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# FOREWORD

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

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: environmental management, tourism management, process management, strategic management, quality management, logistics, economics, sustainable development, industrial management, knowledge management, human resource management, smart city, information management, managerial tools, use of artificial intelligence in management, service management, innovation management, risk management, supply chain management and business analytics.

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# ANALYSIS OF THE COMPATIBILITY OF THE DEVELOPMENT OF AGRICULTURAL BIOGAS PLANTS WITH POLAND'S ENVIRONMENTAL POLICY

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**Purpose**: The purpose of the article is to analyse and evaluate the compatibility of the development of agricultural biogas plants with Poland's environmental policy, particularly with regard to the promotion of RES use locally.
**Design/methodology/approach:** The article focuses on a selected issue in the field of organization and shaping sustainable development policy. Inductive and deductive reasoning, descriptive and monographic methods were used to process the collected data. The research methodology was based on statistical measures of structure and change over time.
**Findings:** The development of biogas plants in Poland is in line with the country's environmental policy, which focuses on increasing the share of renewable energy sources in electricity and heat production and reducing greenhouse gas emissions.
**Practical implications:** The presented study can help economic entities to make effective decisions regarding environmental protection and development of RES.
**Social implications:** The analysis presented can help in the process of identifying the benefits of the development of agricultural biogas plants, not only for the environment, but also as an element stimulating economic development on a local and regional level.
**Originality/value:** The presented study is a new concept for the interpretation of Poland's environmental policy in the context of supporting the development of renewable energy sources (RES) from the perspective of sustainable development.

**Keywords:** renewable energy sources, agricultural biogas plants, environmental policy, sustainable development.

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

## 1. Introduction

Observations of the socio-economic environment indicate that the Polish government's policy towards renewable energy sources (RES) has become an important issue in recent years, in both regional and local contexts. Poland is still one of the largest producers of energy from coal (according to the Central Statistical Office CSO, 2021, the share of coal in electricity production in Poland was over 72%), is noticeable but increasing the share of RES in the energy mix is becoming increasingly urgent due to climate challenges and European Union requirements. According to data from the Energy Market Agency (Energy Market Agency, 2023), by October 2022, RES in Poland generated 31,320 GWh, an increase of 125% compared to 2021 (24,928 GWh). In contrast, the Energy Forum, in its latest report Energy Transformation in Poland (Transformation Report, 2023), indicates that the share of renewables in the energy mix has fallen to around 17%, despite a record production from these sources of 30 TWh (Figure 1).

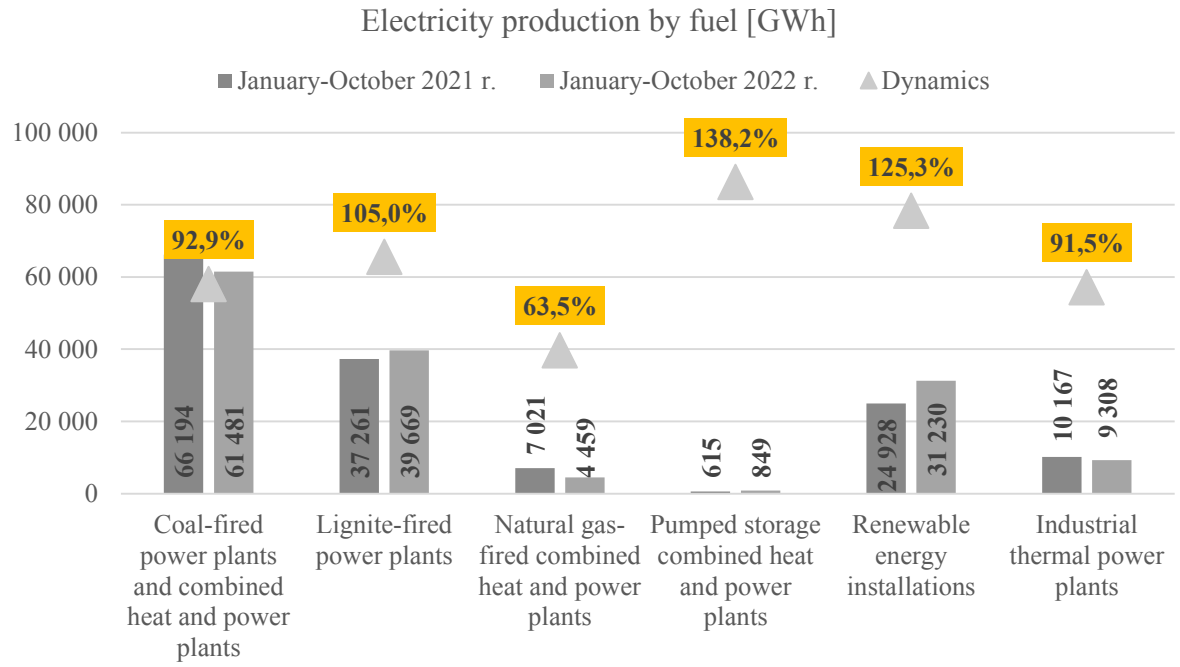


**Figure 1.** Electricity generating capacity of Renewable Energy Sources installations in Poland in 2022 [MW].

Source: Energy Market Agency. Retrieved from: http: //www.are.waw.pl, 12.04.2023.

Available reports and studies emphasize that in terms of renewable energy capacity, solar PV remains in first place. The increase in photovoltaic generating capacity is more than 170% higher than in 2021 (Figure 2).

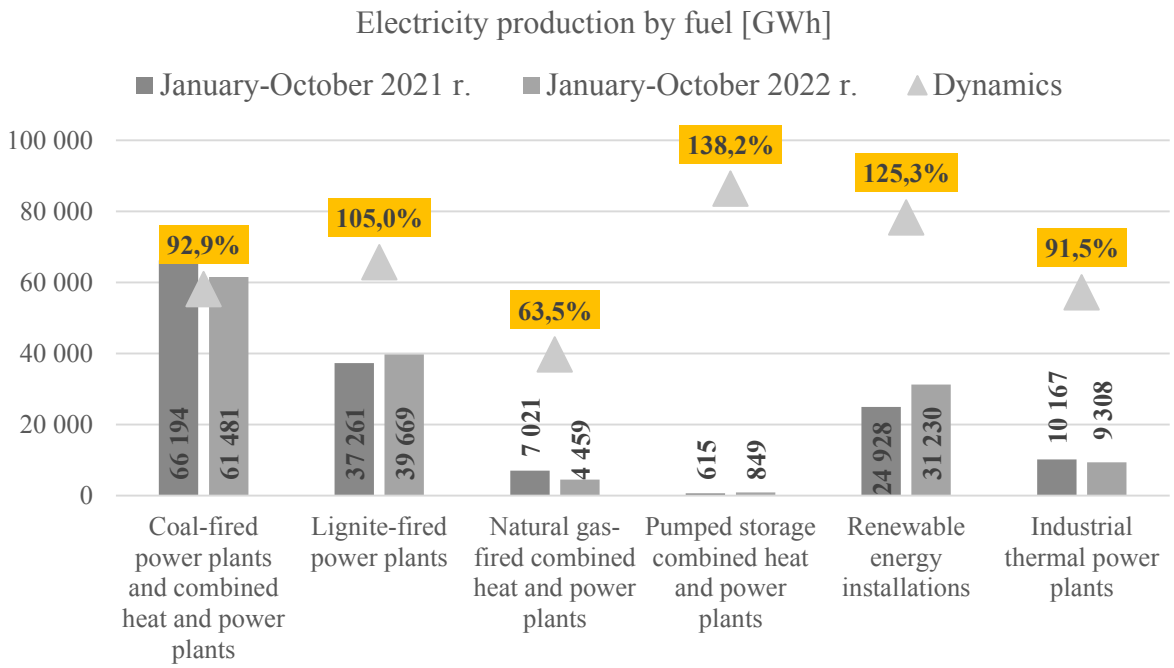


**Figure 2.** Electricity production by fuel [GWh] in Poland in 2022.

Source: Report Energy Transformation in Poland, Edition 2022 (2022). Energy Forum, Analysis and Dialogue.

However, despite the introduction of various forms of support, including feed-in tariffs, the number of RES investments in Poland is still low compared to other EU countries. (European Environmental Agency, 2020). As a member state of the European Union, we are obliged to comply with the provisions of the European Climate Package, which provides for a reduction in greenhouse gas emissions of at least 40% by 2030 compared to 1990 levels (Directive, 2009). Hence, Poland has introduced a number of legal regulations that implement the emission reduction targets set by the European Union. Among them, it is worth mentioning the amendment to the Environmental Protection Law, also known as the Anti-Smog Law, which, among other things, gives local governments the possibility to introduce restrictions or prohibit the operation of installations where fuel is burned and the types and quality of fuels allowed to be burned (Anti-Smog Law, 2015, p. 1) Undoubtedly, Poland's energy targets are one of the most important topics in the energy and climate policy debates in the country. In 2019, Poland adopted the National Energy and Climate Plan (NERP, 2019) for 2021-2030. The document sets out energy targets, including:

- Increase the share of RES in final energy consumption to at least 23.3% in 2030.
- To increase the share of liquid biofuels and biogas in transport to at least 14% in 2030.
- To increase energy efficiency by 27.5% compared to the level achieved in 2007.

In the following years, the Polish government presented a new energy policy for Poland until 2040 (PEP, 2021), which takes into account Poland's energy goals and the provisions of the climate package. One of Poland's main energy goals according to this document is to reduce greenhouse gas emissions into the atmosphere. To this end, the Polish government plans to

develop the renewable energy sector, which is much more environmentally friendly. According to the strategy plan, it is planned to achieve a 23% share of RES in final energy consumption by 2030. Another Polish energy objective is to ensure the country's energy security. Poland's energy policy plans for Poland to be an energy-independent country by 2040, meaning that it will be able to secure its energy supply in the event of an emergency or lack of supply from abroad. At the same time, the main objective of Poland's energy policy is now to gradually reduce greenhouse gas emissions, in line with its obligations under the Paris Agreement (Paris Agreement, 2015). Poland adopted a target to reduce CO2 emissions by 30% in 2030, compared to 1990 levels, and to increase the share of RES in energy production to 21% in 2030.

According to some experts (Mazurek-Czarnecka et al., 2022), in order to accelerate the development of RES, the government should take more ambitious targets for the share of RES in the energy mix and introduce long-term investment plans that will create a stable market for RES producers and investors. According to the report Poland's energy transition path prepared by the Polish Electricity Committee (Report Poland's Path, 2022), in Poland RES are recognised as an important element of energy policy, however they still represent a small percentage of energy generation. Therefore, the report recommends increasing the share of RES in Poland's energy mix to 23-27% in 2030, up to 32-34% in 2040. On the other hand, the results of an audit carried out by the Supreme Chamber of Control, regarding the development of renewable energy sources (Barriers Report, 2021), indicate that the Polish government's RES policy is not effective enough. The authors of the report point out that support for RES in Poland is less favourable than in other EU countries. They point to limited possibilities of financing investments by entrepreneurs, legal regulations on support, administrative-procedural difficulties and problems with the functioning of transmission networks as the main barriers to the development of renewable energy. However, several researchers have taken notice that agricultural biogas plants may become a significant component of Poland's new energy order (Mamica et al., 2022), under the location of new facilities in places with easier access to substrates, including all types of usable waste. It should also be noted that one of the main challenges of optimising biogas production is to achieve high efficiency (methane yield) and system stability with low susceptibility to disturbances (Westerholm et al., 2018; Bensmann et al., 2016). Therefore, there is a need for a better understanding of the causes and effects of process instability and disturbances, especially the response of the biogas microbiome, in order to avoid them (Theuer et al., 2019). The need to remove development barriers and ensure stability in the area of investment process regulation is also pointed out by the authors of the report (Polish Energy Report, 2022), stressing at the same time that Poland is currently in a good moment for the development of biogas energy.

There is no doubt that increasing the share of RES in Poland's energy mix is needed, both from an environmental and a technological development perspective. Government policy should be conducive to this process.

The energy transition towards more sustainable energy production can be accelerated by private investors, who play a key role in the development of renewable energy sources (RES) including biogas plants. Their involvement can also improve the country's energy security. However, investments in RES tend to be costly and require a long-term commitment, which in turn poses a number of challenges and risks for investors (Ligus, 2009). One of the challenges for private investors in RES is regulatory uncertainty, including changes in government policy and tax and legal regulations. Therefore, it is important for the government and regulators to act in a predictable manner and ensure stability in RES support policies. Another challenge for private investors in RES is access to finance. In order to attract private investors to the RES sector, the governments of other European countries introduce various financial support mechanisms, such as preferential loans, subsidies, tax reliefs. Another important factor influencing private investors' decision to invest in RES is cost-effectiveness. The introduction of new technologies and the reduction of RES energy production costs have made some projects more competitive. However, in some cases, the cost of investing in RES may still exceed the cost of investing in traditional energy sources. In this case, local and self-government authorities should use various support mechanisms to increase the cost-effectiveness of investments in RES.

The analysis of the available literature on the subject showed that there is a lack of research on the new concept of interpreting Poland's environmental policy in the context of supporting the development of renewable energy sources (RES) from the perspective of sustainable development. In particular, regarding the role of the biogas plant in this process. Therefore, the presented research complements the gap in the literature on the subject and constitutes a new approach to energy transformation plans.

Bearing in mind that the purpose of the article is to analyze and assess the compliance of the development of agricultural biogas plants with the environmental policy of Poland, in particular in the field of promoting the use of renewable energy sources at the local level. The article itself has many important political, organizational and practical implications. The article was organized as follows. Chapter 2 describes the local dimension of the development of agricultural biogas plants. In turn, chapter 3 discusses and presents the development of biogas plants in the context of the state's environmental policy. On the other hand, in chapter 4 conclusions are presented and a discussion is started - indicating and identifying the benefits of development agricultural biogas plants not only for the environment, but also as an element stimulating economic development local and regional level. At the same time, it indicates problem areas for Poland's environmental policy in the context of supporting the development of renewable energy sources (RES) from the perspective of sustainable development.

## 2. Local dimension of the development of agricultural biogas plants

Observations of the market reality indicate that the use of renewable energy resources in the form of biomass from agricultural or agri-food production makes it possible to achieve an appropriate level of energy security locally. For the proper development of rural areas, it is essential to rely on stable energy sources and to be independent of external suppliers. Development from a local perspective is the primary objective of each local government unit striving to improve the living conditions of its inhabitants, while maintaining rational management of the local resources at its disposal (Orłowska, 2018, p. 45). Thanks to the use of the advantages of own factor resources (e.g. natural or infrastructural), it is treated as a stimulator of the development of localities, communes, or a combination of several communes (Blakely, 1989; Parysek, 2001; Brol, 1998; Sekuła, 2004). L. Wojtasiewicz defines local development as a complex qualitative transformation that covers a specific area in terms of the level and quality of life of its inhabitants. More generally, it is a phenomenon of positive changes of a quantitative nature and progress of a qualitative nature, in accordance with the needs of the local community and their hierarchy of values and needs (Wojtasiewicz, 1996, pp. 13-14). A similar approach was presented by R. Brol (1998, pp. 10-11). One of the courses of action on both the local and regional side is the pursuit of sustainable development, and therefore the management of public issues requires that a set of commonly accepted values be adopted and respected, influencing the decisions that are taken by local authorities (Domański, 2000, p. 14). Local and regional authorities play an important role in the implementation of the sustainable development agenda, as they are responsible for the maintenance and care of technical infrastructure facilities, e.g. municipal management and water supply. The list of activities of local authorities that contribute to improving the attractiveness of an area can include a wide range of undertakings - e.g. concerning: promotion, marketing, financial support and land management. Similar activities should be carried out at the regional level - covering the provinces (Szewczuk, 2010).

As pointed out by one of the researchers the construction of biogas plants stimulates economic development and creates favourable conditions for local entrepreneurship. Such facilities contribute to the creation of new jobs and contribute to the local gross product (Obrycka, 2014). Considering the financial aspect, the possibility of generating income for the municipality's budget through the payment of taxes by the biogas producer is important. In addition, biogas plants can provide an image element for the locality as a new technology-friendly area. Investments in biogas plants can also benefit local manufacturers of machinery and equipment, local shops offering plant protection products or fertilisers used in biomass production (Kowalczyk-Juśko, 2007-2013, p. 76).

In today's market reality the biomass is one of the most important feedstocks used in renewable energy production. In Poland, according to data from the end of 2021 (CSO, 2021), biomass accounted for approximately 57% of the total installed RES capacity. It is also used to produce heat and biofuels. In 2021, around 95% of RES heat in Poland was produced from biomass. Therefore, it can be said that biomass plays a key role in the Polish RES sector and is an important part of the energy transition. There has been a significant development of agricultural biogas plants in Poland between 2016 and 2020. According to data published by the National Agricultural Support Centre (KOWR, 2023), the number of installations included in the register of agricultural biogas producers has increased from 8 in January 2011 to 116 in 2021 (Table 1).

**Table 1.**
*Number of entities entered in the register of agricultural biogas producers between 2011 and 2021*

| **Number of entities registered in the register of agricultural biogas producers as at** | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 of January 2011r. | 1 of January 2012r. | 1 of January 2013r. | 1 of January 2014r. | 1 of January 2015r. | 1 of January 2016r. | 1 of January 2017r. | 1 of January 2018r. | 1 of January 2019r. | 1 of January 2020r. | 1 of January 2021r. |
| 4 | 10 | 21 | 35 | 50 | 69 | 84 | 86 | 85 | 93 | 99 |
| **of which, number of installations included in the register of agricultural biogas producers** | | | | | | | | | | |
| 8 | 16 | 28 | 42 | 58 | 78 | 94 | 96 | 96 | 103 | 116 |

Source: National Agricultural Support Centre Report, 2022.

The increase in the number of installations included in the agricultural biogas register was mainly due to increasing urbanisation, which prompted farmers to seek alternative sources of income, as well as growing environmental awareness and the need to reduce greenhouse gas emissions. Between 2016 and 2020, Poland had the highest number of agricultural biogas plants in the western provinces, such as Wielkopolska, Lower Silesia, Lubuskie and Zachodnio-pomorskie. The Mazowieckie and Łódzkie provinces were second in terms of the number of biogas plants, and the Kujawsko-Pomorskie and Wielkopolskie provinces were third. Biogas plants in Poland are covered by various strategic documents that define the directions of development of renewable energy, including biogas production. The most important of these documents are presented below:

1. The National Recovery and Resilience Plan (NERP, 2022) - a strategic document that sets out the priorities and objectives of Poland's investment policy after the COVID-19 pandemic. Among other things, the NERP provides for the financing of projects related to the expansion of renewable energy installations, including biogas plants.
2. The National Energy and Climate Plan 2021-2030 (NERP, 2019) - a strategic document that sets out goals and objectives for the development of RES until 2030, including biogas production. The SOZE 2030 includes, inter alia, targets related to the development of agricultural biogas plants and increasing the share of biogas in the fuel mix.

3. The Operational Programme Infrastructure and Environment 2014-2020 (OPI&E) and the Programme European Funds for Infrastructure, Climate, Environment 2021-2027 (OPI&E, 2014) - strategic documents that set out priorities and objectives for investments in infrastructure and environmental protection. Among other things, these documents provide for the financing of projects related to the production of energy from renewable sources, including biogas plants.
4. The National Strategy for Regional Development 2030 (NSRD, 2019) - a strategic document that sets out goals and objectives for the development of Poland and the voivodeships until 2030. Among other things, the 2030 Strategy provides for the development of energy production from renewable sources, including biogas plants.

Support programmes, such as the Rural Development Programme (RDP, 2014-2020), which provided for the financing of investments related to energy production from renewable sources, including biogas plants, were also an important factor influencing the development of agricultural biogas plants in Poland. At this stage of summaries, it is also necessary to mention the perspective of the EU and the private sector, which more and more often seeks co-financing for this category of investments.

## 3. Biogas development and national environmental policy

Polish ecological policy prioritises the development of RES, including biogas plants, as a key element in achieving environmental protection goals and improving the quality of life of the country's inhabitants. The implementation of investments in the construction of biogas plants contributes to the sustainable development of the country and the improvement of air quality, which is in line with the objectives of Poland's ecological policy. The construction of biogas plants also allows the efficient use of different types of organic waste, such as plant residues, slurry or sewage, to produce biogas, which is a fully renewable energy source. The use of biogas in place of traditional fossil fuels contributes to the reduction of greenhouse gas emissions, which is in line with Poland's climate policy objectives.

As mentioned above, the implementation of biogas plant investments contributes to the sustainable development of the country The most widespread definition of sustainable development is that derived from the report Our Common Future (Report, 1991), which states that sustainable development is development that ensures that the needs of the present generation are met, without compromising the ability of future generations to meet their own needs. Thus, sustainable development is striving to improve the quality of life while maintaining social equity, biodiversity and abundance of natural resources. The pursuit of improving one's own quality of life, however, cannot take place while condemning others to poverty (Gerwin, 2008). European policy on sustainable development, including environmental

sustainability, is based on the provisions of the Rio Declaration signed in 1992 (Declaration, 1992), whose main objective is to implement Agenda 21. The Global Programme of Action, popularly known as Agenda 21 (Agenda, 1992), is a comprehensive document based on the 27 principles of the Earth Charter. It contains a set of recommendations and courses of action that should be taken for sustainable development in local life in the perspective of the 21st century. Implementing the principle of sustainable development is based on combining political, economic, social and individual actions to balance the environmental access opportunities of individual societies and their citizens - both present and future generations.

