Yanamandra, R., Abidi, N., Srivastava, R., Kukunuru, S., Alzoubi, H.M. (2023). Approaching Quality 4.0: The Digital Process Management as a Competitive Advantage, 2nd International Conference on Business Analytics for Technology and Security. ICBATS.

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BLOCKCHAIN TECHNOLOGY FOR SUPPLY CHAIN MANAGEMENT IN THE CONTEXT OF AI-BASED SOLUTIONS

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Purpose: The purpose of the article is to emphasize the growing popularity of using tools based on artificial intelligence and blockchain technology in supply chain management, as well as to show the synergistic potential of using them together. Additionally, the author aims to present and discuss the concept of using both technologies for the purposes of constructing an ordering goods system in the supply chain based on AI tools supported by blockchain technology.
Design/methodology/approach: The purposes of the paper were achieved by analyzing literature, industry reports and online publications in the field of blockchain technology and artificial intelligence in supply chain management. The theoretical scope of the article is the description of application areas of both described technologies within the supply chain, their main characteristics and the potential for synergy in their combined use.
Findings: The author presented the results of the analysis of literature, industry reports and online publications, demonstrating the growing popularity of the use of blockchain technology and artificial intelligence-based tools in supply chain management, characterized key features of analyzed technologies, comparing them on the basis of opposites, and indicated their resulting synergistic potential. Drawing conclusions from this potential, the author indicated the possibility of using both technologies together as part of the blockchain-AI supported ordering system's concept. The article ended with the author's suggestions regarding the potential of future research aimed at concretizing the proposed concept and looking for opportunities to decentralize AI tools used so far based on their support with blockchain technology.
Practical implications: The use of blockchain technology and tools based on artificial intelligence in business shows measurable benefits, as shown by the submitted analysis of industry reports. Observed increasing adoption of both technologies contributes to cost decrease and revenue increase in many industries as shown in the paper.
Originality/value: The originality of the paper consists in comparing the opposites and drawing conclusions regarding the potential complementarity of the features of both analyzed technologies, and is also expressed in the proposed concept of Blockchain-AI supported ordering system.

Keywords: distributed ledger technology, blockchain, artificial intelligence, supply chain management.

Category of the paper: Research paper.

1. Introduction

The growing popularity of tools based on artificial intelligence usage has been clearly noticeable in recent months. Their popularity coincides with the growing importance of distributed ledger technology, with particular emphasis on blockchain technology. This article aims to outline the relationship between the development of tools using artificial intelligence and solutions based on blockchain technology and propose a concept of using both analyzed technologies for supply chain management. The advantages of blockchain technology seem to strengthen the potential of AI-based techniques that are increasingly used, also in the business activities of enterprises. Transparency and the elimination of the need for trust between market entities, which are the main benefits of using blockchain, enhance the opportunities arising from the use of AI tools in many areas of everyday life of people, but also in management in both the private and public sectors. The combination and synergy of two of the most trending modern technologies can result in the creation of modern solutions applicable in supply chain management. The article presents the results of literature research on the popularity of AI-based tools, the advantages of their use in business practice, the benefits of using blockchain technology, especially smart contracts, and the synergistic potential of both described technologies. This research was supported by the analysis of reports from leading analytical companies in the field of AI and blockchain. Conclusions from the literature research and analysis of solutions currently being developed in business led to the creation of the concept of using both technologies to improve the ordering of goods in the supply chain. In the course of research work leading to the creation of the article, a research gap was identified, four research questions were asked and, consequently, the objectives of the article were defined.

Research gap: To determine the synergistic potential of using blockchain technology and AI-based tools for goods ordering systems.

Research question 1: What are the areas of application of AI-based tools in supply chain management?

Research question 2: What is the popularity of the use of AI-based tools in supply chain management and what benefits does it bring to companies?

Research question 3: What complementary features do blockchain technology and AI-based tools have?

Research question 4: Is it possible to develop a goods ordering system that uses both blockchain technology and AI-based tools?

Main objective: To present and discuss the concept of using both technologies for the purposes of constructing an ordering goods system in the supply chain based on AI tools supported by blockchain technology.

Intermediate objective 1: To emphasize the growing popularity of using tools based on artificial intelligence and blockchain technology in supply chain management.

Intermediate objective 2: To present the synergistic potential of using both the blockchain technology and AI-based tools.
Article hypothesis: Is it possible to develop a goods ordering system that uses both blockchain technology and AI-based tools.

2. Materials and methods

A literature review - in particular bibliometrics - was carried out for research without the publishing time limitation on the topics of Blockchain technology and Artificial Intelligence in Supply Chain Management. The first step was to analyze publications included in the Scopus database. However, for a comprehensive study, the analysis was deepened to include the Web of Science database. The following queries were run on September 21st 2023:

Scopus:

- TITLE-ABS-KEY (“blockchain AND supply AND chain AND management”),
- TITLE-ABS-KEY (“artificial AND intelligence AND supply AND chain AND management”),
- TITLE-ABS-KEY ("AI AND tools").

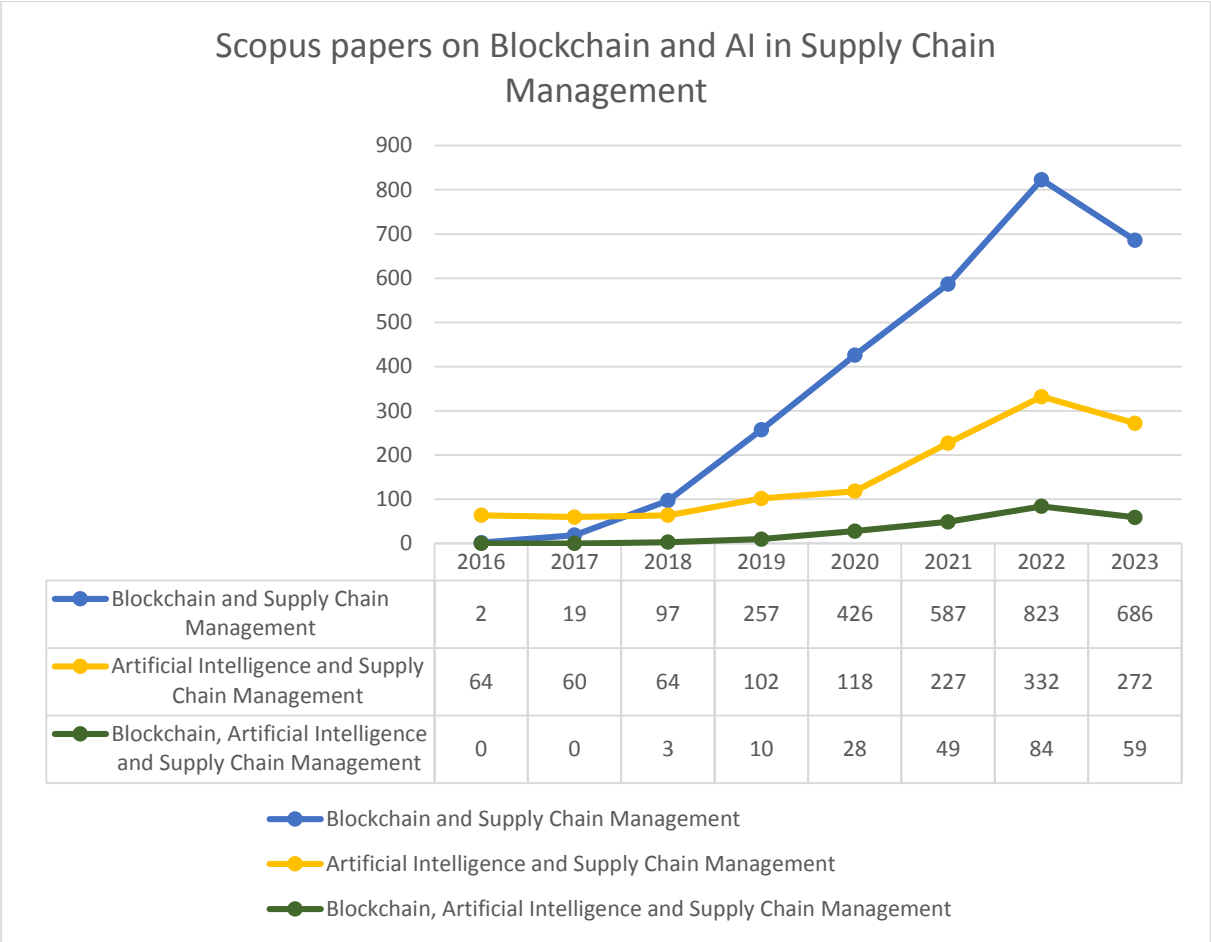
Web of Science:

- TOPIC: ("blockchain supply chain management"); Indexes: SCIEXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCREXPANDED, IC.
- TOPIC: ("artificial intelligence supply chain management"); Indexes: SCIEXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCREXPANDED, IC.
- TOPIC: (“blockchain artificial intelligence supply chain management"); Indexes: SCIEXPANDED, SSCI, A&HCI, CPCI-S, CPCI-SSH, BKCI-S, BKCI-SSH, ESCI, CCREXPANDED, IC.

The search results showed given numbers of publications in subject areas:

- Blockchain in Supply Chain Management: Scopus – 2895, WoS – 2661,
- Artificial Intelligence in Supply Chain Management: Scopus – 1812, WoS – 1926,
- Blockchain and Artificial Intelligence in Supply Chain Management: Scopus – 233, WoS – 253.

Figure 1 and Figure 2 show the number of publications on analyzed topics since 2016 in both analyzed databases.



	2016	2017	2018	2019	2020	2021	2022	2023
Blockchain and Supply Chain Management	2	19	97	257	426	587	823	686
Artificial Intelligence and Supply Chain Management	64	60	64	102	118	227	332	272
Blockchain, Artificial Intelligence and Supply Chain Management	0	0	3	10	28	49	84	59

Figure 1. Scopus papers on Blockchain and Artificial Intelligence in Supply Chain Management. Source: own elaboration.

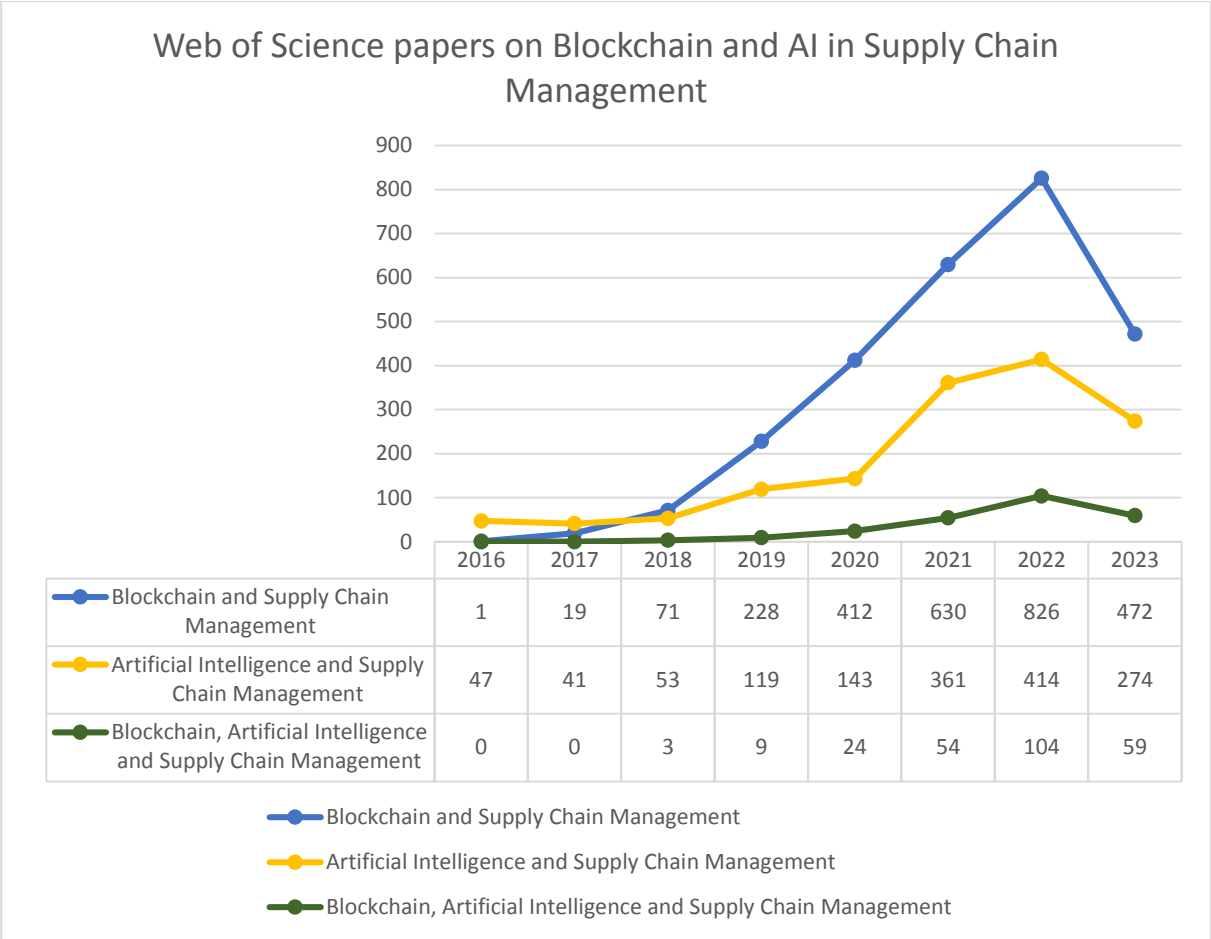


Figure 2. Web of Science papers on Blockchain and Artificial Intelligence in Supply Chain Management.

Source: own elaboration.

The search results including indicate a relatively small number of publications (Scopus – 233, WoS – 253) embedding the topic of both blockchain technology and artificial intelligence in the field of supply chain management, which confirms the author's assumptions about the legitimacy of in-depth analyzes in this area. During the preparation of this article, the literature review resulting from the above bibliometric analyzes was supplemented with a review of industry reports and reports of analytical and consulting companies.

3. AI-based solutions in supply chain management

During the fourth industrial revolution, which is characterized by the use of a fusion of breakthrough technologies, it is necessary to search for and use modern solutions, such as systems based on artificial intelligence (Sahai, Rath, 2021). Conventional management, production or provision of services has been largely modified over the last decade by the use of unprecedented amounts of data (data-driven management), cyber physical systems and the

Internet of Things (Lee, Azamfar, Singh, 2019; Rüßmann et. al., 2015). These solutions significantly strengthen the efficiency and productivity of supply chains and increase its visibility (Ben-Daya, Hassini, Bahroun, 2019). A special place among disruptive technologies is occupied by the extensive use of artificial intelligence offering interoperability and analytical capabilities (Baryannis et. al., 2019). AI is generally understood as the use of computers for reasoning, pattern recognition, gathering knowledge from the experience of working with data and developing forms of problem solving in search of optimal solutions (Min, 2010). Its use in supply chain or enterprise management can radically modify current business practices and ways of performing managerial tasks.

Regarding the areas of application of AI tools in supply chain management, Sharma et al. indicated that these include: supplier selection, inventory planning, Green Supply Chain Management, Supply Chain Network Design, Healthcare and demand forecasting (Sharma et al., 2022).

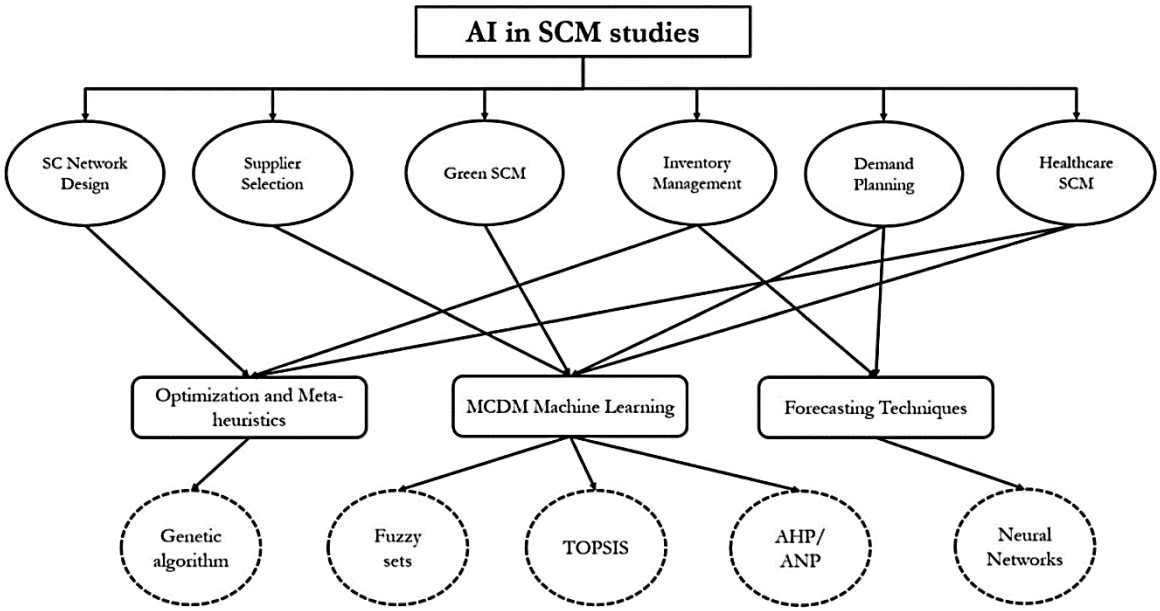


Figure 3. AI-based tools' areas of application and basic AI techniques.

Source: Sharma et. al., 2022.

Figure 3 illustrates the connections between the areas of application of AI tools in SCM and specific AI techniques (which are not directly the subject of this article). According to the McKinsey & Company Survey 2022 report, the use of AI tools, according to respondents, contributes to reducing costs and increasing revenues of enterprises, which is shown in Figure 4. The greatest savings are noticed by respondents in the SCM area (52% of respondents).