The principle of sustainable development has been elevated to the status of a constitutional principle in Poland. The Constitution of the Republic of Poland in Article 5 (Constitution, 1997) provides for the protection of the environment guided by the principle of sustainable development. The principles of eco-development have become the basis for the nationally implemented document adopted by the Sejm of the Republic of Poland, „National Ecological Policy 2030" (PEP, 2019).

Therefore the development of agricultural biogas plants is in line with the principle of sustainable development. The construction of agricultural biogas plants contributes to the preservation of the abundance of natural resources and thus to the reduction of natural resource depletion. Substrates that can be used in installations include potato pulp, vegetable substrates (maize silage and other green biomass) and animal manure. Other products, such as post-boiler stock and bakery waste, may also be used. In addition, reducing carbon emissions prevents environmental degradation, so that the needs of the present generation can be met without compromising the ability of future generations to meet their needs. The realisation of investments in the development of biogas plants in terms of preserving biodiversity fulfils the principles, as well as the objectives, of Poland's ecological policy. The production of energy in a biogas plant reduces the exploitation and combustion of fossil non-renewable energy sources, as well as prevents environmental degradation by reducing carbon dioxide emissions and thus fulfils Poland's obligations to increase the share of energy from renewable sources.

Linked to sustainable development is environmental policy. From the changes in EU programmes and priorities, it can be concluded that it stems precisely from harmonious and sustainable development.

Environmental policy is state interference towards achieving environmental protection and sustainability goals, which will only function properly with the operation of market mechanisms. In 2013, a decision of the European Parliament and of the Council on a general EU programme of action up to 2020, the so-called „Good quality of life within the limitations of our planet" programme, was adopted (Decision, 2013, p. 171). The adoption of the programme commits the Union institutions and the Member States to undertake tasks and actions to support the achievement of the Seventh Programme's priority objectives.

It obliges public authorities to cooperate with businesses, social partners, European society and citizens in implementing the programme.

The Seventh Programme includes a vision for 2050, in which citizens are assumed to enjoy a good quality of life. The goal should be achieved while taking into account the ecological limitations of the planet. The objectives of the Environmental Policy resulting from this programme are primarily:

- preserving, protecting and improving the quality of the environment,
- protection of human health,
- prudent and rational use of natural resources,
- the promotion of action at international level on regional or global environmental problems.

The above objectives should be achieved while respecting the principles of environmental policy:

- the prevention principle,
- the principle of rectifying damage at source,
- the polluter pays principle,
- the subsidiarity principle,
- sustainable development.

The development of biogas plants is in line with priority objective no. 2: „Transforming the Union into a resource-efficient, green and competitive low-carbon economy" (Decision, 2013, p. 182), as well as priority objective No. 6 „Ensure investment for environmental and climate policy and address environmental externalities" (Decision, 2013, p. 193). The implementation of this type of investment contributes to the reduction of carbon emissions and the use of local energy resources. In addition, the construction of biogas plants increases the use of renewable energy sources both locally and nationally, thus increasing Poland's competitiveness in Europe.

Preventing dangerous climate change is one of the environmental priorities for the European Union. The EU is showing great efforts to significantly reduce its own greenhouse gas emissions, while encouraging other countries and regions to do the same.

EU priorities for 2030:

- a reduction of at least 40 per cent in greenhouse gas emissions compared to 1990,
- obtaining at least 27 per cent of energy from renewable sources,
- at least a 27 per cent increase in energy efficiency.

The implementation of the biogas plant development is in line with all the objectives indicated above. The construction of an agricultural biogas plant contributes to reducing greenhouse gas emissions by limiting carbon dioxide emissions into the atmosphere (use of energy from renewable sources, limiting the use of fossil fuels - reducing pollutant and greenhouse gas emissions into the air). In addition, it contributes to improving energy security by increasing the supply of energy on renewable energy carriers produced from domestic raw materials.

The use and production of renewable energy, in this case biogas, is not only important from the point of view of meeting EU targets, but above all can and should facilitate environmental protection and provide an additional source of energy.

The implementation of the investment contributes to solving the problems of efficiency and stability of the energy supply. This results in an increase in local and, consequently, national energy security, significant development of rural areas and professional activation of farmers, increasing their income.

In addition, the development of agricultural biogas plants allows the following intermediate objectives to be achieved:

- environmental aspect: improvement of air quality in the area where the project has a close impact, as well as improvement of air quality in the whole country, maintaining resilience to climate change,
- social aspect: supporting social and economic development - the construction of a biogas plant offers the possibility of creating new jobs, increasing the attractiveness of the region, being seen as an attractive region for potential investors, being open to new technologies. This makes it possible to combine the production of energy from biogas with science and education, and in the future with tourism,
- in terms of the economy: leading to energy independence, utilising local energy resources.

The implementation of biogas plant projects also contributes to compliance with the precautionary principle and the preventive action of the environmental policy.

The precautionary principle obliges the institution or person who intends to undertake certain activities to prove that its activities will not cause a risk to the environment. Where it is not possible to demonstrate that there is no risk to the environment, action must be taken to protect the environment.

The principle of the application of preventive action implies the need to consider the potential effects of a specific action and to take preventive action on the basis of this analysis. The principle of prevention is confirmed in all EC Action Programmes and is prioritised in many pieces of environmental legislation. Examples of its application are the provisions on the environmental impact assessment of projects and plans and programmes.

The pollution prevention principle, i.e. elimination of pollution at source, means that when selecting measures to prevent and eliminate the effects of pollution, actions should be evaluated according to the following hierarchy:

- avoidance of pollutant generation (modern technologies producing minimal amounts of pollution),
- recirculation - closing the cycle of materials and raw materials, recovering energy, water and raw materials from waste, waste water and waste gases,
- pollution neutralisation - treatment of waste water, waste gases, neutralisation and storage of solid waste.

The implementation of this principle comes down to the promotion of low-carbon, environmentally friendly technologies, reducing the use of traditional raw materials and energy-intensive areas of farming. The 'polluter pays' principle means that those who cause environmental damage should bear the full costs of those activities that are necessary to remove the pollution or the costs of equivalent activities to achieve environmental protection objectives. According to this principle, users of infrastructure facilities should contribute both to the costs of abatement and to the costs of operating, maintaining and replacing the infrastructure components having an impact on the environment.

Pursuant to paragraph 2 of Article 71 of the Act on providing information on the environment and its protection, public participation in environmental protection and environmental impact assessments of 3 October 2008 (Dz.U. of 2008, item 1405, 1566, 1999), obtaining a decision on environmental conditions is required for planned:

- projects which may always significantly affect the environment,
- projects which may potentially significantly affect the environment.

In accordance with §3, sec. 1, item 80 of the Regulation of the Council of Ministers of 9 November 2010 on projects which may significantly affect the environment (Journal of Laws of 2010, item 71), investments in the construction of biogas plants are qualified as projects which may potentially significantly affect the environment, for which the obligation to prepare a report may be required. In accordance with Article 71(2)(2) of the Act of 3 October 2008 on the provision of information on the environment and its protection, public participation in environmental protection and environmental impact assessments (Journal of Laws 2017, item 1405), hereinafter referred to as the EIA Act, it is a project for which a decision on environmental conditions is required. In the case of an amendment to the decision on environmental conditions of consent for the implementation of the project, the provisions of Article 87 of the aforementioned EIA Act shall apply.

## 4. Discussion and Conclusions

The referenced documents emphasize that the Polish Energy Policy for 2021-2030 assumes an increase in the share of RES in the country's energy mix to 23.5% by 2030. This climate pressure is dictated by three basic premises. The first of them are regulations that in the

EU region are related to the implementation of the idea of the European Green Deal - the construction of a climate-neutral continent by 2050. The idea of radical reduction of greenhouse gas emissions and compensation of remaining emissions through solutions or reconstruction of ecosystems supports, among others, CSRD (Corporate Sustainability Reporting Directive), strengthening the requirements for reporting sustainable development by all participants of the modern market, both in the economic and social dimension.

Another determinant is the changing rules for financing investments, placing more and more emphasis on supporting the green and digital economic transformation and introducing exemptions that make it difficult or even impossible to obtain funds from the market for investments in energy from fossil fuels. This trend is favored by the European Union's policy, which creates a framework for facilitating sustainable investments in the common EU energy market in the regional and local dimension. The last, no less important element of the ongoing changes is civic and consumer activism. This process is characterized by a wide range of activities: from new ecological movements that stimulate (not only) people from the millennial generation to act, to the activism of shareholders and entire entities demanding better integration of social and environmental aspects with the business model of the company. The impulse for action is the scientific reports of the IPCC (Intergovernmental Panel on Climate Change), which clarify the consensus on climate issues and indicate the necessary changes in the functioning of the global economy and individual countries, such as Poland.

Therefore, according to the authors, one of the ways to fit into these trends may be the development of local biogas plants, which, among others, enable the production of both electricity and heat. This is supported not only by the mentioned increase in the number of installations, but also by biogas producers in rural areas. The documents indicated by the authors clearly emphasize that the Polish environmental policy is aimed at reducing greenhouse gas emissions and counteracting climate change. According to the authorities, biogas plants are part of this trend, which contribute to the reduction of greenhouse gas emissions by using organic waste that would otherwise end up in landfills and emit methane that is harmful to the environment. The authors postulate that the well-thought-out development of local networks of biogas plants will allow Poland to increase energy independence by generating energy from domestic sources, which will certainly bring the measurable economic and social benefits indicated by the authors, which are also directly in line with the idea of sustainable development. The presented considerations also pointed to the practical dimension of the scientific discussion in this area. Emphasizing that Poland's energy policy requires greater government involvement in legislative processes and issues related to financing investments in the area of RES development. At the same time, strengthening the role of biogas plants in the local or regional dimension, and not energy from photovoltaics, as so far.

The presented research focused on the analysis and assessment of the compliance of the development of agricultural biogas plants with the Polish environmental policy, with particular emphasis on the promotion of the use of RES at the local level. The research methodology was

based on statistical measures of structure and changes over time, excluding economic aspects. Against the background of scientific considerations, the question should be answered whether such a model of behavior can be a new concept for interpreting Poland's environmental policy in the context of supporting the development of renewable energy sources (RES) from the perspective of sustainable development? According to the researchers, the adoption of this vision must certainly be verified by broader analyses, in particular on a broad economic background. Including min. strategy for the development of agricultural economy and the role of biogas plants, both at the local and regional level.

To sum up, the presented research on the analysis and assessment of the compliance of the development of agricultural biogas plants with the Polish environmental policy, with particular emphasis on the promotion of the use of RES at the local level, does not fully exhaust the essence of the issue. Their verification will certainly be taken care of by the market, indicating whether biogasification will become one of the key elements of the RES development process in accordance with the assumptions of the state policy in the field of environmental protection and sustainable development.

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# INNOVATIVE TRENDS IN HEALTH TOURISM – MEDICAL, LEGAL AND ORGANIZATIONAL ASPECTS

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**Purpose:**[1] The aim of the article is an attempt to show how important the field of tourism is health tourism, including medical tourism, legal, organizational and, above all, medical aspects are the key things presented in this article.
**Design/methodology/approach**: The authors used the legal comparative method and the dogmatic-exegetical method, requiring the analysis of legal acts and views of the doctrine.
**Findings:** The authors focused on presenting the most important things related to the subject of the article. In the era of post-pandemic COVID-19, maintaining proper health is crucial for many societies. We showed innovations in modern medical tourism from the point of view in medical, legal and organizational aspects.
**Research limitations/implications**: Our research was limited to trends in organized medical tourism created by tour operators.
**Originality/value:** We showed a new approach to the subject, from the point of view of three aspects: medical, legal and organizational. We have analyzed trends in organized medical tourism created by tour operators. The three approaches, which we present in the case of medical tourism should be discussed together. The article is addressed to people dealing with health and medical tourism, lawyers as well as people dealing with management and economy, as well as people professionally dealing with health care issues.

**Keywords:** tour operators; health tourism; COVID-19; innovation; travel.

**Category of the paper:** Viewpoint article. The article presents the results of the research used the legal comparative method and the dogmatic-exegetical method.

[1] The author of chapter I, II and V is mainly Szymon Raniszewski, chapter III - Małgorzata Bugajska and chapter IV- Dominik Borek. The views expressed in this paper are those of the authors and should not be taken as reflecting the position of any authority, entity or institution. This article presents the legal status as of 25 December 2022.

## 1. Introduction

At the beginning of this article it should be stressed what health tourism and what medical tourism is. The basic term which is used by the authors of this article is health definition that is used around the world and it says that *Health is a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity* (www.who). Also *The enjoyment of the highest attainable standard of health is one of the fundamental rights of every human being without distinction of race, religion, political belief, economic or social condition. The health of all peoples is fundamental to the attainment of peace and security and is dependent upon the fullest co-operation of individuals and States* (www.who). The following term that is used in this article are the definitions of health tourism and medical tourism as well. For this article, the authors adopted the following definition of health tourism i.e. conscious and voluntary going outside for certain period of time aloof from town in the time off form work in order to recover, thanks to physical and mental active recreation (Gaworecki, 2019). According to A. Łoś, health tourism can be understood as an *organized trip by the entities of the tourist market for a day or more aloof the town in order to regenerate physical health, mental health, beauty treatments or undergoing treatments and operation in a medical facility* (Łoś, 2017).

There is a discussion in the literature about the full scope of health tourism. It is emphasized that health tourism can only be carried out in health resorts as they perform therapeutic and tourist functions. Many authors of studies puts an equal sign between the notions of healing and health tourism and health resort, it leads to the conceptual chaos and it makes it difficult to understand the structure which is the tourism of this area (Jagusiewicz, 2001).

Health resort tourism can be understood as an activity which is realized in tourist towns, related to the provision of spa treatments services which included the treatment of long term disease, rehabilitation, prophylaxis, education and health promotion. Also, health resorts are separated in order to protect and use natural resources, medicinal raw materials areas where spa treatment is provided (Łoś, 2017).

Spa&wellness tourism in this form of tourism, can be divided into two groups. The first one include tourism whose main goal is to take care of the body and relax (pampering) (Richards, Richards, 2006). Most often, these are beauty treatments including - massages (dry and water), clay and herbs wraps, peeling, gymnastics, gym, irradiation, cryotherapy, etc. The second one includes tourist products whose main goal is wellness. Usually, these are treatments which help to struggle with stress, detoxification and also slimming cure and meditation.

According to A. Łoś and E. Spivack, medical tourism is realized in traditional medical centres (medical institutes hospitals, clinics, plastic surgery centers). This is a kind of tourism which is connected with treatment. It can be understood as a conscious human activity in which, a traveler (medical tourist) aims to obtain broadly understood health care - both at home and abroad – which rely on a better state of health or aesthetic appearance of the body with is

connected with rest of physical and mental strength, sightseeing and tourist values as well as entertainment (Łoś, 2017) and (Lubowiecki-Vikuk, 2010). Viewpoint article. The article presents the results of the research used the legal comparative method and the dogmatic-exegetical method. The last one method required a comparison of the achievements of the doctrine, but also of legislative solutions. The legal comparative method, in turn, made it possible to compare solutions in other areas.

## 2. Legal aspects of health tourism

According to H. Zawistowska noticed that there are not enough studied about legal aspects in health tourism and medical tourism as well. However, there is an essential book, called "Patients with Passports" by Glenn Cohen which includes studies that are related to legal aspects of medical tourism.

It is important to say that medical tourism is a growing branch of tourism in which appropriate legal basic must exist what means that to know those matters, you have to know the terms mentioned below to better understand what medical tourism or health tourism is.

The basic legal act of European Union which refers to the topic of this article is Directive 2011/24/EU of the European Parliament and of the Council of 9 March 2011 of the application of patients' rights in cross-border healthcare (Directive 2011/24).

There are no enough available scientific sources related to other legal aspects of medical tourism, such as patient's consent to perform the procedure, access to medical records, responsibility for medical malpractice, the nature, form and content of contracts for the provision of medical tourism services, and also as H. Zawistowska noticed there is a need for a detailed scientific analysis related to the aspects mentioned above. To understand what the legal basis of medical tourism is, it is important to make a catalog of entities that are interested in the acivity of medical tourism and also they actively participate in it. According to H. Zawistowska entities that participate in medical tourism can be divided into the following groups:

- medical tourists (patient - tourist), these are people who report demand for medical tourism services.
- entities providing tourist and medical services.
- other entities, in particular entities who are financing medical services insurance as part of insurance (social, individual), and also central and local government administration as well as economic and professional self-government (Zawistowska 2018).

The rules of law regulate issues related to medical tourism entities and according to H. Zawistowska, they can be divided into the following groups that are related to certain legal consequences:

- producers of services (medical and tourist) or their consumers, being a consequence of concluding a contract for medical tourism services or commit a criminal offence, crime or offence,
- consumers of services (medical and tourist) or trip organizers classified as medical tourism,
- consumers (medical-tourists) and financing units, under social or individual insurance, medical benefits provided for tourists abroad,
- administration (government, local government) or producers and consumers of services (tourism, medical) (Horowitz, Rosensweig, Jones, 2007), related to starting and running a business in the medical tourism industry, gathering and disseminating information on manufacturers of medical services (Zawistowska, 2018; Wang, 2022).

Health tourism also means contracts for providing services abroad, the rules of law of the European Union are prepared for such event, and thus it is important to establish the conditions that must be met in order to provide health support in the country to which we are going.

Directive 2011/24, hereinafter referred to as the Directive "Patients without borders" entered into force in the EU member states on October 25, 2013 and it is a basic legal act in the EU which defines the rights of patients who use healthcare services in any EU country when they need it and they are not in their country.

This Directive provides free access to medical care abroad (Singh, Chawla, Prasad, Anand, Alharbi, Alosaimi, 2022), and confirms their right to reimbursement costs of healthcare provided in another Member State for people who have insurance in EU member state. Its purpose is:

- establishing rules facilitating patients' access to safe cross-border access healthcare,
- ensuring patient mobility in line with the principles established by the Court Justice of the EU by establishing a legal framework governing the use of healthcare services in a Member State other than a Member State insurance, with the possibility of reimbursement of the costs of these benefits,
- promoting cooperation in the field of healthcare between Member States, in full respect of the competences of the Member States in terms of organization and healthcare services.

The directive defines the obligations of both member countries where medical services are provided and the countries where patients using these services are insured. Countries where medical services are provided, the directive imposes the following obligations:

- ensure that patients obtain information from their national contact point enabling them to make an informed choice of medical service provider,
- ensure transparent procedures and mechanisms are in place to enable patients submitting complaints to those using these services,

- ensuring the existence of professional indemnity insurance schemes or similar guarantees from healthcare providers,
- respecting privacy with regard to the transfer of personal data about patients,
- providing foreigners using medical services with access to written or electronic medical records treatment,
- ensure that fees are charged for services provided to foreigners from Member States in the amount equal to the fees for domestic patients.

Member countries where patients receive medical services in another country are insured in the country, they are obliged to provide patients with:

- reimbursement of cross-border healthcare,
- access to information on patient rights,
- access to potentially necessary follow-up medical care,
- access to their medical records (Zawistowska, 2018).

The Directive regulates the rules for the reimbursement of cross-border medical care.

According to these regulations:

- the patient's home country ensures reimbursement of the costs incurred by the insured benefiting from cross-border healthcare, provided, however, that this care falls within the range of benefits to which is entitled in a Member State Insurance (Emilsson, Ernstson, Gustavsson, Svensson, 2020),
- costs of cross-border medical care are reimbursed or paid directly by the Member State to the level at which the costs would be covered by Member State if the same healthcare was provided to its territory; the relevant national authorities may also decide to reimburse the costs of travel and accommodation (Saviano, Bassano, Piciocchi, Di Nauta, Lettieri, 2018).
- a Member State may not make the reimbursement of cross-border care conditional from obtaining prior consent.

The Directive provides for exceptions to this principle the patient may need prior authorization from their home country before leaving country for treatment if the medical care involves hospitalization for at least one night or using highly specialized and expensive equipment medical or if it poses a particular risk to the patient or to the public (Visconti, Martiniello, Morea, Gebennini, 2019).

The Directive allows for the possibility for national authorities to reject an application for a grant prior authorization if they feel that the country can provide the patient with adequate treatment within a period justified by medical reasons; requests for treatment in another EU country must be dealt with within a reasonable time (Zawistowska, 2018).

## 3. Medical aspects of health tourism and medical tourism

Medical tourism is a dynamically developing branch of the market which according to the report from 2012 is priced at more than 100 billion $ (www.kliniki.pl). Medical services are becoming progressively one of our country's key export products. A branch of medical tourism is currently one of the most developing sectors of the Polish economy. According to data from 2018 collected by the Institute for Research and Development of Tourism Medical, our country was visited by 182,000 foreign patients at that time and indicated an increase in the number of tourist-patients compared to 2016 by approximately 15% (www.gov.pl). Difficulties in estimating the number of foreign patients often result from the fact that the patients are people of Polish descent who are permanently residing in other countries that are not included in the statistics as a foreign patient. Often, patients and centers do not want to share such information.