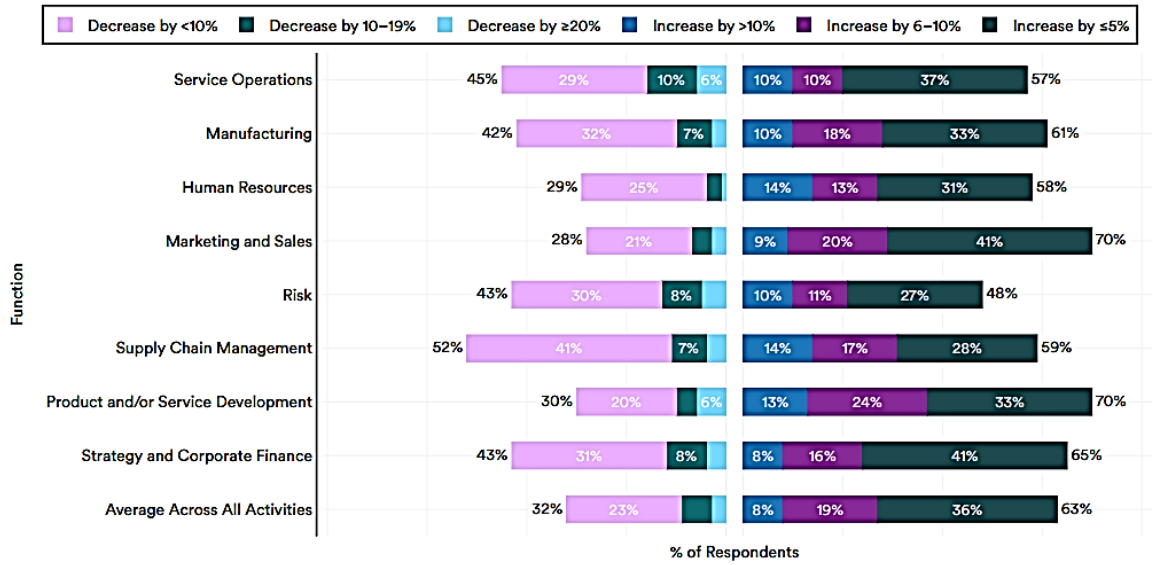


Figure 4. Cost decrease and revenue increase from AI adoption by function in 2021.
Source: McKinsey, 2022.

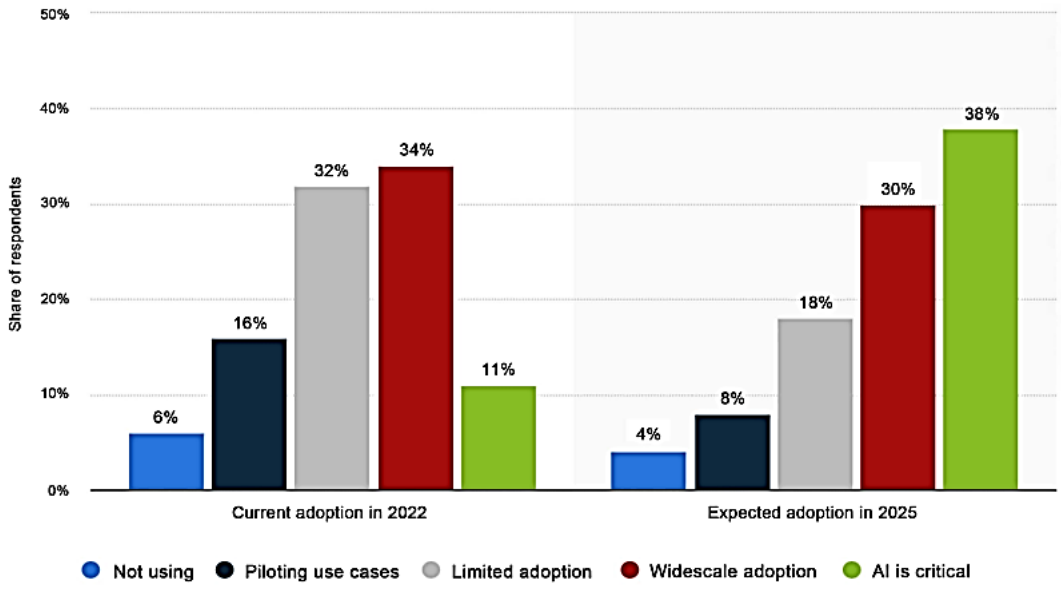


Figure 5. Global AI adoption rate in supply chain and manufacturing businesses (2022 and 2025).
Source: Statista, 2022.

According to a report by Statista, the global adoption of AI solutions in the supply chain and manufacturing industry should increase significantly over the next few years (Fig. 5). On the other hand, the NetBase Quid report (Fig. 6) shows that global corporate investments in the development of AI have recorded a huge increase over the past few years. While the readings for 2022 are slightly lower than those for 2021, the trend remains upward, with the record year 2021 being spent in the order of $276 billion.

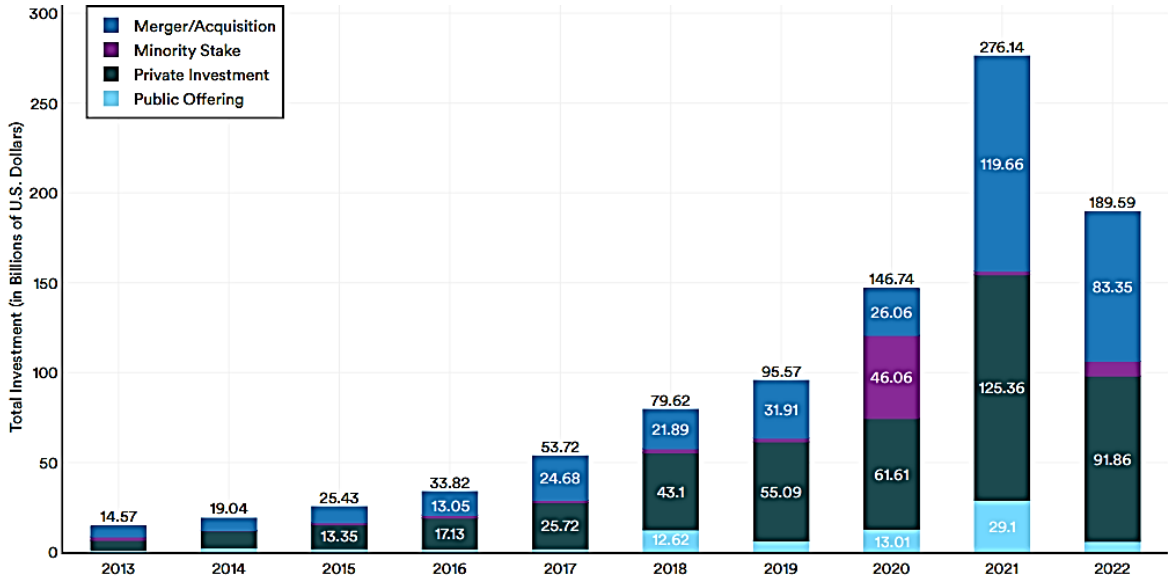


Figure 6. Global corporate investment in AI by investment activity.

Source: NetBase Quid, Stanford HAI, 2022.

Therefore, the fact that AI is increasingly widely adopted and used in the day-to-day operations of entities that are part of modern supply chains does not raise any doubts. AI can and should be used in cooperation with other modern technologies noticed in the concept of Industry and Logistics 4.0. One of them is undoubtedly distributed ledger technology, and especially blockchain technology.

4. Synergistic potential of blockchain and AI-based solutions for SCM

The use of AI is therefore gaining importance in managing business entities, including SCM. In search of synergistic relationships between AI and blockchain, this article indicates the basic advantages of blockchain technology, which may translate into strengthening the benefits of using AI. The integration of AI and blockchain as part of various types of solutions should result in their increased security, efficiency and productivity (Saxena, Gayathri and Kumari, 2023). Blockchain is an open, decentralized, distributed and public ledger in which transactions are recorded on multiple computers, which ensures that it cannot be modified backwards (Sarmah, 2018). Thanks to the use of cryptography and proof of work consensus, the fact of immutability of records in the blockchain is achieved, which eliminates the need to trust entities responsible for entering data into various systems. Each block chain node has access to the data contained in it.

One of the most important mechanisms using blockchain technology is a smart contract. It is a computer program that is executed automatically when predefined conditions are met. A smart contract contains arbitrarily constructed logic and can be used in various types of

applications where users or events can trigger their execution (Ante, 2021). Smart contract is also being defined as a piece of computerized transaction protocol that satisfies contractual conditions such as payment terms, confidentiality or enforcement, reduces exceptions and minimizes the need for trusted intermediaries (Ante, 2021). In supply chain management, it can be used to automate transactions between its participants. That way, a specific event taking place in reality is recorded on the blockchain in real-time (e.g. recording a material flow using an IoT sensor) and triggers a financial and information flow (generating and sending documents) directly using a smart contract without the need for any human activities.

Blockchain technology therefore shows great potential for data sharing in the form of decentralized, secure and reliable records. The basic advantages of blockchain are indicated and characterized in Table 1.

Table 1.
Blockchain technology advantages

Blockchain technology advantages	Description
Immutability of blockchain	A knowledge record or its details cannot be changed until they are processed or added to the blockchain as a block. Nothing can ever change the data stored in a blockchain; it has an indestructible place there.
Decentralization	Due to its ability to provide digital independence to a single consumer, the entire blockchain network can be decentralized. In the network, no organization has control over every other user. Each node functions individually.
Flexibility	To protect transactions, the blockchain network uses sophisticated encryption techniques. Users of the blockchain can safeguard and maintain their privacy.
Security	Blockchain chains include information records that are encrypted using cryptography, which ensures that hackers cannot change or modify those data. All blocks on the blockchain are connected by encrypted hash functions, making it unlikely for theft or illegal transactions to take place there.
No intermediaries	Because of the blockchain network's point-to-point architecture, transactions between two nodes take place without the need for a middleman. To facilitate transactions between two parties, there is no requirement for an intermediary like PayPal, any bank, Visa, Western Union, etc.
Transparency	All or any individuals who are a neighborhood of the network disposes transparency thanks to the digital distributed ledger system. In a network, each node has a copy of the ledger and the ability to check transactions. Because of this, no one can keep their transactions and personal information a secret from other users, ensuring fair commerce.
Fewer transaction costs	The transaction costs are reduced because there are no middlemen involved in transactions on the blockchain network. One's entire transaction cost rises if there are middlemen because they charge a significant fee.
Consensus-based	The blockchain concept is totally built on consensus, meaning that each transaction between two nodes during a blockchain is accompanied by an invitation for its verification sent to all or some of the opposing nodes. In any scenario, after a transaction has been verified by the nodes, it is added to the memory pool and forms a replacement block. There are many such validated transactions stored in the memory pool.

Source: Saxena, Gayathri, Surya Kumari, 2023.

AI-based tools in supply chain management, on the other hand, are used in many areas. It can support sales and distribution inventory in the field of communication in the supply chain and management of sales teams; enable real-time performance tracking (through forecasting, inventory replenishment scheduling and order generation, as well as advice based on expert

knowledge implemented in the AI tool); provide smart reporting (by generating reports in various areas of activity); ensure supply chain transparency (by transforming data into suggestions for carrying out work, optimizing transportation solutions and proactively detecting disruptions); creating forecasts of demand for goods, or early detection of errors in ongoing processes (Kashem et al., 2023).

Certain features of both considered technologies (artificial intelligence and blockchain) seem to be contradictory, which does not exclude the possibility of seeking synergistic effects resulting from their combination on the basis of complementary technologies. Selected features of blockchain technology and AI-based solutions are summarized on the basis of opposites in Table 2.

Table 2.
Complementary features of blockchain technology and AI-based solutions

Blockchain technology features	AI-based solutions features
Deterministic	Probabilistic
Permanent	Changing
Algorithms and cryptography to record reality	Algorithms to guess the reality
Immutable	Data ingestion
Decentralized	Centralized
Secure	Moderately secure
Consensus-based	Learning process-based

Source: own elaboration.

While blockchain technology is based on a deterministic approach, AI-based solutions use a probabilistic approach (Antonopoulos, 2014). Blockchain, thanks to its structure, ensures the immutability of data registers, and AI shows considerable variability in generating solutions based on available knowledge. The algorithms that constitute the blockchain are aimed at recording reality, and AI aims to predict its future states. The immutability of blockchain-based registers contrasts with the changing behavior of AI as new data arrives, and the decentralized structure of blockchain (Alzahrani, Bulusu, 2018) contrasts with the centralization of currently used AI-based tools (Brynjolfsson, Ng, 2023). The issue of cybersecurity in relation to blockchain is beyond doubt and is one of its greatest advantages, while in relation to the security of AI tools there are many reservations Attkan, Ranga, 2022). The blockchain is built and updated based on the consensus of the nodes that constitute it (Chaudhry, Yousaf, 2018), and the AI tools are controlled by the learning process (Fahle, Prinz, Kuhlenkötter, 2020).

The apparent contradiction observed in the features of blockchain technology and AI-based tools may suggest the potential of their joint use as complementary technologies. Therefore the use of smart contracts and other blockchain technology mechanisms supplemented with AI-based tools seems to offer enormous opportunities to improve the functioning of modern supply chains.

5. The concept of implementing AI-based solutions and blockchain technology in SCM

The nature of smart contracts as self-enforcing mechanisms offers significant opportunities to enhance the benefits of AI. AI models combined with smart contracts offer the potential to, for example, detect the need to replenish stocks (using AI) and automatically order delivery from an external supplier (using a smart contract) (Chainlink, 2023). The combination of blockchain technology and AI is also able to improve supply chain transparency and minimize the impact of counterfeits by digitizing document flow and ensuring real-time tracking of goods in the supply chain. The use of predictive analysis supported by AI in the company of automated flow of information (and finances) via blockchain can provide enterprises with the ability to view and analyze patterns, optimize warehouse management and make data-based decisions, and consequently reduce costs. GMDH Streamline (a company creating platforms for modern support for S&OP processes for supply chains based on AI and blockchain) CEO, noticed that a few years ago inventory management processes were carried out manually. The pandemic experience and the continuous development of modern solutions made entrepreneurs look for more robust solutions (Forbes, 2023). Today, supply chains face the problems of unpredictability, lack of historical data, or numerous supply chain disruptions. They must be able to adapt to changes in the environment at a very fast pace. According to Streamline CEO, the use of AI tools has at least several significant advantages over traditional methods: reducing the number of manual processes, reducing the number of errors resulting from the complexity of the supply chain, supporting the determination of the amount of ordered materials over time. Supply chain managers often use Excel to manage data from ERP systems. This is extremely time-consuming and often causes individual participants in the supply chain to rely on expired data. Blockchain-based solutions integrate data from many sources in near-real time, and based on AI mechanisms, it is possible, for example, to forecast the amount of ordered materials at a given point in time. Other significant problems facing modern supply chains are the issues of forecasting sales volumes, required inventory levels in warehouses, or simply reliable data on the current inventory throughout the supply chain, current status and the possibility of delays in transit. Thanks to the use of blockchain technology, the data held by the participants of the supply chain is up-to-date and cannot be changed retrospectively by any of the actors, making it fully reliable. Each flow of materials within the supply chains is recorded in the blockchain, and knowledge about this flow and the current state of the supply chain is in the hands of all participants in the supply chain in real time.

AI-based tools, on the other hand, can, based on reliable data (provided by blockchain) and recognition of historical patterns or seasonal changes visible in them, make advanced forecasts of future demand for materials. Artificial intelligence is also able to assign tasks to individual employees or issue instructions to implementers of manufacturing processes based on data

whose veracity is beyond doubt (thanks to blockchain). What's more, AI can also improve the process of planning transport routes thanks to machine learning mechanisms and be much more effective in this respect than a human. Among the areas where the use of AI in the supply chain is particularly useful, the following are listed: predictive analytics, production planning, customer response, warehouse management, route efficiency and optimization (Pournader et al., 2021). A hypothetical example of the synergistic operation of systems based on AI and blockchain technology is the concept of the goods ordering process proposed by the author of this article based on available historical data and with the support of the technologies described in this article. A decision-maker (manager) in ordering goods from suppliers in an enterprise based on AI and blockchain could be significantly relieved thanks to the use of technology, both in terms of analytical processes necessary to determine the delivery volume and time of placing an order, as well as the execution activities related to the physical order. In the layer of analytical and decision-making activities, support would be provided by AI techniques, while in the execution layer, blockchain technology (smart contract) would provide support. The proposed structure of the described solution is shown in Figure 7.

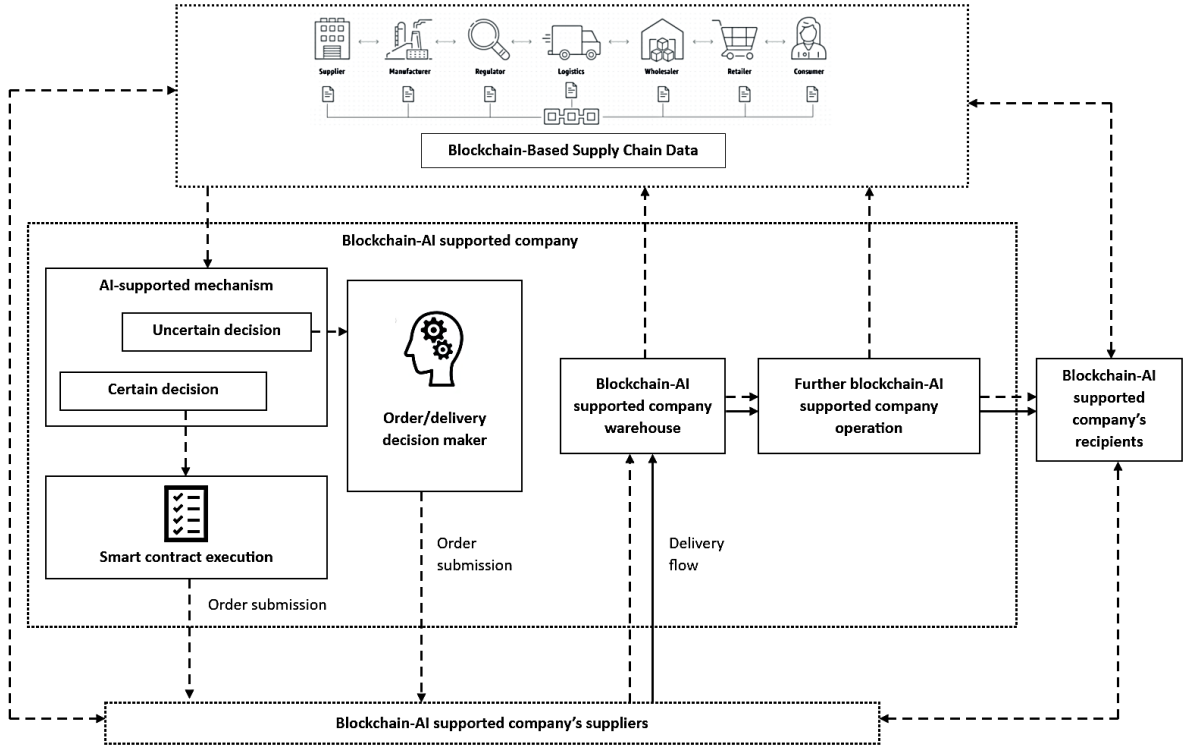


Figure 7. Blockchain-AI supported ordering system concept's structure.
Source: own elaboration.