According to many sources, one of the most attractive countries in terms of medical tourism is Turkey. Annually, Turkey is visited by about 700,000 foreigners, many of them are Poles who use medical treatments and other related services there. One of Turkey's advantage is its geographical location, the proximity to European and Asian countries and also a tourist-attractive climate. Their healthcare system is relatively not that expensive, and many specialists who are practicing in European and American hospitals start move their practice to Turkish hospitals (Mostepaniuk, Akalin, Parish, 2023). In addition, meeting the needs for medical services can be combined with an attractive holiday trip. In this country our compatriots are mainly interested in aesthetic medicine, stomatology and hair transplant (www.treatmentabroad.com).

This is just one of the examples of points of interest for patient-tourists. A trip to Crete can be connected with odontotherapy (www.treatmentabroad.com), a trip to Barcelona can be connected with in vitro fertilization (www.treatmentabroad.com) and a trip to Prague can be connected with bariatric surgery (www.treatmentabroad.com). There are professional companies that provide those services at increasingly lower prices and they combine tourist attractions with healing benefits.

In Poland, medical tourism is developing and gaining more and more popularity.

An outstanding factor is the price, which relatively low, even though the quality of services is comparable with Western European countries. Other advantages of Polish hospitals is Poland's location in the center of Europe, relatively short waiting time for the treatment, excellent qualifications and skills of specialists, and a smaller and smaller language barrier due to the knowledge of foreign languages among the medical staff (www.ibirtm.pl).

The most frequent patients who are coming to Poland are citizens of Germany, Great Britain and Scandinavia, they are also citizens of the United States. The part of medicine which evolves so quickly and which foreign patients choose is stomatology. Dental services are about 50-80% cheaper in Poland than in a country where those patients live.

Most often there are implantology treatments and orthodontic treatment. Norwegians and Swedes are especially interested in orthodontic treatment because for them a travel to Poland and proper treatment is still cheaper option than carrying out similar treatment in their home country. Expect the price, the waiting time is very long. In Norway there is the shortage of specialist who deal with the orthodontics and that's why Norwegians choose a specialists from other country, this is the best way to avoid long queues to see a specialist. Orthodontic services for foreign patients are provided mainly by the facilities located in large urban centers such as Warsaw, Krakow and Wroclaw.

Besides stomatology, plastic surgery and orthopedics are becoming more and more popular. In plastic surgery, the most common are breast augmentation surgery or breast modelling surgery, otoplasty, rhinoplasty, liposuction. For patients from UK, the breast augmentation surgery is 3-4 times cheaper in Poland than a similar treatment in Great Britain (www.estheticon.pl, www.nhs.uk). Patients from Germany, Sweden and Russia often choose facilities in Gdańsk as a place for a simple surgery or orthopedic treatment. Foreign patients come for operations to remove varicose veins, to remove gallbladder or bariatric procedures. Americans often do the hip joint replacement or knee joint replacement in Poland, because the price for this kind of treatment in US is ten times more expensive than in Polish clinics. Then, the combined cost of transport and accommodation expense are still much more cost-effective than performing the procedure in the United States. Also vision correction surgeries are popular.

On the international arena, Poland is famous for its health resorts, sanatoriums and other places like that. The geographical location of Poland makes way to a calm rest by the seaside or more active recreation in the mountains. The most famous spa towns are Ciechocinek, Muszyna, Kołobrzeg, Sopot, Busko Zdroj, Polanica Zdroj, Wieniec Zdroj, Nałęczów, Krynica Zdroj and Szczawnica (Masłoń, 2022). They enable the course of physical and respiratory rehabilitation, rheumatic diseases and cardiovascular. The most important attraction in Ciechocinek are the famous brine graduation towers, which are combined with the possibility of performing treatments in the field of balneology, hydrotherapy, physiotherapy, thermotherapy, cryotherapy and massages as well as basic activities in the area Wellness&SPA. Balneotherapy allows to perform brine baths, compresses, inhalations and other therapeutic and care treatments. Medical aspects of staying in such centers is enriched with a typical tourist and entertainment offer, e.g. activities with yoga, concerts, meetings, sightseeing. All for patients-tourists from abroad it is so affordable that it has been attracting considerable interest for years (www.medi-tour.pl).

Increasingly popular are slimming camps or day case also known as minor operation including laser treatments, removal kidney stones, varicose veins, minor gynecological treatments and simple endoscopic procedures. One day there is an opportunity to operate an rooked nasal septum or tonsils, remove minor, superficial dermatological changes or perform

knee joint arthroscopy. All this can be combined with a typical tourist trip and focused on leisure and entertainment (www.medi-tour.pl).

The main reasons why patients decide to seek treatment abroad are economic issues. Treatments abroad are often cheaper and faster than in home country (Dalen, Alpert, 2019). Also in some countries access to the doctors is restricted. Mostly it is related to oncological and genetic diseases, mostly when the patient doesn't have more options in it's own country or even there's no way to diagnose more. Going abroad allows access to opinion of another specialist with a different technological and scientific background, also there is an access to the latest forms of therapy and modern clinical trials. For patients from Poland who deal with oncological diseases, some of those trips can be reimbursed by the National Health Fund. (www.meditravel.pl, www.fundacjarakiety.pl).

Although there is no big research connected with the risk for medical tourism, we can find some research which shows morbidity performed in centers outside the home country. Most of these studies were performed in smaller centers and there is no comparison with similar ones procedures performed on local patients. Often complications are not reported by patients, which further complicates the collection of detailed data. Complications are more common in less technologically advanced countries, where in hospitals, the technique of the procedure may differ in quality from modern hospitals. Despite the significant price attractiveness pose a high risk of perioperative infections and risk of postoperative wound dehiscence. These are mainly centers of Latin America and South, Africa, Middle East, India and Eastern Europe (McCrossan, Martin, Hill, 2021).

More frequent infections of postoperative wounds come from differences in antiseptics procedures during surgical procedures. An example can be a breast plastic surgery, where the wound is considered to be clean-contaminated by the presence of bacteria in the milk ducts of the gland. During the operation performed in specialized center, the procedure is accompanied by antibiotic prophylaxis. Higher level of infection rates in the less advanced centers suggests the lack of antibiotic prophylaxis or the lack of sterile surgical techniques. Implant explantation procedures are also often necessary breast, and the cause is usually purulent periprosthetic infections. In addition, exotic travels to countries which offers cheaper medical treatments exposes the tourist-patient to contact with hitherto unknown pathogens to which it may not have acquired immunity (Abdul-Rahman, Hassan, Abdou, Abdelmoaty, Saleh, Salem, 2023).

Also, a dangerous phenomenon is doing many medical services during one visit abroad, in the offered packages which are often cheaper. It increases the risk of thromboembolic complications. Long-lasting immobilization and also long air travel, which is common for treatment foreign conduce the risk of complications. This is a potentially life-threatening complication (McCrossan, Martin, Hill, 2021).

The conditions of postoperative care are also different. One of them is the language barrier, but also other procedures. Often, the procedure is already paid for before consultation with the surgeon, which causes that cases of treatment refusal are limited to a minimum and also

omitting minor contraindications to the treatment, which, however, increase the risk of perioperative and postoperative complications. Very often, the costs of caring for a patient are already transferred to the tourist's home country (McCrossan, Martin, Hill, 2021).

The quality of international benefits is ensured by accreditation systems for medical facility around the world. One of the most famous is Joint Commission International. Obtaining the appropriate accreditation informs the patient-tourist about the appropriate technological and scientific level of the hospital. Proper references attracts not only the sick but also specialists from all around the world who are gaining in this new territory for professional development. Inspectors from accreditation companies watch on the proper conduct of the administrative and medical activities in medical centers around the world. They assesses the level of patient care, mediation management (Chi, Yu, Qi, Xu, 2018), adherence to patient rights, prevention of post-treatment complications (including infection prevention), the quality of laboratory and other diagnostic tests and staff qualifications. Obtaining international accreditation provides potential patients about the level of services provided and the safety of entrusting their health to the hands of foreign experts (www.jointcommissioninternational.org).

## 4. Organisational aspects – discussion of trends and brief presentation of statutory regulations in this area

Health tourism is associated mainly with individual travel. The use of medical services is, after all, a very individual matter. However, it should be borne in mind that in this are there exists, for example, the concept of the so-called group therapy that also contributes to solving individual medical problems. Such therapy can be provided, for example, as part of organised travel, usually in the form of a travel package. Similarly, travel by organised groups of patients wishing to improve their health is becoming increasingly popular. Such patients can benefit also from the so-called group travel, which is the opposite of individual travel. The latter primarily concerns the organisation of trips by using multiple tourism service providers. A somewhat autonomous system is the use of so-called dynamic packaging i.e. linking of several travel services (Borek, 2018). Considering the two possibilities for organising health tourism trips we will discuss their organisational aspects and will comment on the statutory regulations in this respect.

We will begin with an analysis of linked travel arrangements i.e. at least two different types of travel services purchased for the purpose of the same trip or holiday, not constituting a package, resulting in the conclusion of separate contracts with the individual travel service providers (Borek, Zawistowska, 2020). A linked travel arrangement is established if a trader facilitates the purchase of travel services by travellers in one of the two systems discussed below with practical examples.

1) The linking of travel services takes place on the occasion of a single visit or contact with a point of sale with the possibility of selecting and paying separately for each travel service.

A visit to a point of sale is defined as a visit to a place where a travel service can be purchased. This place can have a clearly demarcated area as in the case of an immovable office, but it can also be a booking portal or a traditional website. If, as part of our visit, we have the opportunity to select services and pay separately for each of them, such a self-composed package will be a linked travel arrangement (Borek, 2022).

In practice, we most often purchase such packages through websites. For example, when entering a booking portal, in addition to the possibility of purchasing a medical service, e.g. from the area of aesthetic medicine, one has also the opportunity to purchase accommodation and car rental services (Borek, 2022). In such case, the customer has the opportunity to book a hotel service targeted at patients looking for a hotel facility near the hospital. The patient can make separate bookings and payments to individual operators on a single website. Thus, a linked travel arrangement is created, i.e. a travel product, in which each service provider is individually responsible for the quality of the services provided and their performance.

2) The linking of travel services takes place in a targeted manner, i.e. the purchase of a travel service entails the purchase of at least one additional travel service from another trader and a contract with such other trader is concluded at latest 24 hours after the confirmation of the booking of the first travel service (Borek, 2022).

Targeted facilitation can take place in connection with trade relationships which are often based on remuneration. In practice, this may involve an invitation to book a travel service following confirmation of the booking of the first service, e.g. a dental service. The additional travel service, for example hotel accommodation or car rental must be available at the selected travel destination. It is important that the invitation to use the additional service is generated not within the same point of sale but, for instance, by an additional link to the booking site of the other travel service provider or by a telephone contact (Borek, Zawistowska, 2021). The key aspect is that the facilitation has to be targeted, i.e. that the first trader suggests an action to the customer whose contact with the second trader can be significantly facilitated because the first service provider is aware of the customer's situation, e.g. the date of his/her stay, the customer's needs, etc. Such practice can take place both at immovable retail point with the additional contact facilitated e.g. by handing over an information brochure with the telephone number of another service provider, or as part of an online procedure. In the latter case, we are most often confronted with so-called pop-up windows which appear on a website and suggest us to conclude an additional contract for another travel service provided e.g. in the location where we are going to be hospitalised (Borek, Zawistowska, 2020). If such an additional contract is concluded within 24 hours of the confirmation of the booking of the first service, e.g. a dental service, a travel product is created in the form of linked travel

arrangements where each service provider is individually responsible for the quality of their services and their performance.

In turn, a travel package can be created in six different ways, presented below together with specific factual situations.

1) A travel package is created where travel services are combined by one trader, including at the request of or in accordance with the selection of the traveller, before a single contract for all the services is concluded.

A trader whose activity involves performing, on behalf of the traveller, the factual and legal acts connected with the conclusion of a travel contract, creates a travel package. A medical service connected by the trader with a flight service to the place of medical treatment as well as with accommodation service, prior to the conclusion of a contract covering the entire package, constitutes a travel package (Borek, Zawistowska, 2020).

2) The linking of services into a travel package is also effective when the services are purchased from a single point of sale and have been selected before the traveller has agreed to pay.

The example can be so-called dynamic packaging that results in a travel package. In practice, this involves the customer selecting several travel services before making an overall payment through a single sales office. A patient purchasing a medical service in combination with flights and accommodation, by selecting the services from a single website or a single immovable travel agency, leads to the creation by the trader of a travel package before making payment (Borek, 2022).

3) A travel package is also created if a product is offered or sold at an inclusive or total price covering all the services, or if one of the services prices is charged to the buyer.

An offer or contract of sale comprising a list of travel services covered by a single price is a travel package. An example is a classic travel package which can be a medical trip to a sanatorium, if the package includes medical treatment, transport and accommodation (Borek, Zawistowska, 2021).

4) The conclusion of a contract under which the traveller has been authorised to choose from among different types of travel services also results in the creation of a travel package.

A specific contract authorising the traveller to choose from among several different options may also concern medical services in combination with other travel services. By way of example only, it should be pointed out that the selection of an appropriate medical service may be made from among various forms of treatment offered under a single contract, which may additionally include a service of transport and accommodation close to the place where the medical treatment is carried out (Borek, Wyrwicz, 2019).

5) A travel product in the form of a travel package is also created when services are purchased from separate traders via linked online booking processes. It is important that, during these processes, the trader with whom the first contract is concluded transmits to the other trader or traders: the traveller's name, e-mail address and the payment details, and that the contract with this other trader or traders is concluded at the latest 24 hours after the confirmation of the booking of the first travel service (Borek, 2022).

The system described above applies exclusively to a procedure carried out by means of information and communication technology, i.e. remotely (Iandolo, Vito, Fulco, Loia, 2018). The system therefore concerns situations when a contract concluded with a traveller within an organised remote contract-conclusion system, without the simultaneous physical presence of the parties, with the use of one or more distance communication methods only until the conclusion of the contract. However, a sine qua non condition for the use of this form is the conclusion of a subsequent contract with the trader or traders within a maximum of 24 hours (Borek, Zawistowska, 2020). Many times, the conclusion of a subsequent contract is linked to the making of a payment made in a similar mode and time. Many global financial players are involved in the handling and programming of such most complex payments, whereby the payer details are transferred between service providers. The aforementioned ICT capabilities make the use of the described mode quite straightforward; unfortunately, it also seems quite easy to circumvent it by introducing an algorithm to conclude a contract beyond 24 hours.

However, a travel package or a linked travel arrangement may not be created under other conditions too. A travel package is not created despite the fulfilment of the conditions discussed above, where only one type of basic travel service (transport, accommodation or motor vehicle rental) is combined with one or more travel services which:

1) do not account for 25% of the value of the combination and are not advertised as, and do not otherwise represent, an essential feature of the combination, or
2) are selected and purchased only after the performance of the basic travel service has started (Borek, 2022).

The first of the aforementioned cases refers to the combination of, for example, a flight service from Warsaw to Chicago and back, worth 3000 $, and an aesthetic medicine procedure performed in the USA worth 900 $. The additional service, i.e. the aesthetic medicine treatment, added to the basic one, i.e. the flight, represents less than 25% of the total value of all travel services. To be precise, the value of the aesthetic medicine treatment is 23% of the total value. However, if, in the present case, another basic service, e.g. accommodation in Chicago, were to be added to the basic service, then regardless of its value, we would have a travel package or a linked travel arrangement, as two different types of basic travel services would be combined (Borek, 2022).

The second of the abovementioned exemptions relates to the situation where, for example, after the accommodation service provision has started, the customer purchases at the establishment a package of medical treatments for hotel guests including a comprehensive examination of body fat and cardiorespiratory fitness.

The examples discussed have shown that the organisational aspects in health tourism are based on travel products provided for in the legislation in the form of tourist packages and linked travel arrangements. The latter, although more individual in nature and used for an independent package formation, are always provided by a trader. It should be borne in mind that also this individual provider of medical services under the discussed conditions will be treated as a trader and should therefore expect appropriate organisational and legal consequences (Borek, 2019).

## 5. Conclusion

The presented analysis shows how important the field of law as well as medicine is in health tourism. In the face of two years of the COVID-19 pandemic and the health debt incurred (Cretu, Ho, 2023) by EU societies, medical tourism will become increasingly important. Whether the members of the societies of the EU Member States will become healthier or not depends solely on the availability and quality of health services. The article presented the growing importance of health tourism in the world and in Poland. Undoubtedly, the growing interest in destinations considered health-promoting and the related expenses influence the demand, which in turn influences the supply of the tourist and health product and the development of health-promoting tourist destinations. The work presented in the introduction, adequate to the analyzed one, was used research methods that allowed to demonstrate the truthfulness of the subjects hypotheses. Despite the lack of regulations that would directly regulate only those described in the dissertation, issues at both the national and EU level, as a subsidiary general regulations on travelers protection apply. However, it should be remembered that the views of the doctrine are complementary to the existing legal acts. The described topic is part of the new trends, is up-to-date and worth further research considerations.

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# DYNAMIC PROCESS IMPROVEMENT – THEORETICAL AND EMPIRICAL PERSPECTIVES

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**Purpose:** The paper's main objective is to fill the research gap by theoretically and empirically exploring current approaches to business process improvement issues. In particular, attention is paid to the internal factors of dynamic business process improvement.
**Design/methodology/approach**: The article is based on the results of a quantitative survey conducted using the CAWI technique. Respondents to the survey were middle managers representing companies in various industries where process improvement is taking place. Conclusions were drawn from a sample of 444 companies.
**Findings:** The research conducted here made it possible to investigate and clarify aspects of dynamic business process management. The main conclusions that emerge from the results of the study allow to indicate the main internal factors which play the most significant role in dynamic process improvement. Is important to state that organisations must have certain resources in order to be able to implement dynamic process changes. They must also have certain capabilities that allow these resources to produce the desired effects.
**Research limitations/implications**: The study targeted the perspective of middle managers, which was a key factor in selecting respondents for the study. Future research could move in the direction of expanding the pool of respondents to include other levels of management. Qualitative research, and in particular the case study method, could also prove useful in developing the topic further.
**Practical implications:** In line with dynamic capabilities, middle managers should be oriented towards identifying the individual factors determining the company's development, arriving at synthetic, current and reliable knowledge necessary for the decision-making process, and reacting quickly to changes occurring inside and outside the organisation.
**Originality/value:** The subject of this article is the issue of dynamic business process improvement. This is a topic that has not yet been sufficiently researched. The presented research area is interesting from a cognitive point of view and the perspective of management practice. It is part of the current research on the effectiveness of business process execution and, by extent, the effectiveness of entire organisations. It responds to the current need to react quickly to unpredictable, rapid environmental changes, which corresponds to the metaparadigm of dynamic reality.

**Keywords:** business process management, BPM, business process improvement, BPI, dynamic capabilities.

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

## 1. Introduction

The reality in which organisations operate today is fraught with uncertainty that can hardly be compared to any situation in the past. Until recently, the frequency of change and the degree of radicality of change were considerably less, but now there is a marked acceleration in the pace of change and an increase in the demand for it (Hamel, Breen, 2007). Various phenomena and problems overlap, some of which have not been experienced before. Organisations are operating in a "new normal", where previously unimaginable event scenarios become instantly inevitable (Taleb, 2008). In this situation, organisations need to make changes constantly in order to achieve the realistic goal of sustainability, as change has become a kind of "guarantor" of survival and the ability to face future challenges. Making changes in response to the impulses of the environment is realised by a broad (ever-expanding) spectrum of management concepts, approaches and tools – process management is one of them (Osbert-Pociecha, 2019). Business processes are central to an organisation's effectiveness and ability to implement its business strategy successfully, and achieve growth and development (Bakotic, Krnic, 2017). In order to cope with the dynamic complexities of the market, many organisations are forced to make changes to processes in real time. The main value of such an approach lies in innovation, creativity and individualisation (Szelągowski, Berniak-Woźny, 2020). As a result, there is a very high demand for dynamic business process improvement. Organisations are forced to look for opportunities to implement process changes constantly. Today, process improvement must be dynamic, based on continuous assessment, anticipation and adaptation to new trends that may become entrenched and affect the earning capacity of the business and also its viability. It is about being able to implement rapid and urgent change, which is very challenging for many organisations. This approach corresponds with the concept of dynamic capabilities, which has been promoted for some time and is considered one of the most relevant and influential topics in current research (Schilke, 2014; Vogel, Guttel, 2012). A review of national and international literature on business process management (BPM) in the context of business process improvement (BPM) shows that its redefinition was already seen as inevitable due to the need to cope with multiple changes caused by different things (Jeston, Nelis, 2014; Rosemann, vom Brocke, 2015; Badakhshan et al., 2019). Dynamic business process improvement can be regarded as a manifestation of organisational intelligence and a key competence, enabling rapid adaptation of processes to new, previously unknown market conditions. This topic, however, is not sufficiently researched as the changes that are currently

taking place are rapid and undefined. The paper's main objective is to fill the gap outlined above through a theoretical and empirical examination of current approaches to business process improvement issues. In particular, attention is paid to the presentation of the authors' empirical research results into the internal factors of dynamic business process improvement. Accordingly, a research problem was formulated in the form of the following question: which internal factors most influence an organisation's capacity for dynamic process improvement?