All data necessary to make a purchase decision would come from the blockchain (providing access to knowledge about the current state of the entire supply chain in real time), and their initial analysis would be carried out using AI tools. In the case of a standard situation (certain decision), which has often occurred in the past, without any deviations from past purchasing situations, the implementation of a smart contract would allow the order to be placed (and even

paid for) directly by the AI itself, which significantly minimizes (even eliminates) manual work. In the case of an unusual situation (uncertain decision), not previously observed and occurring as a result of disruptions in the supply chain, the AI tool would interact with the decision-maker, suggesting potential management options. The final decision would then be made by a human. The system constructed in this way has enormous potential for savings for the company, resulting from a significant reduction in the workload of people responsible for analytical and management activities.

6. Conclusion

This article demonstrates the broad potential of using AI tools and blockchain technology in modern supply chain management. Both technologies described have many seemingly contradictory features, which enhances the impression of their complementarity. Using the advantages of AI and blockchain as part of coordinated solutions provides new opportunities in supply chain management. This was illustrated in the form of the concept of blockchain-ai supported ordering system, which was presented at a high level of generality. Among the limitations of the proposed solution, it is worth noting the low level of adoption of blockchain technology, and therefore the small number of smart contract developers specializing in their implementation in the field of supply chain management, as well as the high investment costs required to implement the proposed solutions. The direction of further research suggested by the author of this publication should be aimed at concretizing the proposed solution at the technical level, taking into account specific AI techniques for forecasting and analyzing the demand for materials in the supply chain and the programming issues of blockchain-based smart contracts enabling the automation of financial flows. Another direction of future scientific considerations proposed by the author is the decentralization of AI-based tools using blockchain technology, leading to the creation of systems that operate on consensus among multiple nodes, instead of relying on a single central authority, which leads to a more secure, transparent and trustworthy alternative to traditional AI systems. As indicated, the integration of two technologies based on different features and having different advantages is a wide research field for researchers, and as previous research indicates - their separate use in supply chain management provides many measurable benefits for the entities implementing them. The synergistic effect resulting from integration should contribute to increasing the benefits while minimizing the negative aspects of their separate use.

References

1. 5 Ways AI Can Benefit Demand Forecasting And Inventory Planning, *Forbes*. Retrieved from: https://www.forbes.com/sites/forbestechcouncil/2023/02/06/5-ways-ai-can-benefit-demand-forecasting-and-inventory-planning/, 20.09.2023.
2. Alzahrani, N., Bulusu, N. (2018). *Towards true decentralization: A blockchain consensus protocol based on game theory and randomness*. Decision and Game Theory for Security: 9th International Conference, GameSec 2018, Seattle, WA, USA, October 29–31, 2018, Proceedings, 9, pp. 465-485.
3. Ante, L. (2021). Smart contracts on the blockchain—A bibliometric analysis and review. *Telematics and Informatics, 57*, 101519.
4. Antonopoulos, A.M. (2014). *Mastering Bitcoin: Unlocking Digital Cryptocurrencies*. Sebastopol, CA: O'Reilly Media.
5. *Artificial Intelligence Index Report 2023*, NetBase Quid, Stanford HAI. Retrieved from: https://aiindex.stanford.edu/wp-content/uploads/2023/04/HAI_AI-Index-Report_2023.pdf, 20.09.2023.
6. Attkan, A., Ranga, V. (2022). Cyber-physical security for IoT networks: a comprehensive review on traditional, blockchain and artificial intelligence based key-security. *Complex & Intelligent Systems, 8(4),* pp. 3559-3591.
7. Baryannis, G., Validi, S., Dani, S., Antoniou, G. (2019). Supply Chain Risk Management and Artificial Intelligence: State of the art and Future Research Directions. *International Journal of Production Research, vol. 57(7),* pp. 2179-2202.
8. Ben-Daya, M., Hassini, E., Bahroun, Z. (2019). Internet of Things and Supply Chain Management: A Literature Review. *International Journal of Production Research, Vol. 57(15-16),* pp. 4719-4742.
9. Brynjolfsson, E., Ng, A. (2023). Big AI can centralize decision-making and power, and that's a problem. *Missing links in ai governance, 65*.
10. Chaudhry, N., Yousaf, M.M. (2018). *Consensus algorithms in blockchain: Comparative analysis, challenges and opportunities.* 12th International Conference on Open Source Systems and Technologies (ICOSST), pp. 54-63.
11. Fahle, S., Prinz, C., Kuhlenkötter, B. (2020). Systematic review on machine learning (ML) methods for manufacturing processes–Identifying artificial intelligence (AI) methods for field application. *Procedia CIRP, 93*, pp. 413-418.
12. *Global AI adoption rate in supply chain and manufacturing businesses*. Statista. Retrieved from: https://www.statista.com/statistics/1346717/ai-function-adoption-rates-business-supply-chains/, 20.09.2023.

13. Kashem, M.A., Shamsuddoha, M., Nasir, T., Chowdhury, A.A. (2023). Supply Chain Disruption versus Optimization: A Review on Artificial Intelligence and Blockchain. *Knowledge, 3(1),* pp. 80-96.
14. Lee, J., Azamfar, M., Singh, J. (2019). A Blockchain Enabled Cyber-Physical System Architecture for Industry 4.0. Manufacturing Systems. *Manufacturing Letters vol. 20,* pp. 34-39.
15. Min, H. (2010). Artificial Intelligence in Supply Chain Management: Theory and Applications. *International Journal of Logistics: Research and Applications, vol. 13(1),* pp. 13-39.
16. Pournader, M., Ghaderi, H., Hassanzadegan, A., Fahimnia, B. (2021). Artificial intelligence applications in supply chain management. *International Journal of Production Economics, 241, 108250*.
17. Rüßmann, M., Lorenz M., Gerbert, P., Waldner, M., Justus, P., Engel, P., Harnisch, M. (2015). Industry 4.0: The Future of Productivity and Growth in Manufacturing Industries. *Boston Consulting Group, 9(1),* pp. 54-89.
18. Sahai, A.K., Rath, N. (2021). Artificial intelligence and the 4th industrial revolution. *Artificial intelligence and machine learning in business management.* CRC Press, pp. 127-143.
19. Sarmah, S.S. (2018). Understanding blockchain technology. *Computer Science and Engineering, 8(2),* pp. 23-29.
20. Saxena, R., Gayathri, E., Surya Kumari, L. (2023). Semantic analysis of blockchain intelligence with proposed agenda for future issues. *International Journal of System Assurance Engineering and Management, 14(Suppl. 1),* pp. 34-54.
21. Sharma, R., Shishodia, A., Gunasekaran, A., Min, H., Munim, Z.H. (2022). The role of artificial intelligence in supply chain management: mapping the territory. *International Journal of Production Research, 60(24),* pp. 7527-7550.
22. *The state of AI in 2021*. McKinsey. Retrieved from: https://www.mckinsey.com/capabilities/quantumblack/our-insights/global-survey-the-state-of-ai-in-2021, 20.09.2023.
23. *Use Cases of AI in Blockchain.* Chainlink. Retrieved from: https://blog.chain.link/blockchain-ai-use-cases/, 20.09.2023.

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THE IMPACT OF GENDER ON MOTIVATING AND DEMOTIVATING FACTORS IN LEARNING AND WORK AMONG REPRESENTATIVES OF GENERATION Z

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Purpose: The aim of the article is to investigate the influence of gender on motivating and demotivating factors in learning and work among representatives of Generation Z.
Design/methodology/approach: Based on survey data collected from 245 women and 203 men within the Generation Z group (aged 19-26), the most significant motivating and demotivating factors for learning and work were identified. These factors were subsequently analyzed with respect to gender differences.
Findings: The research has shown that gender significantly influences the motivating factors for learning. Substantial and statistically significant differences were observed among 7 out of 13 investigated motivating factors and as many as 16 out of 20 demotivating factors. Women consistently rated the impact strength of all factors on motivation for learning significantly higher.
Research limitations/implications: The limitations of the article lie in its focus solely on students from two educational centers in Poland and individuals aged 19-26 years old.
Practical and social implications: The results indicate that women are more sensitive to the effects of motivating and demotivating factors for learning.
Originality/value: The initial categorization of specific motivators and demotivators into three groups was proposed: the first group concerned benefits, the second comfort, and the third effort. Significant similarities were observed between the motivating and demotivating factors for learning and work among the surveyed Generation Z representatives. The analysis results indicated the need to pay particular attention to demotivating factors for learning, as they hold significantly greater importance than motivating factors.

Keywords: motivation, gender, learning, working, generation, male, female.

Category of the paper: research paper.

1. Introduction

Motivation plays a pivotal role in every individual's life, spanning from early childhood to late adulthood. It applies universally to both men and women. Research conducted over the past

several decades indicates that gender indeed plays a significant role in motivation, such as in learning and work. Several decades ago, women were far less likely to pursue higher education or hold prominent professional positions than they do now (Meece et al., 2009). However, due to social, economic, and particularly cultural changes, the differences in behavior and motivation between both groups have been continuously evolving. Consequently, these differences have been the subject of numerous scientific studies for many years (Bugler et al., 2015; Dai, 2001; Reddington et al., 2015).

The studies (Gardiner et al., 2014; Mahmoud et al., 2020; Sparks, 2012) indicate that behaviors and social attitudes vary depending on age and generation. Generation Z (1995-2012) is the first cohort growing up in a fully digital society. Currently (as of 2023), they range from 11 to 28 years old, and a significant portion of them are both studying and working part-time. This raises questions about the motivating and demotivating factors influencing Generation Z representatives in their studies and work. The objective of the paper is to analyze popular theories of motivation in learning and work and determine the most significant motivating and demotivating factors within the group of Generation Z representatives.

As part of the research on motivation in learning and work, the study sought answers to the following research questions:

1. What are the most significant motivating and demotivating factors for Generation Z representatives (aged 19-26) in their studies and work?
2. Does gender influence the significance of selected factors on motivation in learning and work?

This publication is organized as follows: Chapter 2 describes and compares issues related to selected popular motivation theories. Chapter 3 outlines the methodology used in the conducted research. Chapter 4 presents the obtained results. Finally, the article concludes with a summary.

2. Motivation theories in practice

In scientific literature, one can observe the division of motivation theories into three different groups (Osuch, 2012; Stoner et al., 2001; Zdonek et al., 2021):

- Content theories, which emphasize the significance of internal factors (related to human needs) that drive a person to act in a specific way;
- Process theories, which determine how and as a result of what goals individual employees are motivated;
- Reinforcement theories, illustrating how the effects of past behavior influence future behaviors in an employee's learning process.

One of the most frequently encountered motivation theories in the content theories group is Abraham Maslow's hierarchy of needs theory (Cox, 1987; Maslow, 1954). It presents levels of human needs, starting from physiological needs (e.g., food and sleep, safety), through social needs (e.g., belongingness, acceptance, love, respect, recognition), cognitive needs (to know, understand), and aesthetic needs (beauty, order), culminating in self-actualization needs (personal development and fulfillment) (Daniels, 1982; Maslow, 1999; Wahba, Bridwell, 1976). This theory assumes that people seek to fulfill their needs, starting from the lower levels of the hierarchy and progressing to higher levels.

Another theory is Douglas McGregor's Theory X and Y (McGregor, 1960; Pardee, 1990). He distinguished two opposing theories regarding the nature of people and their motivation. Theory X assumes that people are inherently lazy, dislike work, and need external control, whereas Theory Y assumes that people are naturally active, enjoy working, and can be self-directed and creative if properly motivated and supported.

McClelland (McClelland et al., 1953) identified three main motivational needs: the need for achievement (the drive for success and setting ambitious goals), the need for power, and the need for affiliation. This theory suggests that different individuals are driven by different needs.

Herzberg (Herzberg, 1968) proposed that satisfaction and dissatisfaction do not exist on the same continuum and therefore are not opposites. He further stated that motivator factors can cause satisfaction or lack thereof, while hygiene factors cause dissatisfaction when absent and absence of dissatisfaction when present, each having its own strength (Pardee, 1990).

Victor Vroom's Expectancy Theory (Huitt, 2001; Vroom, 1964), belonging to the group of process theories, assumes that people take actions based on their expectations regarding outcomes. Motivation arises from the belief that action will lead to a desired outcome, and that outcome is valuable to the individual. This theory takes into account three key factors:

- Expectancy (the perception of the probability of success).
- Value of Obtaining Goal (how important and valuable the goal is to the individual).
- Instrumentality (the belief that a particular action leads to the goal).

These three groups of factors are combined into a formula where motivation is the product of expectancy, instrumentality, and the value of obtaining the goal (Formula 1). Therefore, all three must be present at a relatively high level for motivation to occur.

$$\text{Motivation} = (\text{Expectancy}) * (\text{Instrumentality}) * (\text{Value of Obtaining Goal}) \quad (1)$$

The Self-Determination Theory (SDT) (Deci, Ryan, 2013; Ryan, Deci, 2017) has garnered significant popularity in recent years. It suggests that all individuals have three basic psychological needs: autonomy, competence, and relatedness, which impact motivation, satisfaction, and well-being. Autonomy relates to the sense of having one's own free choice. Its opposite experience is the feeling of compulsion or control in one's behavior. Competence refers to the experience of effectiveness in actions. Relatedness pertains to the need for a sense of connection and belonging with others

Despite the default association of motivation with something an individual wants to do voluntarily, scientific literature (Bénabou, Tirole, 2003; Ryan, Deci, 2000; Vallerand, 1997) distinguishes its division into external and internal motivation. External motivation involves individuals' behavior to perform tasks and learn new skills due to external rewards or avoiding punishment. The individual engages in the behavior not because it is enjoyable or appealing but to receive a reward or avoid punishment in return. External and internal motivation are often treated separately, focusing on utility (external motivation) or pleasure (internal motivation) (Teo et al., 1999).

3. Materials and Methods

3.1. Research sample and questionnaire

Within the multifaceted study conducted in 2022 and 2023, surveys were carried out among both full-time and part-time students from two universities in Poland (Silesian University of Technology in Gliwice and University of Agriculture in Krakow). In 2022, preliminary research involving 80 respondents (Generation Z) was conducted concerning motivating and demotivating factors for studying. The questionnaire consisted of open-ended questions about motivating and demotivating factors. Based on the provided responses and a literature review, another questionnaire was developed for the actual research, featuring a list of motivating and demotivating factors measured on a Likert scale. Approximately 750 students from 8 fields of study: management, business analytics, logistics, management and production engineering, environmental engineering, spatial economy, geodesy, landscape architecture were invited to participate. Concerns existed about obtaining only around 10-20% correctly completed questionnaires from individuals with certain personality traits (openness, willingness to share knowledge, etc.). Hence, a form of incentive was introduced, offering the chance to earn extra points for participation in the study and discussion during classes related to the addressed issues in the research (such as motivation, generational differences, and ICT technology development). The study received substantial interest. The survey concluded with a unique identifier for each participant, which had to be submitted in a special form as confirmation of participation. Participation was optional and anonymous. After excluding incomplete, qualitatively doubtful responses and those from individuals above 26 years old, as well as responses from individuals declaring a gender other than male or female (due to their small number < 2%), statistical analysis of the results was conducted with 448 responses from individuals aged 19 to 26 taken into account. Table 1 presents the profile of the respondents.

Table 1.
Profile of respondents

Demographic items	Frequency	Percentage (%)
Gender		
Female	245	54.7
Male	203	45.3

Source: Own elaboration

One of the aspects of this research involved analyzing the motivating and demotivating factors for studying from the perspectives of both women and men, considering selected personality traits. Based on preliminary open-ended survey inquiries, a list of motivating and demotivating factors for students' learning was compiled. This list was then analyzed, and based on this analysis and scientific literature, 13 motivating factors and 20 demotivating factors for studying were identified. Each of these factors was assessed in the conducted study on a Likert scale from 1 to 5, where: 1 - no influence or very little influence; 2 - low influence; 3 - moderate influence; 4 - high influence; 5 - very high influence.

The question about motivating factors for studying was: Q5. What motivates you to study or helps in learning (and how does it influence your motivation)? The question about demotivating factors for studying was: Q6. What demotivates you from studying or hinders learning (and how does it influence your motivation)? These questions were primarily directed at individuals simultaneously studying and working. The questions were randomly distributed to only a small portion of the respondents. A total of 94 responses regarding motivating and demotivating factors for studying were obtained.

The lists of motivating and demotivating factors for studying that were subjected to analysis are presented in Tables 2 and 3.

Table 2.
Motivating factors for studying

ID	Motivating factor
MF1	Small but immediate reward (e.g., perks)
MF2	Topics related to personal interests
MF3	Desire to be among the best in the group
MF4	Avoidance of being among the worst in the group
MF5	Interesting practical knowledge
MF6	Interesting theoretical knowledge
MF7	Small immediate penalty for lack of preparation (for studying)
MF8	Obtaining a certificate of acquired skills
MF9	Engaging tasks
MF10	Group work
MF11	Positive atmosphere during classes
MF12	Possibility of obtaining a scholarship
MF13	Listening to music in the background

Note: Own elaboration.

Table 3.
Demotivating factors for studying

ID	Demotivating factor
DF1	Stress during classes
DF2	Noise
DF3	Excessive amount of material to study
DF4	Public questioning "at the board"
DF5	Peer reluctance to study
DF6	Material that is too difficult
DF7	Unfair grading by the teacher
DF8	Impractical knowledge
DF9	Long, monotonous classes
DF10	Theory-heavy with little practical application
DF11	Unpleasant teacher
DF12	Other peers cheating (e.g., copying assignments)
DF13	Outdated and boring material
DF14	Criticism from the teacher
DF15	Nice weather
DF16	Unpleasant atmosphere within the group
DF17	Competition for grades within the group
DF18	(in times of COVID-19) Various distractions (FB, messages, YouTube)
DF19	(in times of COVID-19) Lack of physical contact with peers
DF20	(in times of COVID-19) Lack of physical contact with the teacher

Note: Own elaboration.

The Cronbach's alpha coefficient for questions regarding motivating factors (MF1-MF13, 13 items) was 0.757, and for questions related to demotivating factors (DF1-DF20, 20 items) it was 0.847. The obtained results confirmed high and acceptable reliability of the research tool.

3.2. Statistical Analysis

In the statistical analysis, 448 questionnaires were utilized (n = 448). A comparison between two groups divided by gender was conducted using the Mann–Whitney U test. Statistical hypotheses were verified at a significance level α of 0.05. Factor analysis was also applied to group the studied factors. The statistical analysis was carried out using Microsoft Excel and Statistica Tibco.