The article has a its structure. In the first part, reference is made to the improvement of business processes against the background of the concept of a company's dynamic capabilities. This is followed by the presentation of the research methodology, the results of the empirical study carried out, and a discussion which compares these results with those of other authors. The article concludes with a summary, indication of limitations, and directions for further research.

## 2. Business Process Improvement – literature review

Business processes are a natural component of every organisation, ensuring that they function and, as a result, deliver the objectives written in strategies and operational plans while simultaneously fulfilling customer orders and meeting their expectations (Nowosielski, 2014). Business Process Improvement is a special case of organisational improvement. It is a systematic approach to closing process performance gaps by reducing process execution time, identifying and eliminating causes of poor quality, reducing variability, and eliminating non-value-adding activities (businessdictionary.com).

The improvement activities undertaken aim to make changes to processes, and implement various types of innovative solutions (e.g. technological), often simplifying them but also influencing the interactions taking place between people, technology and all activities in such a way as to deliver the expected products/services to customers. It is argued that effective process change is characterised by correlating the key problems of the organisation, the people affected by those problems (and who will benefit from their solution), and the resources required to do so (Cannon, McGee, 2016). In line with the variability paradigm and assuming that an organisation is only as effective as its processes (Rummler, Brache, 2000, p. 76), it can be concluded that improving them should help companies adapt to new situations. Since the beginning of the twenty-first century, the "focus" in Business Process Management (BPM) has started to shift very strongly towards dynamic business process improvement (dynamic BPI) (Helfat, Winter, 2011; Anand et al., 2009; Szelągowski, 2019; Grajewski, 2013; Bitkowska, 2021). Response times to reported customer needs, process flexibility, and the identification of new internal sources of value growth, error reduction, inefficient material consumption, and associated costs have become more important.

The perception of BPM as a set of dynamic capabilities for adapting existing business processes and creating new ones to achieve alignment with the environment has also begun to come to the fore (Niehaves et al., 2011). Being proactive in this respect fits with the concept of dynamic capabilities (Teece et al., 1997; Eisenhardt, Martin, 2000; Helfat, Winter, 2011; Laaksonen, Peltoniemi, 2018) in terms of managing change in organisations and maintaining high levels of mobilisation (Kotter, 2008), and identifying challenges and seeking answers to them (Bridges, 2009). In an environment characterised by change and uncertainty, dynamic capabilities allow organisations to 'integrate, build and reconfigure internal and external competencies to meet a rapidly changing environment' (Teece, 2007). Today, as Teece (2018) argues, dynamic capabilities are essential not only for understanding competition in the face of rapid technological change but also for coping with the deep uncertainty of technological and market change.

Dynamic capabilities as a theoretical construct correspond very strongly with process management (Ortbach, 2012; Niehaves et al., 2011). Organisations today are required to use unconventional management approaches and technologies, and the obligation to maintain competitive advantage appears to be dynamic, never-ending, and highly individualised (Hanaysha et al., 2022; Alrawabdeh et al., 2022). Business process improvement is now seen as an opportunity to improve current efficiency and strategic growth (Rosemann, 2015; Hernaus et al., 2012). Forstner et al. (2014) and Trkman (2010) argue that by combining the perspectives of business process management with development capabilities, it can be concluded that processes can be identified with operational capabilities, with process improvement being a dynamic function of them.

Traditionally, process efficiency has been viewed from the perspective of time, cost, quality and flexibility (Reijers, Mansar, 2006). Nowadays, however, due to the ever-changing external environment resulting from the fact that the modern economy is subject to increasingly rapid, multi-dimensional change, another criterion comes to the fore, namely the ability to adapt to change. Dynamic business process management is an extension of the classic concept of process management and an attempt to harmonise process management with the learning organisation concept. This is achieved through the ongoing verification of acquired knowledge concerning customer needs by numerous process executors, which leads to the gradual accumulation of knowledge.

Justification is found in intelligent process management, which enables organisations to conduct their business activities efficiently and effectively by integrating analytical, social and mobile technologies into coordinated processes (Trocki, 2016). Business processes largely determine an organisation's quality, innovation and efficiency (Minonne, Turner, 2012). They are considered unique and critical assets that account for a significant proportion of an organisation's costs but, at the same time, offer significant opportunities to improve efficiency (Seethamraju, 2012). Due to its dynamic nature and flexibility, process management

enables organisations to adapt to changing global market conditions (Liu et al., 2009). It is also closely linked to developing a firm's capacity for dynamic change (Niehaves et al., 2014).

At the same time, referring to contingency theory, it can be argued that the development of business process management capabilities is intensified by external factors (Pauwaert, van Looy, 2014). Trkman (2010) argues that dynamic capability theory helps to understand the environment and provides a theoretical framework that contributes to a better fit between the business environment and the business processes implemented. Referring to the meta-capabilities proposed by Teece (2007), Bernardo et al. (2017) state that business processes enable the identification and access to market and technological resources. In their view, processes entail the adaptation of organisational resources to the needs of the environment and the systematic implementation of activities that contribute to continuous renewal.

The dynamic approach to process improvement leads to the need to move away from the classic process improvement cycle based on formalised procedures. These procedures overall significantly increase response times to customer expectations, require additional effort to involve higher hierarchical levels and discourage improvement activities. The process change procedure should, therefore, be flexible enough to adapt the importance and scope of the change to the intensity of the adjustment activities. In this situation, the focus of process implementation on creating customer value cannot be reduced to the routine, repetitive execution of activities in processes and attempts at optimisation from the point of view of different criteria, as customers' expectations, habits, sensitivities and capabilities are different and sometimes even contradictory (Grajewski, 2013). A dynamic approach to process improvement should allow for an appropriately rapid, and for critical situations, even immediate, response to changing relevant operating conditions, personalised customer requirements or competitive movements. The processes themselves should be defined and implemented in such a way that direct executors can make additions and even changes to their implementation. As such, knowledge is systematically uncovered, allowing the intellectual capital of the organisation to be utilised and processes to be improved as they are played out (Szelągowski, Berniak-Woźny, 2020).

## 3. Research methodology

The research methodology comprised three stages. In the first, a narrative literature review was conducted. This method was chosen to show the current knowledge of business process improvement. The choice of method was mainly dictated by the complexity of the phenomenon under study and the conceptual and methodological diversity in the approach to its exploration. The narrative literature review aims to bring together different studies to reinterpret and establish interrelationships in defining the context of the research problem (Baumeister, Leary,

1997). Among its advantages is the possibility of omitting studies whose relevance to the topic is marginal or which do not have a sufficiently high level of relevance and reliability.

The method includes a subjective element, which gives the researcher greater freedom to identify publications for review and discuss the results obtained. The review aimed to identify how the issue of dynamic business process improvement is portrayed in the literature. The literature review began with an examination of the WoS and Scopus academic databases, which offer peer-reviewed, up-to-date, high-quality academic journals published worldwide. The search was conducted between July and August 2019. The following phrases were considered: business process improvement, dynamic business process improvement, capacity to process improvement, capacity to dynamic process improvement, capability to process improvement, and capability to dynamic process improvement. The Scopus database was searched based on article title, abstract and keywords. The WoS database was searched by topic. The analyses covered scientific articles published up to mid-2019. In the initial phase of the study, the relevance of the articles was determined independently by all authors based on the abstracts. In this way, 94 scientific articles were retrieved. The authors then compared their findings and developed a final list of articles. In the next phase, 39 articles were subjected to in-depth full-text analysis. The full-text analysis was carried out independently by all authors. Based on the literature study, seven groups of internal factors were identified that showed a relationship with dynamic business process improvement:

- factors of a managerial nature,
- organisational and decision-making factors,
- Information factors,
- technological and IT factors,
- cultural factors,
- factors of a financial nature,
- factors relating to human resources (concerning persons in managerial and executive positions).

The second stage was based on the search results and consisted in developing a research questionnaire. Respondents were called to answer 68 survey questions on a proposed five-point Likert scale (a value of 1 meant low importance, and a value of 5 meant very high importance). The survey questions (ranging from five to eight questions) were tailored to the groups of factors listed above. The first part of the questionnaire contained questions relating to business process improvement dynamics and factors that may affect an organisation's ability to improve processes dynamically. The second part of the research questionnaire consisted of psychological tools (tests) to help identity which type of work engagement is most related to dynamic process improvement. The third part of the questionnaire was a metric that included questions about: industry, type of business, number of people employed, legal–organisational

form, capital, scope of operations, financial condition, gender of the respondent, number of years in the company, number of years in management, gross salary.

The third stage consisted of an empirical study using a survey technique. Its aim was to identify the key internal factors influencing an organisation's ability to make dynamic process improvements. The survey was conducted using the CAWI (Computer Assisted Web Interview) method. The authors' survey questionnaire was delivered electronically via a prepared web platform, and was targeted to middle management positions because it was considered that the middle management level is closest to emerging issues in process implementation, and that the onus is largely on them to initiate, monitor and evaluate the implementation of process improvement changes (Jørgensen et al., 2003). The survey began on 15 February 2020 and was completed on 3 April 2020. The selection of respondents was purposive, determined by the desire to reach companies that were quality-oriented in their management and had an ISO 9000-series QMS in place. Thus, it was considered that respondents should have experience in the area of business process improvement, as this is required by one of the principles of ISO 9001:2015, to which organisations implementing a QMS based on this standard are obliged to adhere. In the survey, the final selection of respondents depended on obtaining affirmative answers to all questions regarding:

1. whether the company has a QMS based on ISO 9001 guidelines,
2. carrying out business process improvement activities,
3. holding a middle management position.

A negative answer to any of the above questions eliminated participation in the survey. The planned sample size was 417 companies. This was statistically calculated based on the number of organisations with an ISO 9000 series-based certified QMS in 2018. The survey questionnaire, placed on the research platform, was completed by 674 respondents. After initial analysis, 231 questionnaires were rejected because they did not meet the selection criterion or were not fully completed. Overall, 444 complete questionnaires were analysed in depth.

## 4. Findings

A total of 444 middle managers from manufacturing, logistics, service and trading companies participated in the survey. Respondents represented more than 55% of large enterprises (with more than 250 employees) and 26% of medium-sized enterprises (50-249 employees), mainly limited liability companies (60%) and joint stock companies (21%). The survey covered enterprises located in Poland. Regarding the type of business conducted, the survey was dominated by manufacturing enterprises (355) and limited liability companies with 150-249 employees. The second significant group in terms of employment were companies employing more than 1000 people. For the most part, the range of activities

conducted by the surveyed entities was global. These enterprises also assessed their financial condition as good (183) and very good (153). Table 1 further elaborates on the characteristics of the surveyed enterprises.

**Table 1.**
*Characteristics of the surveyed enterprises*

| METRICS | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| **Type of business** | | **The numer of people employed** | | **Organisational and legal framework** | | **Capital** | | **Coverage** | | **Financial condition** | |
| Production | 355 (80,14%) | 10-49 | 25 (5,6%) | General partnership | 8 (1,85%) | Polish | 127 (28,67%) | Local | 3 (0,68%) | Very good | 153 (34,54%) |
| Trading | 37 (8,35%) | 50-149 | 53 (11,96%) | Limited partneship | 8 (1,85%) | Foreign | 284 (64,11%) | Regionl | 3 (0,68%) | Good | 183 (41,31%) |
| Services | 95 (21,44%) | 150-249 | 169 (38,15%) | Ltd. | 313 (70,65%) | Mixed | 31 (6,99%) | National | 29 (6,55%) | Average | 64 (14,45%) |
| Mixed activity | 32 (7,22%) | 250-1000 | 79 (17,83%) | Public corporation | 105 (23,70%) | | | European | 83 (18,74%) | Poor | 18 (4,06%) |
| Another | 13 (2,93%) | Over 1000 | 116 (26,19%) | Another[1] | 9 (2,03%) | | | Global | 325 (73,36%) | Bad | 9 (2,03%) |

[1] cooperative, sole trader, civil partnership.

Source: own study.

In the conducted survey, the majority were men, aged between 31 and 40, with relatively short seniority, having held a management position in the surveyed company for up to three years. These were mostly people whose gross salary was higher than the national average. Table 2 refers in detail to the characteristics of the respondents.

**Table 2.**
*Characteristics of the surveyed respondents*

| **Sex** | | **Age** | | **The Number of years of work in the company under study** | | **The numer of years in a managerial position in the surveyed company** | | **Gross pay[1]** | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | **I don't want to answer** | **69** (15,58%) |
| Woman | 184 (41,53%) | 20-30 | 47 (10,61%) | 0-3 years | 167 (37,70%) | 0-3 years | 248 (55,98%) | Close to the national average | 25 (5,64%) |
| Man | 259 (58,47%) | 31-40 | 242 (54,63%) | 4-6 years | 102 (23,02%) | 4-6 years | 108 (24,38%) | Is slightly below the national average | 17 (3,84%) |
| | | 41-50 | 126 (28,44%) | 7-10 years | 47 (10,61%) | 7-10 years | 48 (10,84%) | Well below the national average | 28 (6,32%) |
| | | 51-60 | 23 (5,19%) | 11-15 years | 61 (13,77%) | 11-15 years | 27 (6,09%) | Is higher than the national average | 166 (37,47%) |
| | | 61-70 | 5 (1,13%) | over 15 years | 64 (14,45%) | over 15 years | 10 (2,26%) | Is well above the national average | 138 (31,15%) |

[1] According to the Central Statistical Office, in 2019 the average gross salary in Poland was PLN 5182.

Source: own study.

When completing the survey questionnaire, respondents rated the importance of the statements proposed in the survey. The resulting responses formed a statistical structure consisting of sets of observations. Aiming to search for latent relationships, relations and links

between subsets of observable variables, the exploratory factor analysis model (EFA)[1] was applied (Bartholomew et al., 2011). Using exploratory factor analysis, irrelevant questions were removed from the final set. The remaining questions were combined into subsets called factors. The study's authors focused on identifying the key factors that describe an organisation's ability to improve its processes dynamically. In the process of grouping questions into factors, an assessment of the model's internal consistency was also conducted using Cronbach's alpha parameter (Cronbach et al., 2004). The study assumed that values less than 0.6 were indicative of measurement reliability.

**Table 3.**
*Values of EFA statistics for the model, including all variables*

| | |
|---|---|
| KMO measure | 0,75 |
| p-value Barlett's test | p = 0,0000 |
| variance in model | 77,5% |
| number of factors | 18 |

Source: own study.

The results of the analysis allowed a preliminary distinction of 18 factors with a satisfactory level of variance. These had a good level of within-factor correlation. Also, at 77.5%, the KMO measure shows the existence of some clustering of variables. The analysis of the rotated component matrix in the model, however, shows that there is room for optimisation. The final form of the model was obtained after five steps. The values of the EFA statistics for the model in its final form allow us to conclude that the model is optimal, even though it has a slightly lower representation of total variability than the null variant. In the model, all alpha-Cronbach's alpha values are above the usually accepted level of 0.7.

**Table 4.**
*Values of EFA statistics for the model in its final form*

| | |
|---|---|
| KMO measure | 0,79 |
| p-value Barlett's test | p = 0,000 |
| variance in model | 74,1% |
| number of factors | 6 |

Source: own study.

Although 18 factors were identified, the scatter plot made it possible to assume that these could be reduced to six due to relevance. These were: actions taken by managers, the management concept used, the IT environment, relations with the market environment, the size of the budget, and employee competence.

[1] This method searches for latent dependencies, relations and relationships between subsets of observable variables. Although it is based on the correlation/covariance coefficient, it gives broader knowledge than the classical study of the correlation coefficient of pairs of variables. It makes it possible, so to speak, to separate groups of correlated variables in such a way that intergroup correlations are as low as possible. This way, certain variables called factors are formed based on the survey questions. It is assumed that these factors show the greatest relevance to the problem under investigation, and questions that are random, irrelevant, or which have no impact on the phenomenon under investigation are omitted.

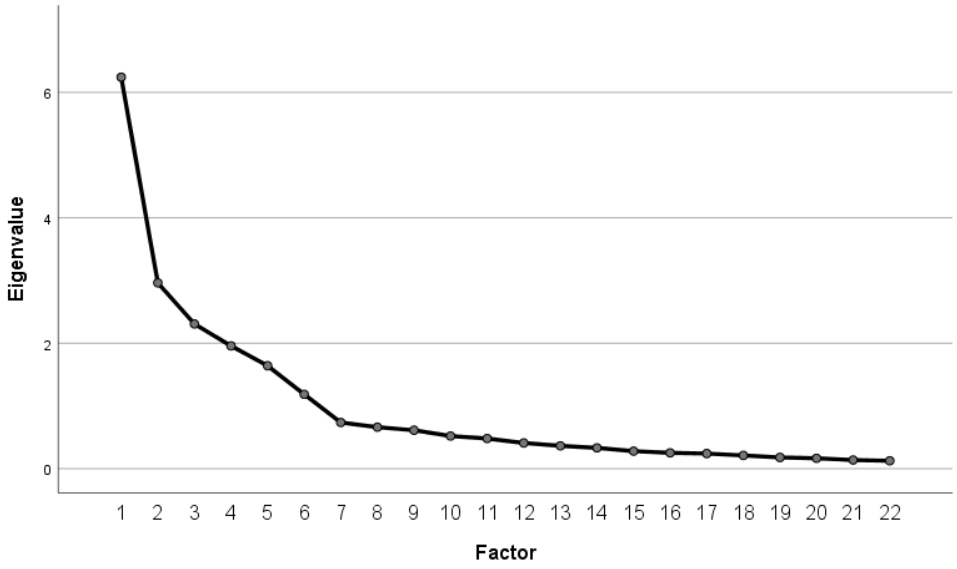


**Figure 1.** Scatterplot for the model.

Source: own study.

The results of the analysis allows us to conclude that the most significant and most strongly represented factor is the manager's role in adapting processes to new conditions. Statistically, this can be considered to have as much as a 19 percent share of the issue (percentage of variance explained), which can be interpreted as meaning that the actions taken by middle managers influence almost 20 percent of the organisation's ability to improve processes dynamically. Next in importance, the factor most influencing an organisation's ability to make dynamic process changes is implementing specific management concepts and IT tools to support these changes (significant in a total of 25%). Respondents pointed to the Lean Management, Six Sigma, and Kaizen concepts. The combination of these concepts with advanced IT solutions, a high degree of automation, and the introduction of digitalisation are crucial here. Slightly less important, as it influences the surveyed issue by 10 percent, is the industry in which the companies operate, particularly in the B2B sector. Also, 10% corresponds to the factor concerning the amount of budget available to managers for process improvements. Analytical skills and creative problem-solving by employees have an impact estimated at 8%.

At the same time, the factor analysis showed that due to the too-low coefficient of variation, factors such as a collaborative organisational culture and interdepartmental cooperation were less important for dynamic process improvement.

Concerning the characteristics of the respondents, no statistically significant relationships were found between gender, number of years at work, number of years in a managerial position, and any type of involvement in dynamic business process improvement.

At the same time the psychological tests used could determine behavioural, emotional and cognitive-pragmatic levels of commitment to dynamic process improvement. In the study conducted, this proved to be relatively even, with a slight tilt in favour of behavioural engagement, which manifests itself in specific behaviours.

## 5. Discussion

The analysis shows that the factor that plays the most significant role in dynamic process improvement is the actions taken by middle managers, such as making an ongoing assessment of the needs and possibilities for introducing changes to processes, coordinating the introduction of improvements, strongly emphasising the need to introduce changes to processes, systematically measuring the results of processes, and taking care of the development of knowledge and process competence among employees. The results of the psychological tests carried out correspond to the above. Although they indicate some level of balance, the behavioural commitment, manifested in the specific behaviours and actions of middle managers, is leading. Then, there is emotional involvement based on their strong interest in dynamic process improvement, a climate of understanding their needs, and positive emotions. This is followed by cognitive-pragmatic commitment, which is based on calculations as to whether participation in process improvement will bring specific benefits. Cognitive-pragmatic commitment refers to the theory of social contracts within companies and to interdependencies as seen from the perspective of exchange relationships. Central to this is the notion of reciprocity, i.e. the willingness to repay a present or future favour. When managers engage in dynamic process improvement, they do so in proportion to the resources, rewards or support they receive (Lewicka, Krot, 2015). Referring to Force-Field Theory for understanding what and why people do things in an organisation (Burrnes, Cooke, 2013), the success of business process improvement activities is seen when the forces favouring improvement are greater than the forces constraining it (i.e. forces favouring improvement will weaken the forces that constrain it). This is because the improvements introduced in the process upset the existing equilibrium of the system. In this situation, it is important to identify the stimulating and inhibiting forces of change, and to take action to weaken the limiting forces by, among other things, overcoming resistance, and eliminating fears and anxieties.