4. Results

In the analyzed population, there were 448 respondents, comprising 245 women (54.7%) and 203 men (45.3%). The gender structure of the surveyed population reflects the composition of students in Polish universities. According to data from the Central Statistical Office (GUS) and the POL-on system in 2022, approximately 1.2 million individuals were enrolled in education in Poland. There were more female students than male students (58% vs. 42%) (Website GUS, 2023). Based on the obtained results, motivators and demotivators for learning

were ranked from the most to the least significant. Table 4 presents motivators and demotivators sorted from the most to the least significant based on respondents' responses.

Table 4.
Ranking of Motivating Factors (MF) and Demotivating Factors (DF) for learning

ID	Median	Mean ±SD		ID	Median	Mean ±SD
MF2	4.00	4.11 ±1.05		DF9	5.00	4.29 ±0.96
MF5	4.00	3.95 ±1.06		DF8	4.00	4.14 ±1.02
MF8	4.00	3.93 ±1.13		DF7	4.00	4.07 ±1.11
MF11	4.00	3.84 ±1.12		DF3	4.00	4.05 ±1.06
MF9	4.00	3.56 ±1.16		DF13	4.00	4.02 ±1.05
MF6	3.00	3.33 ±1.12		DF10	4.00	3.98 ±1.05
MF10	3.00	3.07 ±1.22		DF11	4.00	3.97 ±1.12
MF4	3.00	3.06 ±1.4		DF4	4.00	3.7 ±1.3
MF12	3.00	3.02 ±1.5		DF1	4.00	3.68 ±1.3
MF13	3.00	2.83 ±1.45		DF2	4.00	3.62 ±1.24
MF1	3.00	2.75 ±1.27		DF6	4.00	3.62 ±1.15
MF3	3.00	2.68 ±1.31		DF16	4.00	3.58 ±1.22
MF7	2.00	2.35 ±1.31		DF14	4.00	3.55 ±1.24
				DF18	3.00	3.35 ±1.34
				DF15	3.00	3.21 ±1.38
				DF19	3.00	3.17 ±1.4
				DF12	3.00	2.9 ±1.38
				DF17	3.00	2.78 ±1.37
				DF20	3.00	2.73 ±1.36
				DF5	2.00	2.52 ±1.2

Note: Own elaboration.

Respondents indicated that the most motivating factors for learning were: topics related to their interests (MF2, 4.11 ±1.05), interesting practical knowledge (MF5, 3.95 ±1.06), acquiring a certificate for acquired skills (MF8, 3.93 ±1.13), as well as a positive atmosphere during classes (MF11, 3.84 ±1.12).

The most demotivating factors for learning were: long, monotonous classes (DF9, 4.29 ±0.96), impractical knowledge (DF8, 4.14 ±1.02), unfair grading by teachers (DF7, 4.07 ±1.11), excessive study material (DF3, 4.05 ±1.06), outdated and boring materials (DF13, 4.02 ±1.05), excessive theory with little practice (DF10, 3.98 ±1.05), and an unsympathetic teacher (DF11, 3.97 ±1.12).

The results of the analysis showed significant differences in the impact of individual motivators and demotivators for learning based on gender. The analysis indicates that the motivating and demotivating factors for learning are significantly more influential for women than for men. The results are presented in Tables 5 and 6.

Table 5.
Variations in the impact of specific motivating factors on motivation. Mann-Whitney U test results for the variable on gender: Female (n = 245), Male (n = 203)

Variable	Test probability (p)	Significance	Female	Male
MF1	0.0070	**	2.89 ±1.23	2.58 ±1.29
MF2	0.1107		4.18 ±1.01	4.01 ±1.1
MF3	0.1271		2.76 ±1.32	2.57 ±1.3
MF4	0.0911		3.16 ±1.44	2.95 ±1.35
MF5	0.7745		3.97 ±1.02	3.92 ±1.1
MF6	0.0061	**	3.46 ±1.07	3.18 ±1.16
MF7	0.9520		2.36 ±1.35	2.33 ±1.27
MF8	0.0103	*	4.05 ±1.08	3.78 ±1.17
MF9	0.0050	**	3.69 ±1.12	3.39 ±1.19
MF10	0.4899		3.1 ±1.23	3.02 ±1.21
MF11	0.0311	*	3.93 ±1.1	3.72 ±1.13
MF12	0.0000	***	3.4 ±1.45	2.57 ±1.43
MF13	0.0046	**	3.02 ±1.5	2.62 ±1.35

Note: Own elaboration.

Table 6.
Variations in the impact of specific demotivating factors on motivation. Mann–Whitney U test results for the variable on gender: Female (n = 245), Male (n = 203)

Variable	Test probability (p)	Significance	Female	Male
DF1	0.0000	***	4.04 ±1.13	3.24 ±1.35
DF2	0.0000	***	3.85 ±1.12	3.34 ±1.31
DF3	0.0007	***	4.21 ±0.98	3.86 ±1.13
DF4	0.0000	***	4.09 ±1.15	3.22 ±1.32
DF5	0.3377		2.56 ±1.16	2.47 ±1.25
DF6	0.0048	**	3.76 ±1.1	3.45 ±1.19
DF7	0.0000	***	4.31 ±0.95	3.78 ±1.21
DF8	0.4975		4.18 ±0.99	4.1 ±1.05
DF9	0.0015	**	4.41 ±0.9	4.14 ±1.01
DF10	0.0369	*	4.07 ±1.03	3.87 ±1.07
DF11	0.0024	**	4.11 ±1.08	3.8 ±1.16
DF12	0.0006	***	3.11 ±1.33	2.66 ±1.4
DF13	0.8667		4.01 ±1.07	4.03 ±1.03
DF14	0.0000	***	3.86 ±1.11	3.17 ±1.29
DF15	0.0232	*	3.35 ±1.35	3.05 ±1.41
DF16	0.0005	***	3.77 ±1.13	3.35 ±1.28
DF17	0.0001	***	3 ±1.34	2.51 ±1.34
DF18	0.0004	***	3.55 ±1.31	3.1 ±1.35
DF19	0.0079	**	3.33 ±1.37	2.98 ±1.41
DF20	0.0573		2.84 ±1.37	2.6 ±1.34

Note: Own elaboration.

In the further stage, to cluster motivators and demotivators, a factor analysis was employed. An effort was made to incorporate the most significant ones. Consequently, 12 variables were selected, which, after the factor analysis, were divided into 3 groups. The cumulative explained variance amounted to 54.68%. The identified factors were named: benefits, comfort, and effort. The results were presented in Table 7.

Table 7.
Factor analysis. Division into 3 groups of factors

ID	Benefits	Comfort	Effort
MF2	0.721827	0.019224	0.288022
MF5	0.801860	-0.024872	0.111638
MF8	0.589117	0.107344	0.043001
MF9	0.751488	0.119376	-0.026552
DF8	0.133469	-0.005508	0.825360
DF9	0.140095	0.213197	0.773106
DF3	-0.016447	0.401650	0.636162
DF4	0.004871	0.747020	0.067973
DF1	-0.000776	0.795728	0.140058
DF2	0.049096	0.434895	0.113934
DF16	0.177915	0.607167	0.074145
DF14	0.084087	0.751141	0.191480
Explained variance	2.154678	2.546787	1.860968
Contribution	0.179556	0.212232	0.155081

Note: Own elaboration.

To the Benefits group, the following factors were assigned:

- MF2 - thematic interest related topics,
- MF5 - interesting practical knowledge,
- MF8 - obtaining a certificate of acquired skills,
- MF9 - engaging tasks.

To the Comfort group, the following factors were assigned:

- DF1 - stress during classes,
- DF2 - noise,
- DF4 - public questioning "at the board",
- DF14 - criticism from the teacher,
- DF16 - unpleasant atmosphere within the group.

To the Effort group, the following factors were assigned:

- DF3 - too much study material,
- DF8 - Impractical knowledge,
- DF9 - long, monotonous classes.

Ultimately, the analysis involved examining data regarding motivators and demotivators for work, gathered based on open-ended questions among students who were both working and studying (n=94). The most frequently occurring responses were grouped and presented in Tables 8 and 9, aiming to align them with the previously identified three groups of factors.

Table 8.
Motivating factors for work

Benefits
• work related to interests • money/earnings • satisfactory level of pay commensurate with the job performed • bonuses/non-monetary benefits (e.g., holiday packages, company team-building events, health care, multisport cards) • opportunity to learn/acquire new skills • opportunity to receive task-related bonuses • interesting tasks to perform • opportunity for advancement • chance to meet new people • opportunity for recognition based bonuses
Comfort
• positive atmosphere, friendly environment, cohesive team • fair, understanding boss • praises/recognition • shared goal between employees and employer, shared direction of action, sense of contribution to the company/organization's growth • pleasant/visually appealing environment/office
Effort
- flexible/adjustable working hours - remote/hybrid work

Note: Own elaboration.

Table 9.
Demotivating factors for work

Benefits
• low salary/inadequate pay for the work done • poor or lack of bonuses • lack of development opportunities
Comfort
• bad/negative atmosphere/unpleasant company • unpleasant boss (unfriendliness, dishonesty, explosiveness, lack of respect, incompetence) • unnecessary stress/pressure • lack of cooperation among employees • complaining/criticism from superiors • lack of praise/recognition • noise • passing off responsibilities onto others • ignoring workplace issues by superiors • lack of influence on achieved outcomes/goals • lack of efforts to improve work quality • competition among employees • unfair compensation • knowing the pointlessness of a task/work • lack of dedication to work by other employees
Effort
• the monotony of work • excessive working hours • excessive workload/too many responsibilities • inflexible/rigid work hours • unclear task allocation/workscope/employer expectations • high effort resulting in fatigue • unpleasant conditions (e.g., high temperature) • good weather outside • useless regulations/policies

Note: Own elaboration.

5. Discussion

The obtained research results indicate a significant resemblance between motivating factors for learning and work. In the case of work, the benefits are associated with money (salary, benefits, etc.), while for learning motivators, they are confirmed skills (diploma and certificates). Benefits are crucial in both cases. In the workplace, maintaining good relationships with superiors is important, while in school, it's a positive atmosphere during classes. Comfort in learning or work is equally essential. Effort is also similar; in the workplace, it's the burden of excessive workload, while in school, it's dealing with an overwhelming amount of difficult study material. There are numerous such similarities in each of the mentioned categories. Analyzing the presented motivation theories reveals that each has some reflection in these factors, offering different perspectives on motivation. Hence, they complement each other, and understanding their existence and significance in educational processes and employee motivation is valuable. Motivation also influences the income earned (Gwiazdowska, Klinkosz, 2012) or benefits. For students, income or benefits can be acquired knowledge, skills, certificates, while for work, it's the salary.

However, it's important to note that some experiments suggest that additional motivators related to benefits, such as monetary rewards, don't always positively impact increased efficiency and engagement. In the longer term, they weaken intrinsic motivation, namely satisfaction and joy from one's work (Zhang, 2018). Hence, it's essential to pay attention to intrinsic motivation, which isn't solely tied to rewards and punishments.

With the advancement of internet technology and among individuals aged 19-26 (Generation Z), one can formulate a thesis about their increasing awareness of the significance of practical knowledge and skills in the future. Access to an immense array of educational materials and tutorials online makes individuals in this age group increasingly aware of content they don’t necessarily expect in the educational process. Hence, the direction of higher education's development in the form of an increasing number of elective courses seems very appropriate in the context of these studies.

Moreover, long and monotonous classes should be replaced with short interactive sessions focusing on specific topics and tasks. The development of IT technology has made younger people increasingly impatient and less capable of focusing on one task for extended periods compared to previous generations (e.g., listening to lectures). The effort associated with long and dull classes is highly demotivating for learning. This indicates that the direction of class development toward working on specific projects is also highly desired in the context of this research. Implementing such changes in the educational process is time-consuming and not an easy task. However, these studies signal that this direction is expected by Generation Z.

6. Summary

In this article, research conducted among a group of 245 women and 203 men was presented. The study highlighted factors that employers should pay particular attention to in the near future. These individuals are among the first of Generation Z, who are growing up entirely in a digital world and entering the job market. They have specific expectations regarding motivating factors and are highly sensitive to demotivating factors. Employers aiming to attract these individuals to work should be aware of what motivates and demotivates them. The research indicates a significant importance of demotivators (according to Herzberg's hygiene factors). Additionally, attention should be paid to the differences in the perception of various motivating and demotivating factors between women and men. The study suggests that women are more sensitive to both motivating and demotivating factors than men. The most significant differences were found in: the possibility of obtaining a scholarship, stress during classes, noise, excessive study material, public questioning at the board, unfair grading by teachers, peers cheating (e.g., copying tasks), teacher criticism, unsympathetic group atmosphere, competition for grades within the group, and (during COVID-19) various distractions (Facebook, messages, YouTube). The most critical motivators for both genders are: topics related to interests, obtaining certificates for acquired skills, and interesting practical knowledge. The most significant demotivators for women are: long, monotonous classes, unfair grading by teachers, and excessive study material. The most significant demotivators for men are: long, monotonous classes, impractical knowledge, and outdated and dull material. The results of this research can be useful not only for educators but also for managers of training companies. Further work could delve into a more detailed analysis of motivating and demotivating factors for work and self development.

References

1. Bénabou, R., Tirole, J. (2003). Intrinsic and extrinsic motivation. *The Review of Economic Studies*, *70*(3), 489–520.
2. Bugler, M., McGeown, S.P., St Clair-Thompson, H. (2015). Gender differences in adolescents' academic motivation and classroom behaviour. *Educational Psychology*, *35*(5), 541–556. https://doi.org/10.1080/01443410.2013.849325
3. Cox, R. (1987). The rich harvest of Abraham Maslow. *Motivation and Personality*, 245–271.

4. Dai, D.Y. (2001). A Comparison of Gender Differences in Academic Self-Concept and Motivation Between High-Ability and Average Chinese Adolescents. *Journal of Secondary Gifted Education*, *13*(1), 22–32. https://doi.org/10.4219/jsge-2001-361
5. Daniels, M. (1982). The development of the concept of self-actualization in the writings of abraham Maslow. *Current Psychological Reviews*, *2*(1), 61–75. https://doi.org/10.1007/BF02684455
6. Deci, E.L., Ryan, R.M. (2013). *Intrinsic motivation and self-determination in human behavior*. Springer Science & Business Media.
7. Gardiner, S., Grace, D., King, C. (2014). The Generation Effect: The Future of Domestic Tourism in Australia. *Journal of Travel Research*, *53*(6), 705–720. https://doi.org/10.1177/0047287514530810
8. Gwiazdowska, S., Klinkosz, W. (2012). Motywacja osiągnięć i osobowość mężczyzn uzyskujących stały oraz nieregularny dochód miesięczny. *Studia z Psychologii w KUL*, *18*, 11–26.
9. Herzberg, F. (1968). *One more time: How do you motivate employees* (Vol. 65). Harvard Business Review Boston, MA.
10. Huitt, W. (2001). Motivation to learn: An overview. *Educational Psychology Interactive*, *12*(3), 29–36.
11. Mahmoud, A.B., Fuxman, L., Mohr, I., Reisel, W.D., Grigoriou, N. (2020). We aren't your reincarnation! workplace motivation across X, Y and Z generations. *International Journal of Manpower*, *42*(1), 193–209. https://doi.org/10.1108/IJM-09-2019-0448
12. Maslow, A.H. (1954). Motivation and personality Harper and Row. *New York, NY*.
13. Maslow, A.H. (1999). *Toward a psychology of being* (3. ed). Wiley.
14. McClelland, D.C., Atkinson, J.W., Clark, R.A., Lowell, E.L. (1953). *The achievement motive. Appleton-Century-Crofts*.
15. McGregor, D. (1960). *The human side of enterprise, Vol. 21, Iss. 166.* New York: McGraw-Hill.
16. Meece, J.L., Glienke, B.B., Askew, K. (2009). Gender and motivation. *Handbook of Motivation at School*, 425–446.
17. Osuch, J. (2012). Motivation as a management factor. *Acta Scientifica Academiae Ostroviensis. Sectio A*, *1*, 101–120.
18. Pardee, R.L. (1990). *Motivation Theories of Maslow, Herzberg, McGregor & McClelland. A Literature Review of Selected Theories Dealing with Job Satisfaction and Motivation.*
19. Reddington, L.A., Peverly, S.T., Block, C.J. (2015). An examination of some of the cognitive and motivation variables related to gender differences in lecture note-taking. *Reading and Writing*, *28*(8), 1155–1185. https://doi.org/10.1007/s11145-015-9566-z
20. Ryan, R.M., Deci, E.L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67.

21. Ryan, R.M., Deci, E.L. (2017). *Self-determination theory: Basic psychological needs in motivation, development, and wellness*. Guilford publications.
22. Sparks, A.M. (2012). Psychological empowerment and job satisfaction between Baby Boomer and Generation X nurses: Psychological empowerment and job satisfaction. *Journal of Nursing Management*, *20*(4), 451–460. https://doi.org/10.1111/j.1365-2834.2011.01282.x
23. Stoner, J., Freeman, R., Gilbert, D. (2001). Kierowanie, PWE, Warszawa. *Search In*.
24. Teo, T.S.H., Lim, V.K.G., Lai, R.Y.C. (1999). Intrinsic and extrinsic motivation in Internet usage. *Omega*, *27*(1), 25–37. https://doi.org/10.1016/S0305-0483(98)00028-0
25. Vallerand, R.J. (1997). Toward a hierarchical model of intrinsic and extrinsic motivation. In *Advances in experimental social psychology* (Vol. 29, pp. 271–360). Elsevier.
26. Vroom, V.H. (1964). *Work and motivation*. Wiley.
27. Wahba, M.A., Bridwell, L.G. (1976). Maslow reconsidered: A review of research on the need hierarchy theory. *Organizational Behavior and Human Performance*, *15*(2), 212–240. https://doi.org/10.1016/0030-5073(76)90038-6
28. Website GUS (2023). Available Online: https://Radon.Nauka.Gov.Pl/Raporty/Studenci_2022, 21.08.2023.
29. Zdonek, I., Hysa, B., Zdonek, D. (2021). Academic Staff in the Context of Known Theories of Motivation. *European Research Studies*. https://ersj.eu/journal/2080/download/Academic+Staff+in+the+Context+of+Known+Theories++of+Motivation.pdf
30. Zhang, X. (2018). Motivation of Enterprise Motivation Management Mechanism Based on Neuromanagement. *NeuroQuantology*, *16*(5). https://doi.org/10.14704/nq.2018.16.5.1245

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