The literature (Jørgensen et al., 2003; Fannon et al., 2022) emphasises that middle and lower-level managers directly impact the attitudes, behaviours and actions of employee process performers. The role of middle- and lower-level managers is to support improvement team leaders and employees in their efforts to make process improvements. In fact, it is difficult to talk about business process improvement without the strong involvement of managers (Radnor, Bucci, 2008). Middle managers filter, as it were, the organisation's priorities; with their

influence on process performers, they ensure that strategic goals are met. Their respective attitudes contribute to employee engagement and, indirectly, to product and process improvement (Soltani et al., 2005). Process improvement needs managers not as sole and infallible decision-makers but as coaches (Witt, Witt, 2010). They are required to delegate such authority to employees so that they can carry out their tasks with some freedom and improve them. At the same time, in line with dynamic capabilities, managers should be oriented towards identifying the individual factors determining the company's development, arriving at synthetic, current and reliable knowledge necessary for the decision-making process, and reacting quickly to changes occurring inside and outside the organisation.

The results also indicate the importance of contemporary management concepts such as Lean Management, Kaizen and Six Sigma. In their assumptions, they are process-oriented optimisation processes. At the same time, they recognise the important role of middle managers (Holmemo et al., 2016; Haikonen et al., 2004). The concept of Lean Management is based on analysing the processes in place and bringing improvement ideas quickly to the implementation stage. To this end, a value stream is identified to assess how much the individual activities in the process contribute to the value that the customer expects (Agyabeng-Mensah et al., 2020). With this in mind, it is not just about obtaining short-term results and quick gains but about the sustainability of the results and organisational learning, both so important in dynamic process improvement. In practice, the implementation and operation of Lean Management is often accompanied by the Kaizen method, which is treated as the main cultural basis for improvement. Kaizen involves process-oriented thinking, whose aim is to eliminate waste and improve the results obtained. It is, however, an evolutionary method that takes time, so its relationship to dynamic process improvement would need to be examined in more depth. As far as the Six Sigma method is concerned, process improvement is an important element and takes place as a result of improvement projects. Until recently, the positive impact of Six Sigma had been indicated only on operational issues, such as cost savings and defect reduction (Zhang et al., 2016). Recent research (Gutierrez-Gutierrez et al., 2020), however, confirms the positive association of Six Sigma with dynamic capabilities and operational and strategic flexibility. Thus, research shows that Six Sigma practices can lead to better adaptation of organisations to environmental changes.

It is noteworthy that, despite the selection of organisations in the research sample with an ISO 9001 quality management system in place, this concept was not indicated as a condition conducive to dynamic process improvement in the surveyed organisations. The absence of linking these two areas is surprising, especially when a continuous dynamic approach to processes affecting product and service quality is indicated. It is highlighted that, in relative terms, most information on the tool layer of continuous process improvement can be found in ISO 9001, among others (Cannon, McGee, 2016; Jeston, Nelis, 2014).

Another important factor relevant to dynamic process improvement is the degree to which IT tools are used in the operation of the companies surveyed. Rapid process change is possible when the information acquired is used correctly. Thus, it must be based on digital transformation, available IT and technology solutions and taking advantage of existing knowledge and experience. The use of information and information technology is now one of the main factors in development and competition. The literature provides evidence that contemporary process improvement relies heavily on contractor commitment and innovation, but also uses next-generation techniques, such as IT tools or the Internet (van Looy et al., 2011; Zuhaira, Ahmad, 2021). Increasingly, there is application of the Business Intelligence concept (Harmon, Garcia, 2020), which implies using management information, business intelligence and data analysis to respond flexibly to environmental changes. IT tools improve the fluidity of process execution, facilitate the recording and processing of process information, and standardise processes. The literature, however, also points out that excessive standardisation of work resulting from IT tools can adversely affect the improvement of business processes and the flexibility of operation needed in new situations (Potoczek, 2020).

Another factor influencing the process in question is doing business in the B2B sector. Successfully implemented process improvement tools in the supply chain contribute to mutually beneficial relationships between partners in the B2B market. This mainly relates to the requirements for guaranteeing the technical quality of purchased products, as well as the organisational efficiency relating to improving process effectiveness and ensuring delivery reliability. This translates, in many cases, to assistance provided to suppliers in implementing process improvement tools, which undoubtedly contributes to increasing their growth potential and meeting the ever-increasing expectations of buyers.

In contrast, analytical skills and creative problem-solving by employees had relatively little impact. Such a result may come as a surprise, since by enabling process executors to change their processes dynamically, the entire enterprise management system becomes open to creative initiatives from a wide range of employees. Implementing the principle of dynamic process management is a factor that strongly directs ambitious members of the organisation to learn new methods and ways of implementing activities. This leads to real, day-to-day improvement of business processes based on the cumulative knowledge of a wide range of employees, verified, on a continuous basis, by customers (Grajewski, 2013). According to Szelągowski (2019), the actual source of all new possibilities offered by dynamic business process management is the dynamism of knowledge workers. Not just their knowledge but also their willingness to work is decisive in terms of whether the course of performance will see agile, intelligent adaptations with the aim of tailoring process performance to the context of that performance, which stems from the experiences of the process performers themselves.

## 6. Conclusion

Strong capabilities for dynamic business process improvement are critical in many organisations today. They foster the organisational agility required in an uncertain, rapidly changing environment. They also determine the ability of companies to adapt and create change that benefits customers and disadvantages competitors. Identifying the internal drivers of dynamic business process improvement attempts to address the contemporary challenges and needs of many organisations. The presented article is part of the current research on the effectiveness of business process execution and, thus, the effectiveness of entire organisations. It deals with a rarely addressed topic, so the authors hope that it will contribute to a better understanding of research needs in the field of business process management. Organisations working to adapt to rapidly changing environments should recognise the importance of the factors identified. The main conclusions that emerge from the results of the study allow the formulation of the thesis that middle-level managers and the specific actions they undertake, such as making ongoing assessments of the needs and possibilities for introducing changes to processes, coordinating the introduction of improvements, strongly emphasising the need to introduce changes to processes, systematically measuring the results of processes, and also taking care of the development of knowledge and process competence among employees, play the most significant role in dynamic process improvement. The survey results presented, however, do not indicate the crucial importance of the ISO:9001 quality management system.

In conclusion, it is important to state that organisations must have certain resources in order to be able to implement dynamic process changes. They must also have certain capabilities that allow these resources to produce the desired effects.

Finally, one must also consider that the research process has limitations, which affect the generalisability of the results. The study targeted the perspective of middle managers, which was a key factor in selecting respondents for the study. Future research could move in the direction of expanding the pool of respondents to include other levels of management. Qualitative research, and in particular the case study method, could also prove useful in developing the topic further.

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# APPLICATION OF THE SWOT-TOWS ANALYSIS AS A SUPPORTING TOOL WHEN SELECTING A STRATEGY FOR THE IMPLEMENTATION OF LOCAL CONCRETE ROADS

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**Purpose:** The aim of the article is to present the practical application of the SWOT-TOWS analysis when choosing a strategy for the implementation of local government roads in concrete technology.
**Design/methodology/approach**: The research includes the identification of the characteristics of concrete pavement and the indication of the most advantageous action strategy using the SWOT analysis extended by examining additional TOWS connections. Elements of the statistical and observational methods were used, based on literature reports.
**Findings:** The analysis showed a correlation between internal and external factors, which resulted in the selection of the most optimal solution in the examined case, which turned out to be an aggressive strategy.
**Research limitations/implications**: The presented analysis is not comprehensive, but it is a helpful tool for strategic analysis, the results of which are important information for further research on the discussed issue.
**Practical implications:** The presented analysis can be successfully used by investors and contractors as an auxiliary tool when choosing a road investment implementation strategy, thanks to the possibility of adjusting the criteria of weights conditioned by the location of a given project and the agreed preferences.
**Originality/value:** Simultaneous use of the SWOT-TOWS analysis with other analytical tools will allow in practice for quick and easy decision making when choosing the most advantageous strategy for the implementation of road investments.

**Keywords:** SWOT-TOWS analysis, local government roads, concrete roads, road investments.

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

## 1. Introduction

Communal and district roads account for approximately 88% of all roads in Poland. The main problem for the administrators of these roads is their poor technical condition, which is largely due to insufficient financial resources to cover the costs of repairs necessary to be carried out. The need for remedial action concerns mainly bitumen roads, which are the dominant part of the road network in Poland. According to the data of the Polish Cement Association, as much as 80% of municipal roads and 90% of district roads require immediate renovation. Based on the results of CATI surveys conducted in 2022, the main causes of damage to local government roads were determined. These include, among others: freight transport (in 46% of the surveyed local governments), maladjustment of the pavement to local conditions (15%) and improper construction of the pavement (9%) (Tobota, 2022).

The solution to the existing problem may be the construction of roads with a concrete pavement. According to the report of the European Concrete Paving Association prepared at the end of 2021, concrete pavements have been implemented on over 45 km of provincial roads, 600 km of district roads and 1,200 km of municipal roads (Deja, 2022). According to the data of the General Directorate for National Roads and Motorways, there are currently about 1000 km of motorways and expressways, which constitutes about 21% of the road network.

Concrete technology fits very well into the area of activities related to environmental protection. This material is environmentally friendly due to its recycling features. In addition, it creates the possibility of secondary management of various types of waste, including waste from polymeric materials and waste from the copper industry (Pietrzak, 2018; Helbrych, 2019). Often these activities also improve the quality of concrete. Tests carried out on concrete samples modified with polypropylene fibers have shown that the resulting composite has better frost resistance, which is an important aspect in the case of concrete pavement exposed to cyclical frost (Pietrzak, Ulewicz, 2018). In recent years, the implementation of local roads in rolled concrete technology has become increasingly popular (Gruszczyński, 2016; Przybylski, 2021). This solution enables the use of equipment intended for asphalt works, which significantly facilitates the construction of new roads (Piestrzyński, 2022).

Unfortunately, despite the constantly increasing length of the local government concrete road network (approx. 150 km per year), investors and contractors still have low awareness of the advantages and benefits of using this technology. Faced with the choice of implementation technology, they most often decide on a solution that is less complicated in their opinion, which is the implementation of asphalt pavements. An additional argument is the dominance of contractors specializing in the construction of roads using this technology on the market. Therefore, it is obvious that it is necessary to make decision-makers aware of the advantages and disadvantages of all possible solutions, using easy-to-use supporting tools. It is important that the chosen action strategy is as cost-effective and effective, both at the implementation and

operational stages. The use of the SWOT-TOWS analysis will make it possible to identify the strengths and weaknesses of a given solution, identify the resulting opportunities and threats, and the impact of the environment on internal factors. Thanks to this, it is possible to easily and quickly estimate which strategy should be adopted so that the process of implementing the planned road investment is as beneficial as possible in given conditions (Nieżurawski, Nieżurawska-Zając, 2021). SWOT analysis is a tool often used in the construction industry. In the study (Matuszko, Parzych, Hozer, 2018) it was used to determine the possibility of introducing low-energy construction to the Polish market. The advantage of the strengths of such a solution over the weaknesses allowed us to conclude that it is necessary to take actions aimed at the development of this type of construction. Another example is the use of the SWOT analysis to select an action strategy in construction companies dealing, for example, in the production of cement (Szczesny, Klimecka-Tatar, 2017), comprehensive construction of single-family houses (Czajkowska, 2016), or the production of window and door joinery elements (Ingaldi, Jagusiak-Kocik, 2014). It is worth noting that for the purposes of obtaining more detailed results, the basic concept of the SWOT analysis can be modified, for example by expanding TOWS links or creating a TOWS-SWOT hybrid, which is used in the assessment of activities related to construction projects implemented as part of innovative construction (Miszewska, Niedostatkiewicz, 2020). The SWOT-TOWS analysis can be a useful tool supporting the management of construction companies, but it should be used in conjunction with other analytical tools. Currently, many companies are implementing the Lean Management concept in order to improve the implementation of projects in accordance with the assumed budget, schedule and quality level, which can significantly contribute to increasing the effectiveness of activities undertaken in enterprises (Ulewicz, R., Kleszcz, Ulewicz, M., 2021; Ulewicz, R., Ulewicz, M., 2019).

The aim of the research was to present the use of the SWOT-TOWS analysis as a tool supporting the selection of a strategy at the planning stage of a road investment in concrete technology.

## 2. Features of concrete pavements

The strength of roads with a concrete pavement is primarily their high durability and resistance to rutting, which translates into their longer service life. The service life of concrete roads is estimated at up to 50 years (Korentz et al., 2021). In addition, these pavements do not require as frequent renovations and repairs as their asphalt counterparts. However, if there is a need to carry out renovation activities, it is a more complex process, due to the need to replace the entire slab using heavy specialized equipment. This results in higher financial costs and a long waiting period for the repair to be completed. Cutting expansion joints in the concrete

pavement results in division into slabs, which can lead to the phenomenon of "keying". This effect negatively affects both driving comfort and sound quality. Compared to asphalt pavements, the implementation of concrete roads is associated with a long waiting time for commissioning, due to the fact that the concrete reaches its full strength only after 28 days. Therefore, concrete pavements are implemented in undeveloped areas, they work well as access roads, bicycle paths or in industrial areas. The initial costs generated by the construction of concrete roads often exceed the costs of implementing roads in asphalt technology, but in the perspective of the entire period of operation, concrete roads are a more profitable solution. The easy availability of raw materials for the production of concrete mix and the developed infrastructure in terms of the availability of concrete mixing plants and the necessary machines in almost every location are also important. However, it should be remembered that concrete works are highly dependent on the prevailing weather conditions. Too low temperature prevents them from being carried out, and additional care treatments are required during hot weather.

The construction of roads with a concrete pavement is a great opportunity to improve road safety also due to their good reflectivity. Due to the light color of the material used, traffic participants and road technical devices are better visible to the driver, which creates good conditions to reduce the number of accidents and collisions. In addition, the lack of negative impact on the environment allows the use of this solution in "green" and protected areas (Deja, 2021).

## 3. Methodology of research

The research was carried out using the SWOT-TOWS analysis. As part of the SWOT analysis, input data on concrete pavements obtained from current literature reports were divided into 4 categories: strengths and weaknesses as well as opportunities and threats, from which 5 priority features were selected, each of which was assigned the appropriate weight (Table 1). The sum of the weights in each category was 1. Next, tables were developed containing answers to the questions of how internal factors (strengths and weaknesses) affect external factors (opportunities and threats). For this purpose, the identification of dependencies in the 0/1 system was used, where "0" means no links, and "1" the presence of dependencies. The next step in this part of the analysis was to add up the number of interactions in each row and column and assign a rank, defining the strength of a given feature, on a scale of 1 to 5. Based on the weighted values obtained, the rank "1" was assigned the highest value obtained, while the rank "5" - the lowest.

The SWOT analysis was supplemented with TOWS links, i.e. the study of dependencies “from outside to inside” in a similar way. The last stage of the work was to prepare a tabular summary containing the number of interactions and their weighted number, which are the sum

of the connections of the SWOT and TOWS matrix systems, and to indicate, based on the highest result, one of the four action strategies to be adopted (Kowalik, 2020; Sadłowska-Wrzesińska, Marczewska-Kuźma, Jakubowicz, 2020; Kucharczyk, Kardas, 2018):

- aggressive (maxi-maxi) - strengths and opportunities prevail; this strategy consists in strong development and expansion of activities with the maximum use of strengths,
- conservative (maxi-mini) - strengths and threats predominate; the strategy consists in using the strengths in order to minimize the existing threats to the environment,
- competitive (mini-maxi) – weaknesses and opportunities predominate; strategy is to take advantage of emerging opportunities while eliminating weaknesses,
- defensive (mini-mini) – weaknesses and threats predominate; the strategy consists in counteracting weaknesses and threats so as to ensure the possibility of survival in unfavorable environmental conditions.

**Table 1.**
*List of SWOT factors with the weights assigned to them*

| S | Strengths | Weight | W | Weaknesses | Weight |
|---|---|---|---|---|---|
| S1 | High durability | 0.3 | W1 | Cannot be used on bridges | 0.15 |
| S2 | Availability of raw materials for making concrete | 0.2 | W2 | The need to cut expansion joints and texture the pavement | 0.15 |
| S3 | Rutting resistance | 0.2 | W3 | Difficult demolition of the pavement | 0.25 |
| S4 | Good reflectivity | 0.05 | W4 | Long technological breaks after concreting | 0.25 |
| S5 | Developed infrastructure (concreting plants, machines) | 0.25 | W5 | Concrete corrosion | 0.2 |
| **O** | **Opportunities** | **Weight** | **T** | **Threats** | **Weight** |
| O1 | Increasing road safety | 0.25 | T1 | High investment costs | 0.2 |
| O2 | Low running costs | 0.2 | T2 | Limited scope of use | 0.15 |
| O3 | Development of infrastructure mainly in undeveloped areas | 0.25 | T3 | Long and costly repairs and renovations | 0.25 |
| O4 | No negative impact on the environment | 0.15 | T4 | Possibility of "keying" or cracking of the pavement | 0.1 |
| O5 | Management of recycled materials | 0.15 | T5 | Time-consuming execution | 0.3 |

S – Strengths; W – Weaknesses; O – Opportunities; T – Threats.

Source: own study.

## 4. Results and discussion

Tables 2-5 present the results of the “inside-out” factor analysis, which are the answers to the following questions: does the strength enhance the given opportunity? (Table 2); does the strength mitigate the threat? (Table 3); does the weakness prevent taking advantage of the opportunity? (Table 4); whether the weakness amplifies the threat (Table 5).

**Table 2.**
*Dependence strengths/opportunities*

| S/O | O1 | O2 | O3 | O4 | O5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **S1** | 1 | 1 | 1 | 0 | 0 | 0.3 | 3 | 0.9 | 1 |
| **S2** | 0 | 1 | 1 | 1 | 1 | 0.2 | 4 | 0.8 | 2 |
| **S3** | 1 | 1 | 1 | 0 | 1 | 0.2 | 4 | 0.8 | 2 |
| **S4** | 1 | 1 | 1 | 0 | 0 | 0.05 | 3 | 0.15 | 5 |
| **S5** | 0 | 0 | 1 | 0 | 1 | 0.25 | 2 | 0.5 | 4 |
| **Weight** | 0.25 | 0.2 | 0.25 | 0.15 | 0.15 | | | | |
| **N** | 3 | 4 | 5 | 1 | 3 | | 32 | | |
| **S** | 0.75 | 0.8 | 1.25 | 0.15 | 0.45 | | | 6.55 | |
| **R** | 3 | 2 | 1 | 5 | 4 | | | | |

N – number of interactions; S – interaction weighted value; R – rank.

Source: own study.

**Table 3.**
*Dependence strengths/threats*

| S/T | T1 | T2 | T3 | T4 | T5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **S1** | 0 | 0 | 1 | 1 | 0 | 0.3 | 2 | 0.6 | 2 |
| **S2** | 1 | 1 | 0 | 0 | 1 | 0.2 | 3 | 0.6 | 2 |
| **S3** | 0 | 0 | 1 | 1 | 0 | 0.2 | 2 | 0.4 | 4 |
| **S4** | 1 | 0 | 0 | 0 | 0 | 0.05 | 1 | 0.05 | 5 |
| **S5** | 1 | 1 | 1 | 0 | 1 | 0.25 | 4 | 1 | 1 |
| **Weight** | 0.2 | 0.15 | 0.25 | 0.1 | 0.3 | | | | |
| **N** | 3 | 2 | 3 | 2 | 2 | | 24 | | |
| **S** | 0.6 | 0.3 | 0.75 | 0.2 | 0.6 | | | 5.1 | |
| **R** | 2 | 4 | 1 | 5 | 2 | | | | |

Source: own study.

**Table 4.**
*Dependence weaknesses/opportunities*

| W/O | O1 | O2 | O3 | O4 | O5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **W1** | 0 | 0 | 0 | 0 | 1 | 0.15 | 1 | 0.15 | 4 |
| **W2** | 0 | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 | 5 |
| **W3** | 0 | 1 | 0 | 0 | 1 | 0.25 | 2 | 0.5 | 1 |
| **W4** | 0 | 0 | 1 | 0 | 0 | 0.25 | 1 | 0.25 | 3 |
| **W5** | 1 | 1 | 0 | 0 | 0 | 0.2 | 2 | 0.4 | 2 |
| **Weight** | 0.25 | 0.2 | 0.25 | 0.15 | 0.15 | | | | |
| **N** | 1 | 2 | 1 | 0 | 2 | | 12 | | |
| **S** | 0.25 | 0.4 | 0.25 | 0 | 0.3 | | | 2.5 | |
| **R** | 3 | 1 | 3 | 5 | 2 | | | | |

Source: own study.

**Table 5.**
*Dependence weaknesses/threats*

| W/T | T1 | T2 | T3 | T4 | T5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **W1** | 0 | 1 | 0 | 0 | 0 | 0.15 | 1 | 0.15 | 5 |
| **W2** | 1 | 0 | 0 | 1 | 1 | 0.15 | 3 | 0.45 | 2 |
| **W3** | 0 | 0 | 1 | 0 | 0 | 0.25 | 1 | 0.25 | 4 |
| **W4** | 1 | 1 | 1 | 0 | 1 | 0.25 | 4 | 1 | 1 |
| **W5** | 1 | 0 | 0 | 1 | 0 | 0.2 | 2 | 0.4 | 3 |
| **Weight** | 0.2 | 0.15 | 0.25 | 0.1 | 0.3 | | | | |
| **N** | 3 | 2 | 2 | 2 | 2 | | 22 | | |
| **S** | 0.6 | 0.3 | 0.5 | 0.2 | 0.6 | | | 4.45 | |
| **R** | 1 | 4 | 3 | 5 | 1 | | | | |

Source: own study.

The obtained data show that the greatest number of connections (32) are between the categories "strengths/opportunities" and its weighted value is 6.55. Interestingly, similar results were obtained for the relationships “strengths/threats” (24) and “weaknesses/threats” (22). The fewest interactions were identified between the “weaknesses/opportunities” categories (12) with a weighted number of 2.50.

**Table 6.**
*Dependence opportunities/strengths*

| O/S | S1 | S2 | S3 | S4 | S5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **O1** | 0 | 0 | 0 | 1 | 0 | 0.25 | 1 | 0.25 | 3 |
| **O2** | 0 | 0 | 1 | 0 | 0 | 0.2 | 1 | 0.2 | 4 |
| **O3** | 1 | 1 | 0 | 0 | 1 | 0.25 | 3 | 0.75 | 1 |
| **O4** | 0 | 1 | 0 | 0 | 1 | 0.15 | 2 | 0.3 | 2 |
| **O5** | 0 | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 | 5 |
| **Weight** | 0.3 | 0.2 | 0.2 | 0.05 | 0.25 | | | | |
| **N** | 1 | 2 | 1 | 1 | 2 | | 14 | | |
| **S** | 0.3 | 0.4 | 0.2 | 0.05 | 0.5 | | | 2.95 | |
| **R** | 3 | 2 | 4 | 5 | 1 | | | | |

Source: own study.

**Table 7.**
*Dependence threats/strengths*

| T/S | S1 | S2 | S3 | S4 | S5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **T1** | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 3 |
| **T2** | 0 | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 | 3 |
| **T3** | 1 | 0 | 0 | 0 | 0 | 0.25 | 1 | 0.25 | 1 |
| **T4** | 1 | 0 | 0 | 0 | 0 | 0.1 | 1 | 0.1 | 2 |
| **T5** | 0 | 0 | 0 | 0 | 0 | 0.3 | 0 | 0 | 3 |
| **Weight** | 0.3 | 0.2 | 0.2 | 0.05 | 0.25 | | | | |
| **N** | 2 | 0 | 0 | 0 | 0 | | 4 | | |
| **S** | 0.6 | 0 | 0 | 0 | 0 | | | 0.95 | |
| **R** | 1 | 2 | 2 | 2 | 2 | | | | |

Source: own study.

**Table 8.**
*Dependence opportunities/weaknesses*

| O/W | W1 | W2 | W3 | W4 | W5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **O1** | 0 | 0 | 0 | 0 | 0 | 0.25 | 0 | 0 | 2 |
| **O2** | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 2 |
| **O3** | 0 | 0 | 0 | 0 | 0 | 0.25 | 0 | 0 | 2 |
| **O4** | 0 | 0 | 0 | 0 | 1 | 0.15 | 1 | 0.15 | 1 |
| **O5** | 0 | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 | 2 |
| **Weight** | 0.15 | 0.15 | 0.25 | 0.25 | 0.2 | | | | |
| **N** | 0 | 0 | 0 | 0 | 1 | | 2 | | |
| **S** | 0 | 0 | 0 | 0 | 0.2 | | | 0.35 | |
| **R** | 2 | 2 | 2 | 2 | 1 | | | | |

Source: own study.

**Table 9.**
*Dependence threats/weaknesses*

| T/W | W1 | W2 | W3 | W4 | W5 | Weight | N | S | R |
|---|---|---|---|---|---|---|---|---|---|
| **T1** | 0 | 0 | 0 | 0 | 0 | 0.2 | 0 | 0 | 4 |
| **T2** | 0 | 0 | 0 | 0 | 0 | 0.15 | 0 | 0 | 4 |
| **T3** | 0 | 1 | 0 | 1 | 1 | 0.25 | 3 | 0.75 | 1 |
| **T4** | 0 | 1 | 1 | 0 | 0 | 0.1 | 2 | 0.2 | 3 |
| **T5** | 0 | 0 | 0 | 1 | 0 | 0.3 | 1 | 0.3 | 2 |
| **Weight** | 0.15 | 0.15 | 0.25 | 0.25 | 0.2 | | | | |
| **N** | 0 | 2 | 1 | 2 | 1 | | 12 | | |
| **S** | 0 | 0.3 | 0.25 | 0.5 | 0.2 | | | 2.5 | |
| **R** | 5 | 2 | 3 | 1 | 4 | | | | |

Source: own study.

The results of the "outside-inside" factor relationship analysis are presented in tables 6-9. They contain answers to the following questions: will the identified opportunity increase the strength? (Table 6); Will the identified threat weaken the strength? (Table 7); whether the identified opportunity will mitigate the given weakness? (Table 8); Will the identified threat magnify the given weakness? (Table 9).

Based on the results of the TOWS analysis, it was found that the largest number of associations (14) and the highest weighted number of interactions (2.95) occurred between the "opportunities/strengths" categories. It is worth noting that the number of interactions was only 2 less in the case of the "threats/weaknesses" relationship. The smallest correlation (2) occurred between the "opportunities/weaknesses" categories, where the weighted number of interactions was only 0.35.

Table 10 presents a summary of the results of the SWOT-TOWS analysis with a reference to the action strategy. According to the obtained data, the highest number of interactions equal to 46 and the highest weighted value of 9.50 were recorded between the categories "strengths/opportunities". In such a situation, the most optimal solution is to adopt an aggressive strategy based on the use of the advantages of concrete technology, which include, above all, high durability and easy availability of raw materials and machines for making the concrete mix. The development of these features will allow for greater opportunities in the context of road safety, environmental protection and savings resulting from the operation of these roads.

**Table 10.**
*A summary of the obtained results of the SWOT-TOWS analysis*

| | **Opportunities** | **Threats** |
|---|---|---|
| **Strengths** | **Aggressive strategy** | **Conservative strategy** |
| | Number of interactions<br>46 | Number of interactions<br>28 |
| | Weighted number of interactions<br>9.50 | Weighted number of interactions<br>6.05 |
| **Weaknesses** | **Competitive strategy** | **Defensive strategy** |
| | Number of interactions<br>14 | Number of interactions<br>34 |
| | Weighted number of interactions<br>2.85 | Weighted number of interactions<br>6.95 |

Source: own study.

## 5. Conclusions

On the basis of the literature analysis, the strengths and weaknesses of roads with a concrete pavement as well as the opportunities and threats resulting from their implementation were identified. The conducted SWOT-TOWS analysis determined the most optimal solution in the examined case, which would be the adoption of an aggressive strategy. Contractors, deciding to implement roads in concrete technology, should therefore focus on strengthening its advantages in order to achieve the desired effects. However, it should be remembered that the SWOT-TOWS method in this case provides a structured approach, not a comprehensive solution to the problem. It only defines a potential strategy of action that can be adopted, but does not contain a detailed plan for its implementation.

In conclusion, the SWOT-TOWS analysis can be a useful tool supporting the selection of a strategy for the implementation of local concrete roads. However, it should be used in conjunction with other analytics tools. The SWOT-TOWS analysis should not be treated as the sole basis for decision-making.

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# POSSIBILITIES OF USING QUALITY MANAGEMENT SYSTEMS TO UNDERTAKE INNOVATION ACTIVITIES IN AN ORGANISATION BELONGING TO THE CHEMICAL INDUSTRY

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**Purpose:** The main objective of this article is to identify the possibilities of using quality management systems to undertake innovation activities in an organisation representing the chemical industry.
**Design/methodology/approach:** A literature review was carried out to find out the state of the research on the subject. It was conducted according to the research methodology proposed by J.W. Creswell (2013). Ten employees from one of the key departments of an organisation belonging to the chemical industry were interviewed.
**Findings:** The interviewees are of the opinion that their organisation's quality management system is a useful tool. However, if the system is to support innovation activities, employees should be trained more extensively, they should be provided with information on the potential benefits of quality improvement and innovations, competitions for best organisational solutions should be organised and the quality management system itself should be improved so that it is less documentation-intensive.
**Research limitations/implications:** A literature review is not a perfect way to obtain information. Previous research has been conducted in different organisations and in different cultures. Secondly, it is important to remember the limitations inherent in qualitative research.
**Practical implications:** Based on the results of the research, those responsible for the functioning of management systems can take appropriate measures aimed at increasing the scope of innovation activities of employees.
**Originality/value:** Quality management systems conducive to innovation activities in the chemical industry are not a frequent research topic.

**Keywords**: quality management system, innovation, chemical industry, knowledge.

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

## 1. Introduction

The functioning of quality management systems has been an interesting research topic for a long time. Various analyses of its usefulness, possibilities for improvement, or combination with other management systems or concepts have been undertaken. This article focuses on how a management system based on the ISO 9001:2015 standard can be used to support innovation activities in a chemical industry enterprise. For this purpose, we will use a literature review and the results of a qualitative study conducted in one organisation belonging to the chemical industry. We will first identify the factors that are important for innovation activities and in the subsequent step we will review those studies that have addressed the relationships between quality management systems and innovation.

After the diagnostic research, we will try to answer the question of what needs to be done in order for a quality management system to support innovation activities.

Organisations producing various chemicals are specific due to the hermetic nature of their processes, which are carried out according to the laws of physics and chemistry. This characteristic also makes the knowledge and skills of the personnel conducting and supervising such processes unique. This is essential to ensure work safety at the highest level. The uniqueness of the processes also has a negative side, as it generates training problems for those people who support the production processes but do not have the particular technological knowledge. Various studies indicate the need to develop competencies in knowledge management as well as quality management (Dżwigoł-Barosz, 2018). In chemistry, innovations often consist in improving existing products, using new production technologies, but technological progress is not possible without knowledge, good work organisation and support provided by various management systems.

The main objective of this article is to identify the possibilities of using quality management systems to undertake innovation activities in an organisation representing the chemical industry.

## 2. Innovations and their drivers

An innovation is a new or improved product or process (or a combination thereof) that differs significantly from an entity's previous products or processes and that has been made available to potential users or put into use by the entity (Oslo Manual, 2018). In practice, many employees understand innovations as simply ideas, inventions or improvements (Slade, 2020). Innovation is rather a process of information and knowledge creation that is carried out by generating and defining a problem to solve or a task to perform (Nonaka, 1990).

Innovations are customarily divided into those related to products, processes, marketing activities and organisational aspects. Due to the interest in new technologies aimed at reducing negative environmental impacts, the term eco-innovations is used more and more frequently (Yuan et al., 2022), which means that innovations can also refer to individual areas of activities.

In quality management, any type of innovation plays an important role. However, in the case of manufacturing enterprises, any technological innovation that contributes to improving product quality is significant (Nasierowski, 2000).

Therefore, the implementation of improvement and not necessarily innovation activities undertaken within well-functioning quality management systems should be integrated with employee innovation management programmes.

In quality management, it is employees that constitute the source of innovations (Oakland, 1995). A critical prerequisite for undertaking innovation activities is an appropriate organisational culture (Slade, 2020) characterised by high levels of trust (Bugdol, 2010), positive psychological capital of employees and a climate of innovation (Ren, Zhang, 2015).

The huge number of publications that address the conditions conducive to innovation activities point to the need to train employees and to shift the organisation's focus towards learning (Seleshi, Birnberg, 2012; Halvarsson, Gustavsson, 2018; Engelen et al., 2018). Employees must want to share knowledge and the influx of new knowledge must be ensured. A work environment that supports learning practices can increase organisational innovativeness (Smith, 2017). Employees must have both technical and soft skills that enhance their ability to innovate and that are being continuously developed from the initial training phase (Zergout et al., 2020).

The cultural basis of innovation activities is the responsibility of managers. Their role consists in rewarding employees for innovative solutions (Campbell-Allen et al., 2008), fostering a culture of learning (Lin, Lee, 2017), developing a system of incentives and objective indexes for evaluating ideas (Day, Shea, 2020), properly selecting tools and procedures for the preparation, implementation, monitoring and evaluation of innovative ideas (Butt et al., 2021), planning innovation activities, ensuring effective communication and developing unambiguous guidelines (Hiltunen et al., 2021).

A significant proportion of innovative solutions are initiated in practice by various quality improvement teams. The prerequisites for working out innovative solutions, however, are the disjunctive type of tasks, the adequate size of a team and, above all, the organisation of work that ensures cooperation among individual team members (Wuchty et al., 2007). If an adequate level of high quality innovations is to be ensured, the heterogeneity of quality teams must be taken into account (Hu et al., 2021).

The prerequisites for successful innovations listed above can be applied to any organisation. Additionally, what should be emphasised in the case of quality-oriented organisations is the need for a process-based approach to innovation activities. Quality management systems based on the ISO 9001:2015 standard incorporate risk-based thinking and strongly focus on process

management (SILVA et al., 2016). Process improvement is closely linked to both quality improvement and innovations (Waddock, Bodwell, 2004). In the industrial sector, the knowledge of technological processes (Bello-Pintado et al., 2019) allows for the implementation of technological innovations (Nasierowski, 2000).

In such circumstances, employees must possess the knowledge of process analysis, integration and optimisation, as well as the knowledge of particular chemical processes.

## 3. Quality management systems and innovativeness

Many innovative solutions can be achieved through the use of quality improvement methods (Mättö, 2019). The use of quality management systems provides many opportunities for practical innovative solutions. Various research projects on the relationships between quality management systems and innovation activities have already been undertaken (Martínez Rojas et al., 2020; Saadia, 2021). Although proving the existence of such relationships, the results of such research are not conclusive. Most of the studies conducted so far have indicated a direct relationship between quality management and innovations, ignoring, however, potential variables that may influence this relationship (Escrig-Tena et al., 2018).

The studies cited suggest that a quality management system facilitates continuous quality improvement, but is not a strong factor in undertaking innovation or development projects (Martínez Rojas et al., 2018) ). The results of other studies conducted using structural equation modelling show the direct impact of the hard dimension of quality management (e.g. data collected, quality records) on product and process innovations, while the effects of the soft dimension of quality management are created through proactive behaviours of employees (Escrig-Tena et al., 2018). Quality management systems based on the ISO 9001 standard can foster innovations and statistically better financial performance, but what also needs to be ensured is an innovativeness strategy and policy (Latan et al., 2020).

A quality management system based on the ISO 9001 standard has a positive effect on innovativeness, which is confirmed by some of the analysed innovation indexes. And therefore, in order to significantly improve innovation performance, organisations must have a solidly established quality system (Saadia, 2021).

Among other things, a quality management system fosters innovations because it increases organisational knowledge. Through knowledge management practices, ISO 9001 certificate holders improve their quality systems and consequently achieve productivity gains (Matos et al., 2022). Issued in 2015, ISO 9001:2015 is the first standard to include a specification of organisational knowledge. There are many relationships among quality, process and knowledge management systems. It can even be argued that there is a complementarity between quality management and knowledge management (Wilson, Campbell, 2020). The accumulation of

knowledge should also be fostered by improvement activities. Similarly to Lean, quality management systems provide for employees to be able to learn from their mistakes as well as to propose measures aimed at preventing the occurrence of mistakes. Organisations must ensure that outputs that do not meet their requirements are identified and monitored to prevent their unintended use or delivery. They should take appropriate preventive measures based on the nature of non-compliance and its impact on the conformity of products and services (Wolniak, 2020). One of the conditions for the accumulation of useful knowledge in innovation activities is the acquisition of useful data. Various publications constantly emphasise that organisations should evaluate the effectiveness of their quality management systems and monitor their processes on a continuous basis. A system based on KPIs can be particularly useful for evaluating processes under implementation (Wolniak, 2021).

## 4. Research problem, objective and method

A literature review was used to gain insight into the state of the research on the subject. It was conducted according to the methodology proposed by J.W. Creswell (Creswell, 2013).

The applied procedure was consistent with the principles of research conducted in management sciences. First, key words for the issues under review were identified (innovation, quality management system, chemical industry, process approach, knowledge). The review focused on publications collected in databases subscribed to by universities (Academic Search Ultimate, Business Source Ultimate, Eric).

A qualitative approach was used in the empirical part of the research. Interviews were conducted in 2023 among 10 specialists (management staff, engineers) working in the chemical industry.

The aim of the research is to show the potential for using quality management systems in innovation activities. Once we have identified the factors facilitating such activities, we intend to confront them with the ISO 9001 criteria. The performed qualitative research aims to establish the level of familiarity with quality management systems. On this basis, practical recommendations for the organisation participating in the study will be formulated.

Pursuing the stated objective, the authors formulated the following research problems:

1. In the opinion of the employees, does the quality management system functioning in the organisation contribute to the development of employees' competencies?
2. According to the respondents, does the organisation's management show commitment to improving the system and leadership in undertaking improvement and innovation activities?
3. According to the interviewees, are the conditions for the recognition of and rewarding for innovation activities clearly defined in their organisation?

4. In the opinion of the employees, does the management take steps to identify the internal context and try to remove barriers to innovation activities?
5. In the opinion of the employees, do the existing forms of work enable quality problems to be solved by teams?

The conducted literature review shows that knowledge, pro-innovation leadership, an incentive system, an appropriate organisational climate and teamwork ensuring cooperation among individual employees are of key importance to taking up innovation activities.

A quality management system based on the ISO 9001 standard can be a tool for creating new knowledge, integrating it with existing resources, as well as developing knowledge for quality improvement (Lin, Wu, 2005).

Knowledge is one of the elements of competence, and in quality systems, according to criterion 7.2 of ISO 9001, the organisation should "identify the necessary competencies of the people performing the work affecting the performance and effectiveness of the system and ensure that employees are competent through education, training or experience" (EN ISO 9001: 2015, 2016).

Thus, if the system is functioning properly, it should foster competence development and, indirectly, innovation activities (Z1).

Strong leadership has a direct impact on commitment, people management and process management, and indirectly on employee satisfaction (Calvo-Mora et al., 2005).

In organisations, we have a variety of managers who are not necessarily leaders. However, ISO 9001 recognises that the top management of an organisation should demonstrate leadership and commitment to the system, which manifests itself in, among other things, taking responsibility for the effectiveness of the system and promoting a process-based approach (EN ISO 9001: 2015, 2016).

It can be concluded that a prerequisite for taking innovation activities is the commitment of the management and the manifestation of leadership in undertaking activities aimed at improvement and innovation (Z2).

Another factor is incentive, motivational and remuneration systems. In quality management systems, leadership, support for employees and incentive systems directly or indirectly support the knowledge utilisation process. In order for people to want to share and use knowledge properly, an appropriate remuneration system is needed, as well as appropriate goal setting (Kulkarni et al., 2006/2007).

Thus, it can be assumed that the propensity to undertake innovation activities exists when the conditions for recognising and rewarding innovation activities are clearly defined in the organisation (Z3).

An organisation may obtain the knowledge of its climate – as a condition for innovation activities – through a diagnosis of its internal context (Bugdol, 2018). It is important to constantly diagnose the number of reported corrective and preventive actions and to look for reasons why employees are unwilling or unable to take improvement actions.

Thus, it can be stated that if research is undertaken to identify the organisation's internal context and the management thoroughly analyses the results of such research and uses them in quality management practices, then barriers to innovation activities are removed (Z4).

The last factor under discussion is teamwork ensuring cooperation among individual employees. I many cases, quality improvement requires teamwork, i.e. the establishment of quality circles and process improvement teams whose job will be to implement quality management systems and concepts. Cooperation should be fostered by the knowledge resulting from the analysis of the organisation's internal context and employees' participation in the setting and pursuit of common quality goals. The level of cooperation should be higher where the awareness of quality issues is greater and the application of the full process-based approach is emphasised.

In our research, we assume that when teams of employees discuss various quality issues and try to solve problems with quality together, their knowledge increases, which can have a positive impact on their undertaking innovation activities (Z5).

## 6. Research results

### 6.1. Quality management systems and the development of employees' competencies

According to the ISO 9001 standard, it is necessary to establish the competencies of the personnel performing work that has an impact on quality and the organisation should take particular measures aimed at improving such competencies.

In the surveyed organisation, employees are trained and periodically have to take tests checking their knowledge of the quality system criteria. One of the interviewees said: "Employees are trained in the quality management system and their competencies in this area are improving, which has an impact on quality, error elimination and continuous process improvement" (woman, specialist, higher education, up to five years' work experience).

Not all respondents share such opinions. Some of them are of the opinion that the system contributes little to competence improvement, but it can have an informative function, familiarising employees with the procedures existing in the organisation.

"The ISO 9001 system with respect to a description of how the company works in terms of procedures and instructions and how they are followed by employees – yes; employees are more aware of quality and the processes in which they are involved" (woman, specialist, higher education, more than ten years' work experience).

Another perceived advantage of the system is problem identification.

"The implemented quality management system allows for the identification of problems, including the monitoring of received complaints. If a particular problem recurs, for example

damaged packaging, the system enables the problem to be effectively solved by, among other things, changing suppliers" (woman, manager, higher education, up to five years' work experience).

### 6.2. Opinions regarding the criterion of "leadership and commitment"

Opinions regarding this criterion vary considerably. The respondents feel that they do not have sufficient knowledge regarding the top management's commitment, claim that this commitment is visible at the corporate level and that rather individual measures are taken. This is reflected in the two following statements: "The organisation's management is committed to the continuous improvement of the quality management system. The quality management procedures are being improved and new solutions are being implemented" (woman, specialist, higher education, up to five years' work experience). "With regard to the top management – no; this is due to system management and strategic management at the corporate level; the top management does not fulfil the leadership function, in my opinion; with regard to the middle management – measures aimed at improvement and innovation are probably being taken" (woman, specialist, higher education, more than ten years' work experience).

### 6.3. Conditions for the recognition of and rewarding for innovation activities

The majority of the respondents claim that the rules for rewarding employees for innovation activities are defined in the relevant procedures and regulations. One of the survey participants said: "The company has an internal regulation that defines the principles of rewarding employees for innovations. Each proposal for an innovation is considered on an individual basis. In order to encourage employees to engage in innovation activities, each proposal or idea, even one that is not eventually implemented, should be appreciated and somehow rewarded, for example in the form of additional bonus points with a direct impact on the employee's remuneration" (woman, manager, higher education, up to five years' work experience). Two other interviewees do not share the above positive opinion: "In my company, the applicable rules are specified in several system documents: two or three instructions and one regulation; I'm not quite familiar with them so I can't assess whether they're clear or not" (woman, specialist, higher education, more than ten years' work experience). "The conditions are not clearly defined, at least not for the rank and file employees. Employees know little about the company's innovation activities and are unable to use the existing tools to implement their ideas. The incentive system is poorly popularised" (woman, specialist, higher education, more than ten years' experience).

### 6.4. Activities aimed at identifying the internal context and removing barriers to innovation activities

Only one respondent explicitly states that actions are taken to identify the organisation's internal context and remove barriers to innovation activities. Some respondents state that innovation-oriented systems and activities probably exist, but employees are not trained and familiarised with them or do not notice such activities: "In my company, the context, including the internal one, is evaluated, but I don't think the result of such evaluation serves anyone to do anything" (woman, higher education, specialist, over ten years' experience). "The management is open to accept innovation activities. If acceptance is seen as removal of barriers, then yes (man, higher education, specialist, from five to ten years' work experience).

The respondents' statements show that they have their own ideas for improving innovation activities: "Innovation activities should be closely linked to a production unit, any office dealing with the development of a new technology or product should respond to the needs of production units. Establishing a separate department responsible for innovation activities and in charge of development significantly hinders the flow and sharing of information and extends the time for the implementation of proposed innovations" (woman, higher education, manager, up to five years' work experience).

### 6.5. Various forms of teamwork facilitate problem solving

Three employees state unambiguously that the existing forms of teamwork (meetings, quality teams, problem solving teams, project teams, task teams) enable them to work jointly on solutions to quality problems. Other respondents formulate their own ideas for improving teamwork: "In spite of the establishment of various teams to develop various plans or documents, some of this work is dumped on other departments or offices. Such teams should consist of employees who are directly involved in looking for solutions to particular problems. This will ensure that key people have direct access to information, training. When new tasks appear, the established team should be trained or instructed in a particular area" (woman, manager, higher education, up to five years' work experience). "There are too few group tasks and projects for me to comment on what benefits they can bring" (woman, specialist, higher education, up to five years' work experience). "Teamwork in the organisation is at a low level. Introducing this form of work is a potential solution to improve this situation" (man, specialist, higher education, from five to ten years' work experience).

### 6.6. Overall usefulness of quality management systems and employees' suggestions

Opinions on the usefulness of the quality management system are mostly positive. The survey participants are of the opinion that having an ISO certificate shows the maturity and professionalism of the organisation and improves its public image. According to their knowledge, thanks to the quality management system, the company's products have better

quality, as errors during the production process are eliminated. The system is necessary to continuously improve the quality of products. At the same time, however, the respondents believe that too much emphasis is put on the system's documentation, which grows excessively.

They suggest the following:

- introducing applications for the submission of innovation proposals as soon as possible,
- holding meetings directly with employees, rewarding employees (also for ideas that are not put into practice),
- informing employees about what activities are being carried out and how introduced changes will affect their jobs and how they will benefit from them,
- organising problem solving competitions,
- increasing the intensity of training (through active participation of employees in innovation activities).

Below is one of the more interesting statements: "The system in some aspects is too detailed and unfortunately requires sticking to certain standards that can evolve over time. Unfortunately, it requires certain additional responsibilities to be delegated to employees, which in a small team can be very burdensome" (man, manager, higher education, more than ten years' work experience).

## 7. Discussion and further research

In 2019, the International Organisation for Standardisation (ISO) published the first international management standard for innovation management, ISO 56002:2019, following previous successful management standards such as ISO 9001 and ISO 14001. The first studies on the usefulness of this standard confirm its significance for innovation activities (Mir et al., 2022).

It is important that the knowledge of the applicability of this standard increase in industrial enterprises and that research be carried out to determine which of its criteria are useful in the management practices of chemical companies, as well as to what extent it is possible to integrate ISO 9001 with ISO 56002.

Two other interesting research topics are pressure placed on innovations and the composition of project teams. Previous studies indicate that too much pressure on innovations has a negative impact on the behaviour of team members and overall quality. Diversity in teams made up of top managers promotes innovation, whereas too much functional diversity in teams working on new products can be detrimental (Fay et al., 2006).

It is also known that organisations often lack flexibility in designing and implementing quality management systems and therefore little use is made of employees' skills and knowledge (Kaziliūnas, 2010). The use of tacit knowledge is very important (Wilson, Campbell, 2020).

Therefore, in both practical applications and diagnostic research, a necessary condition for innovation activities is the correct allocation of resources that is consistent with organisational values and especially a sense of fairness.

## 8. Limitations

First of all, the adopted method of literature review is not a perfect way to obtain information. Previous studies have been conducted in different organisations and in different cultures.

Secondly, it is important to remember the limitations inherent in qualitative research. The interpretation of data obtained through interviews depends on the structure of interviews, the knowledge and skills of researchers and their ability to avoid bias (Easterby-Smith et al., 2015). In the future, research on this subject should be conducted on a larger group of employees and preferably with the use of an additional research method.

It should also be borne in mind that obtained responses may be influenced by the positions held by interviewees in the organisational structure. In this particular case, the respondents represent a capital group, which means that many decisions are taken at the corporate level and the interviewees themselves may not have adequate knowledge of their employer's innovation activities or management systems.

## 9. Conclusions and practical recommendations

The interviewees are of the opinion that their organisation's quality management system is a useful tool. If the system is to support innovation activities, employees should be trained more extensively, they should be provided with information on the potential benefits of quality improvement and innovations, competitions for best organisational solutions should be organised and the quality management system itself should be improved so that it is less documentation-intensive. The majority of the respondents claim that the rules for rewarding employees for innovation activities are defined in the relevant procedures and regulations.

The organisation's internal context is clearly defined; moreover, it is published in its intranet system. However, the knowledge of the context itself is insufficient.

Teamwork needs to be improved. One of the idea already being introduced and useful in the chemical industry is the introduction of interdisciplinary, multi-tasking teams, which in practice is supposed to reduce business risk by increasing the possibility of replacing key personnel. In order for the quality management system to support innovation activities, it is necessary to:

- integrate improvement activities into the overall innovation activity programme,
- increase employees' knowledge (training is needed on all processes involved),
- use process monitoring data for quality improvement and innovation activities.

Employees must have the knowledge of process analysis, integration and optimisation, but also the knowledge of chemical processes. Joint discussions of quality objectives, problems and non-conformities should contribute to increasing employees' knowledge, which can be useful for undertaking innovation activities.

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# IN SEARCH OF EXCELLENCE IN ORGANIZATIONAL STRATEGY FORMATION IN THE CONTEXT OF DETERMINISTIC CHAOS: THE CASE OF GRUPA AZOTY

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**Purpose:** This article addresses the challenge of creating an excellent strategy under nonlinear conditions, focusing on understanding the unique features and values of the 2021-2030 strategy. The framework for shaping the organization's future is presented through the case of Grupa Azoty Capital Group's strategy.
**Project/methodology/approach:** To achieve this goal, a literature review and examination of the selected strategy were conducted. Grupa Azoty served as an autotelic case study. The research method employed allowed for a depiction of the analysed unit. The case study offers potential for adequately achieving the set boundaries of knowledge, which is particularly important in an era of nuanced phenomena. The choice of research methodology was dictated by the need to examine a specific group of organizations and the subject of interest, enabling the identification of unique features and values of the analysed Capital Group. The conceptual elements of the case were diagnostic (how is it?), symptomatic (why is it so?), and intervention-related (what to do?).
**Findings:** It was recognized that the challenge of today's world lies in the constant redefinition of fundamental truths, given that the era of continuity and high predictability of the environment has ended. The importance of social, technological, and environmental determinants and their impact on organizational strategy formation was acknowledged. The case study revealed several changes that needed to be implemented for the Capital Group's development. Grupa Azoty's 2021-2030 strategy confirms the priority of climate and energy transformation, the necessity for investment in innovation, and the importance of environmentally friendly solutions and products.
**Limitations/research implications:** Future research on the influence of the environment on organizational strategy formation seems justified. Efforts to verify the level of achievement of intended goals also appear appropriate. Moreover, it is valuable to explore the performative dimension of the strategy on Grupa Azoty's employees and stakeholders.
**Practical implications:** Individuals responsible for improving organizational strategy should continue to monitor emerging development perspectives in the environment. Regulatory changes resulting from the European Union's intentions, which aim to achieve beneficial social effects through establishing a set of sustainable development goals, warrant particular attention. The actions of the EU (the directives and regulations it creates) can significantly influence the strategy of a specific enterprise.

**Originality/value:** The article allowed for the identification of unique features and values embedded in Grupa Azoty's strategy, serving as a starting point for further explorations. The analysis of the content may be helpful in formulating strategies for other organizations, particularly those operating in the dynamically changing landscape of the chemical industry.

**Keywords:** organizational strategy, future of the organization, case study.

**Category of the paper:** Case Study.

## 1. Introduction

*A true explorer's journey is not about seeking new landscapes,*
*but about gaining new eyes.*
*Marcel Proust*

The world creates conditions in which humanity is compelled to engage in a discourse concerning the redefinition of fundamental truths. The basic premise of metaphysical essentialism points to the existence of two worlds. The first one constitutes a reflection (Platonic shadow) of the immaterial world of ideas (a kind of embodiment of the existence of apparent phenomena). The second world comprises ideal forms, i.e., objects containing essential features (essences), which determine their nature in an immaterial reality. In turn, the premise of pragmatism leads to the rejection of this dualistic world view, with human beliefs serving as the basis for such a stance. In other words, the truth is what best fits the realities of human life and most accurately meets its needs.

The discourse regarding the challenges for the future of organizations in the face of turbulence is fuelled by both essentialists and pragmatists. Similar to literary scholars, this friction seems endless (Markowski, 2001). Reflections on the future of organizations are developed within the framework of research oriented towards exploration (in line with the European tradition) and practice (in line with the North American tradition), with quantitative and experimental research taking precedence. Questions arise concerning the shaping of tomorrow's organizations in the context of new challenges. Representatives of various schools agree that the period of continuity and high predictability has come to an end. The world that proceeded according to a traditional and well-understood direction belongs to history. In today's reality, humanity is grappling with tumultuous social, technological, and economic changes. All these aspects are concerning, especially as they are overlaid with threats posed by the state of the natural environment.

In this uncertain reality, organizational managers design and implement strategies. Disasters that have befallen society in recent years (the Covid pandemic, Russia's aggression in Ukraine) further complicate this work. The change in raw material supply routes for Europe, caused by current geopolitics; the "chocholi dance" of raw material prices with the prices of manufactured

products, among other things, result in market collapses, downturns, and loss of competitiveness. All of this has a probabilistic character and further disrupts the proper formulation of strategies. The strategy then transitions into a phase of scenario management. Nevertheless, times of crisis must eventually come to an end. Moreover, these changes do not reverse green megatrends; at most, they slow them down. Therefore, a properly formulated strategy, as a document, paradoxically gains even greater significance.

## 2. Literature Review

The mentioned circumstances make planning (assuming a high degree of continuity) difficult. Managers of most organizations face this situation daily. In this context, the position of one of the most outstanding management thinkers, Peter F. Drucker, seems interesting. He believes that managers traditionally started planning based on yesterday's trends and made projections for the future based on various possible combinations, but with many of the same elements and configurations. Since the 1980s, as he claims, such planning is no longer possible. One can assume or predict the occurrence of an exceptional event, but it is impossible to plan for it. Drucker proposes implementing strategies that anticipate the probability and content of the most significant changes (Drucker, 1995). In other words - taking advantage of new realities and disturbances, and then transforming them into opportunities. Paraphrasing a quote by Vivian Green: "It's not about waiting for the storm to pass, but about learning to dance in the rain". When a person has no control over what will happen in the future, they can influence their behaviour. This, in turn, gives them a sense of agency. A similar situation occurs in the case of organizations. The manager can, wants to, and should reformat their current way of thinking. Their knowledge (incompatible with modern times) can be symbolized by an anchor. Throwing it in a storm allows for floating on the waves, moving in their rhythm. It is a promising strategy for ships in a safe bay, marina, or port. Using the anchor, we will not tame Mother Nature; we will only allow for safe preparation for new realities. This is a time to give meaning to our future actions. The situation is entirely different for boats in the open sea. Here, survival requires openness, manoeuvring, overcoming fear, faith in success, seeking shelter. There is no template. It is the least comfortable option but also the safest. Paradoxically, the anchor (like the manager's knowledge) can be the "weakest link in the chain" or, using Wojciech Czakon's metaphor, an expression of strategic short-sightedness (Czakon, 2020). Drucker would consider a ship floating on the surface as a strategy of "blissful mediocrity", which cannot ensure survival and even predicts the middle class moving to the margins. He believes in market leadership (which requires recognizing one's strengths). Drucker, thinking about the managers of the future, is blunt, stating: they cannot be passive custodians of the past. He expects managers to engage in rigorous calculations and intellectual honesty to

confront the real results of their actions. It is worth returning to the sentence attributed to Socrates: "I know that I know nothing". It strips the manager of megalomania and encourages freeing oneself from one's beliefs because "it is foolish to think that one knows what one does not know".

Attachment to knowledge and experiences built in realities that do not ensure predictability can be very detrimental. People need humility towards their own beliefs. Beliefs affect the perception of reality. In essence, it may happen that the assumptions made by an individual will reinforce their error. People have a tendency to favour information that confirms their beliefs or ideas and reject those that do not (Lack, Rousseau, 2022). Scientific research shows that reasoning is based on assumptions and beliefs (George, 1995). During decision-making, the so-called confirmation bias (or confirmation effect) emerges, resulting from the existence of beliefs and stereotypes (Nickerson, 1998). This bias can be defined as people's tendency to interpret information in a manner consistent with their expectations (Koehler, 1993; Markovits, Nantel, 1989; Méndez-Sánchez, 2023). Beliefs about the world influence projection, both at the individual and group levels (Degen, Tonhauser, 2022).

Bearing in mind the existence of the "confirmation effect," a manager (understood as a single person or a group of people representing management) should exercise due caution when formulating predictions of exogenous changes in the social, geopolitical, and technological architecture surrounding the organization, as well as endogenous (internal) determinants. Vertical thinking should give way to lateral thinking. A proactive manager's attitude can be equated with their ability to create a stream of ideas transformed into processes that create new values (understood as anticipating changes in the environment and creating unique differentiators) (Bartnicki, 2009; Bartnicki, Kordel, 2002). The modern manager seeks to extrapolate and anticipate the future, not only through their specialized knowledge, experience, but also intuition (Janasz K., Janasz W., 2014). They also cannot do without broad intellectual horizons, a holistic perspective, and emphasizing humanistic attributes understood as the application of a worldview doctrine in management such as happiness, dignity, brotherhood, and freedom, which have a real impact on the organization's effectiveness (Goranczewski, 2018). During proactive development path creation, there may be a need to redefine the mission, define the organization's purpose and position (Shoemaker et al., 2018; Brown, Eisenhardt, 1998; Huy et al., 2014; Martinsuo et al., 2022).

This process of building is referred to as "organizational renewal" (Janasz K., Janasz W., 2014) and is increasingly based on the joint work of many people (especially in the case of significant innovative changes and network organizations – multiple entities) (Dougherty, Dune, 2011; Klessova et al., 2020). The prevailing trend has become to define a new strategic direction that takes into account aspects of sustainable development (Nowisielski, Spilka, Kania, 2010; Balogun et al., 2015; Zarębska, 2017; Zarębska, Żabińska, Zarębski, 2019; Brostoöm, 2021) and corporate social responsibility (Chojnacka, 2013; Wojcik et al., 2021). Pursuing values (appreciated in unstable and uncertain times) encourages the implementation

of strategic transformation through, among other things, new goals, concepts, programs, methods, or guidelines (Stensaker, 2011; Czarniawska, 2018). The challenges of strategic management (along with their advantages and disadvantages) have been widely described in the literature on the subject (Hamel, Breen, 2007; Nag et al., 2007; Artto et al., 2008; Ketchen et al., 2008; Lehtonen, Martinsuo, 2009; Willems et al., 2020). Researchers carry out scientific projects characterized by high academic values, as well as pragmatic ones, which provide managers with specific guidelines (Graebner et al., 2023). Studies within this domain have focused on, among others, strategic determinants inside and outside the organization. R. Scott Livengood and Rhonda K. Reger drew attention to the changes taking place within the organization (specifically in its identity). The authors examined the impact of organizational identity (understood as a cognitive space of psychological value for managers; embodied in capabilities such as motivation or responsiveness) on competitive activity (Livengood, Reger, 2010). Another researcher revealed that the layer of organizational identity constitutes an element of strategic change programs, thus recognizing the importance of mental and social aspects of business transformation (Harikkala-Laihinen, 2022). Other researchers argue that today it is particularly important to align strategic goals with the expectations of external stakeholders (being part of the partnership network) (Haniff, Galloway, 2022). The aspirations of individual players may be important. For example, striving to strengthen the innovation effect can lead to the integration of inter-organizational knowledge within a joint project (Nisula et al. 2022). Urgent challenges include short product life cycles, co-creation with customers and partners, and the need to absorb scientific and technological knowledge (Fjelstad et al., 2012). Shaping the organization of the future requires enthusiasm when undertaking real actions and passion in their implementation (Chojnacka, 2021). The strategy must include a goal and a development problem, as well as guidelines. These three elements (goal, problem, guidelines) determine its effectiveness. A strategy without a goal is unguided, one that does not contain a problem is confusing, and one without guidelines is unrealistic (Yu, 2021). For years, the relationship between strategy and outcomes has been analysed, but due to conflicting results, the discussion on this issue is diminishing (Luoma, 2015).

Shaping the future trajectory of an organization represents striving to ensure continuity and durability of the entity. It allows building a bridge between the unknown and the expected. For those involved in strategy development, it also provides a sense of agency (which seems deeply justified). Strategies also open up perspectives for creating a high degree of mobilization of all stakeholders in actions for social order. Strategies also serve a performative role, as noted by Barbara Czarniawska (2010), and may be responsible for creating organizational identity. Paradoxically, it is successes that can lead organizations to the already mentioned organizational short-sightedness (Czakon, 2020). This is not the only paradox. W. Czakon notes that it is straightforward to fall into the trap of "simplified thinking" and put forward not only naive but even harmful proposals. The set of these recommendations is abundant. It includes, among others, a recommendation dedicated to strategists, pointing to the need to see the bigger picture,

its complexity, and its reciprocal impact on the organization. The seemingly harmless proposal could prove harmful if the strategist understood this as an unforgiving error of broad scanning of the competitive landscape or perfect market situation recognition, resulting in decision paralysis, information overload, and consequently, a worse competitive response. Another example concerns the suggestion to have a long-term planning horizon, reaching far beyond daily needs. A seemingly innocuous proposal, if misinterpreted, could mean losing sight of customer needs or disappointing investors due to loss of short-term profitability and neglect of current issues. The demand for seeking partners with whom strategic ventures can be implemented may also appear risky. Here, the risk lies in the possibility of strengthening the partner at the expense of the organization. The proposal encouraging collegiality in management (Sahlin, Eriksson-Zetterquist, 2016; Eriksson-Zetterquist, 2019) or digitization in management (Kriegel, Rissbacher, 2022; Brönneke et al., 2021) without considering the organization's context and limitations could also cause many problems. Short-sightedness is, therefore, a multidimensional issue that can bring contrasting effects. The existence of paradoxes in management has received due attention (Smith, Lewis, 2011; Gruszczyńska, Malec, Waligóra, 2017; Schad, Lewis, Smith, 2019; Polowczyk, 2022). Antinomic pairs are referred to as dualisms (Putnam et al., 2016). They can concern adopted perspectives, approaches, requirements, identities, goals, or practices (Lewis, 2000). These peculiar contradictions share a characteristic which is universally recognized as very interesting. The issue concerns the mutual interdependence of their extreme poles (Clegg et al., 2002). This may lead to the conclusion that managing paradoxes requires creating a whole in between the extremes (like a coin with heads and tails). The golden mean is balance, oscillating between the two opposite poles of the same image. This attitude enables meeting both needs, balancing them, and recognizing them as equivalent. Development requires recognizing the interdependence and coexistence of opposites. The emergence of tensions has intensified the search for other actions to eliminate paradoxes. In addition to the mentioned synthesis (i.e., an attempt to find a broader context and develop creative solutions allowing for the combination of contradictions), the following types of behaviours (reactions) have been distinguished:

- acceptance - coming to terms with their occurrence and assigning meaning,
- spatial separation - separating contradictions by conducting an analysis that allows identifying places of their occurrence,
- temporal separation - separating contradictions by choosing one variant and then changing it over time.

Managers responsible for shaping strategy in organizations should approach propositions with particular caution, as their origin lies in routine and established patterns and mechanisms of action. In a changing environment, it is essential not to fall victim to cognitive inertia.

Taking the above into consideration, it seems justified to establish (as the goal of this study) unique features and values in the strategy of an organization that is shaped under the illuminated circumstances.

## 3. Research Method

The study presents part of the research that constitutes a larger project. At this stage, an insight into the strategy of the selected organization was conducted, which serves as an example of an intrinsic case study (Stake, 2009). The choice of research methodology was dictated by the need for an in-depth examination of a specific organization and the subject of interest (Lisiecka, Kostka-Bochenek, 2009). It was recognized that the case study, as a bridge between traditional research paradigms (Luck, Usher, 2006), offers the potential for adequately achieving the delineated boundaries of knowledge. The objective was to appreciate the unique features and values of the strategy developed for the years 2021-2030. This is particularly important because most phenomena are nuanced (Lee, Saunders, 2017). The distinguished elements of case conceptualization were the following formulations: diagnostic (what is it like?), symptomatic (why is it so?) and intervention-related (what to do?). The work of Len and Jonathan Sperry (2020) served as an inspiration for presenting these components, applying the documentary method (Baran, 2021). The basis was the Company strategy, a document developed between 2020-2022 by teams of employees (specialists), then organized by the Corporate Strategy and Development Department, and approved by the Management Board of the Grupa Azoty S.A. capital group (CG). In the future, an instrumental approach to case study is planned to deepen the knowledge of the phenomenon from a broader perspective and draw more general conclusions. The choice of the target organization was purposive: in connection with the conference entitled: *Innovation Management and Artificial Intelligence in the Chemical Company*, organized by GA Zakłady Azotowe Kędzierzyn S.A. in cooperation with the Jagiellonian University, which took place on February 17, 2023, its participants, including the author of the text, were asked to verify the newly created and approved strategy from the perspective of their scientific interests.

Awareness of the potential weakness of the research methodology, described as the "researcher's interpersonal expectations effect" (Brzeziński, 1997), prompted the author of the study to appoint two independent reviewers (who wished to remain anonymous). The mentioned effect is related to the researcher's personality, attitudes, values, knowledge, and information they possess on the subject. Neglecting such (preventive) measures could result in, among other things: lack of tolerance, authoritarianism, rigid thinking, seeking social approval, resistance to information, which Agnieszka Wojtczuk-Turek (2012) warns against. The subjectivity of the expert is not the only problem. Another weakness of the case study is

the possibility of succumbing to cognitive illusions, and as a result – the possibility of a one-sided interpretation of reality in an unjustified way. To eliminate this aspect, the author consulted the content (facilitation) with anonymous experts through structured discussion.

The methodological flexibility of the case study is one of its advantages, manifesting, among other things, in the approach to designing tasks. What seems to be an asset may remain uncertain regarding the appropriate procedural steps required to ensure methodological rigor. This aspect is addressed, among others, by Rosenberg and Yates (2007).

## 4. Case Study

Grupa Azoty S.A. is an undisputed leader in the fertilizer and chemical industry. The dominant entity in the group is Grupa Azoty S.A., based in Tarnow, however, it comprises several dozen business entities, among which the four most important are: Grupa Azoty Zakłady Azotowe "Puławy" S.A, Grupa Azoty Zakłady Chemiczne "Police" S.A., Grupa Azoty Zakłady Azotowe Kędzierzyn S.A. An inherent feature of the Group is its continuous development. Innovations are one of the pillars of Grupa Azoty's strategy. The values it adheres to revolve around responsible business principles. It is worth noting that it is the first Central European organization to be included in the list of the forty most influential entities of the global chemical market ICIS TOP 40 Power Players in 2015. Additionally, the international strategic consulting firm Boston Consulting Group placed Grupa Azoty on the list of the most attractive chemical companies for investors worldwide. Grupa Azoty's offer includes a diversified portfolio of products, including: Butt fertilizers, multi-component, mineral, sulphur-containing, as well as other products mainly manufactured in raw material connection with fertilizers, such as polyamides, OXO alcohols, plasticizers, titanium dioxide, and melamine.

In accordance with the declarations included in the CSR Policy of Grupa Azoty Capital Group companies, the entity wants to be perceived as an ethical and socially responsible organization. This approach leads Grupa Azoty, among other, to engage in local community initiatives and projects aimed at learning and popularizing the history and traditions of the Polish chemical industry. Moreover, a comprehensive implementation doctorate program is being carried out, which significantly raises the level of identity and self-awareness. The Group also has its research and development centres that serve as a basis for product, development, and environmental research aimed at protecting the natural environment and counteracting the degradation of natural resources. In its ethical code, Grupa Azoty declared adherence to values such as thrift, professionalism, cooperation, respect, and transparency. Table 1 presents a synthetic representation of the strategy conceptualization elements.

**Table 1.**
*Capital Group strategy for 2021-2030*

| Subject | Elements of Grupa Azoty's (GA) Case Conceptualization | | |
|---|---|---|---|
| | **What is it like?** | **Why is it so?** | **What to do?** |
| Introduction | The context, key points of the strategy, and challenges faced by GA have been presented in a synthetic manner. | The introduction is an important element outlining the entire content of the study. It draws attention to GA's priorities. The message was made public on behalf of the Board by the President. | Maintain. |
| Key challenges of the contemporary world | The most important environmental and social issues were identified. | The study refers to climate change and environmental degradation, which are considered significant threats to civilization. Ambitious goals have been set to limit the negative impact on the environment. Sustainable development and responsible business were recognized as priorities. The COVID-19 pandemic was taken into account as an important issue affecting global supply chains, the need for changes in the approach to employees and customers.<br><br>Food production and sustainable agricultural development were recognized as priorities. Land is a public good and has economic, ecological, and social value. | Continuously diagnose phenomena, trends, mechanisms of the contemporary world and their interdependencies, and respond to them. |
| GA Mission, Vision and Values (MVV) | The Mission, Vision, and Values were defined for the 2030 perspective.<br>Mission is as follows: in harmony with the environment, GA produces fertilizers, materials, and chemical products, improves the quality of life for Europeans, and effectively participates in building food security for our continent.<br>Vision: GA is a provider of effective solutions, a reliable producer of fertilizers, materials, and green chemistry.<br>Values: people, development, environmental protection, energy. | GA is recognized as an efficient and flexible, integrated and divisional CG, focused on production in Europe. In its mission, GA identified the needs it intends to meet. Through the vision, GA defined the image it will strive for in the perspective of implementing the 2030 strategy. Four key areas were outlined in the context of values, namely: people, development, environmental protection, and energy. In relation to people, values include: active participation of CG in meeting their food needs; addressing needs related to increasing agricultural efficiency; solving the challenges of modern agriculture. Values related to development are associated with the implementation of new environmentally friendly and climate-neutral products. In relation to the natural environment, values include: intensifying actions for the protection of the natural environment, as well as the realization of the "Green Azoty" project. In the energy area, actions aim to reduce energy consumption. | Conduct an analysis of the extent to which the indicated values correspond with the values of GA's internal and external stakeholders.<br>Investigate whether the Mission, Vision, and Values (MVV) have a performative impact.<br>Diagnose whether cooperation is based on shared values and goals.<br>Determine the level of co-responsibility for climate, environment, and society.<br>Examine the co-responsibility for shaping the value chain.<br>Continuously build awareness of the Mission, Vision, and Values (MVV) among employees. |

Cont. table 1.

| | | | |
|---|---|---|---|
| Business segments | Focus on segments within three areas of activity – Agro; Plastics; Chemistry. | In line with its assumptions, GA is implementing a new organizational model, as it expresses hope for achieving full synergy due to the integration of management support functions. The key development directions defined within individual business segments will be elements of the implementation of the strategic program "Green Azoty". | Determine the level of achievement of key objectives for each segment.<br>Identify the values offered to customers in the segments.<br>Indicate the level of synergy achieved. At the same time, it is essential to maintain space for independent actions within the entities that are part of the Group (internal flexibility). |
| Energy sector | It was pointed out that there is a need for an energy transformation to achieve improved efficiency. | The need to ensure diversified energy sources necessary for conducting chemical processes was addressed. The importance of moving towards decarbonization of energy generation sources was highlighted. It was considered reasonable to undertake actions in the field of internal energy transformation, understood as saving energy consumption and improving energy efficiency in chemical installations. | It is necessary to limit the expansion of fossil fuels and balance it with renewable energy sources (RES). Work on increasing energy yields. Implement the conclusions of the Best Available Techniques (BAT).<br><br>Consider further steps on what to do and how to process the energy obtained from RES. |
| The „Green Azoty" project | It was recognized that the climate and energy transformation in GA is a priority. The project assumes the activation of actions in favour of: green products, green technologies, and a green organization. | Changes in the regulatory environment were seen as an opportunity to introduce the "Green Azoty" project. This is conditioned by the possibilities of implementing technical solutions in the field of alternative, ecological renewable energy sources (RES), such as: photovoltaics, wind power, green energy production from biomass, and waste heat from production facilities. Changes result from the intentions of the EU, which aims to achieve climate neutrality by 2050 (intermediate goal - reducing greenhouse gas emissions to the atmosphere by at least 55% by 2030 compared to 1990). Environmental policies, such as the European Green Deal, directives and regulations, are systematically being implemented, which intensify the "Green Azoty" project. The EU's hydrogen strategy corresponds to research and development work related to the production and use of green hydrogen. | Expand photovoltaic and wind farms. Produce energy from steam derived from technological processes, using synergy between energy and chemistry. Build gas sources. Construct biofuel incineration plants.<br><br>Participate in the implementation of the EU Hydrogen Strategy. Engage in the development of the hydrogen energy sector. |

Cont. table 1.

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| Financial Strategy | GA aims to further consolidate its financial functions to provide active support for management at the level of individual business segments. This goal is supported by the existence of the SAP competence centre, which includes financial and accounting systems (S4HANA, SAP BUSINESS), data warehouses (BW4HANA), and planning and budgeting systems. | The adopted financial strategy enables the implementation of key investment projects. The financial structure aims to provide short- and long-term financing sources on competitive terms, sufficient to finance operational activities and implement the investment program. "Green" financing allows for investment in "Green Azoty". The possibility of obtaining funds from the National Reconstruction Plan and other support mechanisms for investments is intended to activate technological transformation. An integrated platform for reporting financial and operational data allows for serving as a database system (both in static and dynamic terms) and continuous monitoring of operational and strategic goals. | Ensure the long-term development of the company (by taking into account exogenous and endogenous factors and creating strategic goals based on them), while also paying attention to financial analysis at the operational level (such as profitability, return on investment, liquidity). Design and analyse key performance indicators. |
| ESG strategy<br>E – environ-ment, including climate<br>S – social domain<br>G – corporate governance | These pillars and goals of ESG correspond to the Sustainable Development Goals (SDGs), which include:<br>1. Climate and Environment (decarbonization and emission reduction, energy transformation);<br>2. Sustainable Products (closed-loop economy, sustainable agriculture and green products);<br>3. Sustainable Supply Chain (collaboration based on shared values and goals, responsibility for climate, environment, society, and shaping the value chain);<br>4. Local Community (partnership key to organizational and regional development, responsibility for the local community, dialogue with stakeholders); | For CG, ESG provisions refer to the basics disclosed in legal acts and international initiatives directed at businesses. They respond to market and stakeholder expectations and support preparation for the challenges of the upcoming decade resulting from climate change. The regulatory area includes the European Green Deal, directives on non-financial disclosure (NFRD->CSRD and SFRD), taxonomy, and the "Fit for 55" package. Key international initiatives refer to the Paris Agreement, SDGs within UNGC, guidelines on disclosing financial information related to climate impact (TCFD), and the Carbon Disclosure Project. The pillars of GA's ESG strategy fit into SDGs, i.e.: zero hunger, quality education, clean water and sanitation, economic growth and decent work, innovation, industry, infrastructure, responsible consumption and production, climate action.<br>With regard to ESG goals, CG should strive to increase positive impact on the socio-economic environment. This can manifest itself, among other things, through engagement in issues important to the local community, as well as taking extraordinary actions appropriate to the circumstances. | ESG reporting should be provided, including the average reduction in CO2 emissions compared to previous years. The GK should be aware of the number of severe and fatal accidents on the premises and strive to eliminate them. Ensuring pay equity between women and men is also important. There should be a focus on the succession planning of key positions. Data on achieving the energy mix should be analysed to ensure that the share of electricity from coal is less than 50% of the total electricity produced. Analysing risks and opportunities, such as regulatory or technological ones, is also important. It is necessary to translate and raise awareness of the importance of ESG among the GA stakeholders. |

Cont. table 1.

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| | 5. Friendly and Safe Workplace (equality, diversity, openness, employee safety, and professional development). | Examples of good practices may include actions such as: educating farmers in sustainable agriculture, supporting scientific centres in organizing internships and training, engaging in dialogue with future staff through organizing courses and training, and establishing cooperation with regional authorities and associations acting in accordance with ethical values. | |
| Raw Materials Strategy | GA is highly dependent on external suppliers, so the key goal is to ensure security and continuity of supply. In accordance with the purchasing policy, raw material procurement should be carried out with respect for the environment and natural surroundings while maintaining efficiency. | GA plans to continue cooperation with reliable suppliers during natural gas procurement while monitoring the regulatory market situation and proactively optimizing the supply portfolio. When procuring strategic chemical raw materials, GA plans to take actions aimed at maximizing the internal production potential of raw material assets and streamlining raw material management at the group or business segment level. It is also open to joint projects with state-owned companies. Procurement of energy raw materials in the group will involve seeking competitive pricing conditions due to the scale effect. GA will strive to increase the volume of green energy procurement. | The recommendation is to study the carbon footprint of products and manage it accordingly. This requires primarily operationalizing the strategy of obtaining information on the level of carbon footprint of raw materials and semi-finished products from suppliers, and ultimately setting reduction criteria for them for 2030 and 2050. |
| Strategy of Innovativeness | GA is focused on seeking innovations, which it perceives as investments.<br>GA's activities encompass 4 areas: innovative projects, support for corporate projects, innovation system development, and innovation focused on minimizing the effects of regulatory risks. | The Proactive Innovator strategy enables stable development and maintenance of the position among the leaders in current market segments. It allows for retaining key customers and markets by providing constantly improved products. Such an approach strengthens the competitive advantage, which undoubtedly involves flexibility in reacting to market trends in terms of offered products and creating trends related to niche technologies.<br><br>The strategy involves moderate risk, acceptance of failures, high financial costs, and tremendous organizational effort, but at the same time is a chance for long-term maintenance of technological advantage over the competition. | Monitor the costs of conducting R&D projects (including costs of maintaining employees and infrastructure), establish measurable indicators of acceptable results with their stage verification, and implement a digital tool for monitoring R&D projects. Determine the feasibility of launching new projects and their direction based on qualitative analyses. Explore niche opportunities in products and markets and effectively utilize them to gain a competitive advantage in this area. |

Cont. table 1.

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| Strategy of operational excellence | Includes logistics, asset management, and IT. | The logistics area is an integral part of the supply chain in GA. It relates to planning, managing, and controlling the structure of material flows and related information and capital flows. Asset management focuses on the energy and production efficiency of manufacturing assets. The IT area will obtain a unified, coherent, and integrated architecture and IT solutions for all business segments of GA to increase its efficiency and quality of services provided. Implementations will allow, among other things, transparency of logistics processes, management of logistics processes across the entire company, improvement of operational efficiency, and standardization of IT solutions. | To monitor possible regulatory restrictions that may affect the scope and cost of transportation processes related to the goals of the European Green Deal. Also, to explore the possibility of diversifying transportation methods in favour of intermodal transport. |

CG – Capital Group; GA – Grupa Azoty; MWiW – Mission, Vision and Values; ESG – strategy, environment including climate, social area and corporate governance; SDGs - Sustainable Development Goals; NFRD – Nonfinancial Disclosure Reporting Directive; CSRD – Corporate Sustainability Reporting Directive; UNGC – United Nations Global Compact; TCFD - Task Force on Climate-related Financial Disclosures; R&D&I - research, development and innovation.

Source: own elaboration based on Azoty Group materials.

The elements of the strategy presented in Table 1 demonstrate the efficiency in recognizing the perspectives that lie ahead of Azoty Group. This may stem from the experience and intuition that the creators of the strategy possess. It contains all the elements that together create a coherent whole, indicating Azoty Group's expansiveness expressed through investments, ambitions to increase market share, and expanding the product portfolio. The strategy addresses threats to civilization, including climate change and environmental degradation (Kądzielawski, Goranczewski, 2022). This context led to the development of ambitious goals to reduce the negative impact of its own activities on the environment. Furthermore, it recognizes sustainable development and responsible business as priorities. The impact of the COVID-19 pandemic on the perception of global supply chains was also acknowledged. Azoty Group identified food production and sustainable agriculture as key issues. Much attention was paid to new technologies and innovations, which are seen as opportunities to maintain an advantage over competitors. However, little attention is given to employees, their engagement, and motivation, as key factors in effective management (Goranczewski, Szeliga-Duchnowska, 2021). While employee competencies were mentioned alongside excellent service, timely deliveries, and product quality as important attributes in maintaining a solid business partner position, such reference to employees can be considered insufficient. The strategy also referred to the idea of a friendly workplace, where Azoty Group declared its commitment to the employee safety and equal treatment, adherence to diversity principles, and professional development. It also mentioned the assessment of employee engagement and satisfaction, as well as promoting a healthy lifestyle. Such an approach compensates for the aforementioned shortcomings.

## 5. Summary

*Strategic management is a great challenge and a fascinating intellectual journey.*
*Wojciech Czakon*

The constant challenge facing modern managers is building bridges between the unknown and the expected to ensure continuity and sustainability of the managed organization. This task is and should be seen as a priority. The complexity and multidimensionality of the environment present a significant obstacle for those involved in shaping strategy, as changes in the organization's environment are not so much turbulent as they are hurricane-like. As numerous authors have pointed out, the existing methods for predicting the future (necessary for determining development strategies) are inadequate. They have relied on quantitative methods. "Contemporary research methods increasingly need to employ qualitative research methods to describe and explain changes in economic life" (Dylewski, Marek, 2013, p. 10). Therefore, there is a need to present a strategic framework for development that anticipates the organization's future using a case study method, as presented in this article.

Grupa Azoty is characterized by a high level of expectations from various stakeholder groups that it must meet. The presented research results will allow for the identification of unique characteristics and values of the organization. Grupa Azoty's strategy refers to contemporary conditions in accordance with the general segmentation of the environment into socio-cultural, technological, environmental, political, legal, and economic spheres. The strategy also shows the impact of these determinants on the organization's development. Grupa Azoty's strategy for 2021-2030 confirms the priority of climate-energy transformation and the need to invest in innovative solutions.

One of the areas that show a lack of adequate interest in the strategy is the area of people. People are the organization's greatest and most valuable capital. Given the proportions resulting from the structure of the presented document, the share of social potential is only represented symbolically. Every organization is made up primarily of people, and therefore this aspect should be taken into account in the next strategy review (iteration).

The presented strategy, like most of this type of document, is flexible. In the case of dispersed entities such as Grupa Azoty, this efficiency should be two-pronged. The first is internal flexibility. It involves leaving dependent entities the possibility of carrying out local tasks with the reservation of non-contradiction with the Group's goals, as well as prioritization of group tasks in the situation of making such choices. The second efficiency is external flexibility, understood in a classical way as the ability to quickly adapt to the changing environment. In the author's opinion, this postulate seems so significant because there was no mention in the presented document regarding the current geopolitics and the related change in the direction of raw material supplies, which is likely causing enormous perturbations that the organization is facing. It seems justified to conduct further explorations allowing for:

1. Examining the strength of the influence of the dynamically changing environment on shaping the organization's strategy.
2. Showing the evolution of values included in strategies in the context of changes occurring in the environment.
3. Verifying the level of achieving intended goals revealed in the organization's strategies.
4. Showing the performative impact of the strategy on employees and other stakeholders.
5. Identifying the biggest difficulties of predicting the future when creating strategies.

The proposed research proposals may concern the Azoty Group, but also other organizations.

This article is a prelude to further in-depth research on the shape of created strategies in conditions of high complexity, variability, instability, and ambiguity of the environment.

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# ASSORTMENT ABC CLASSIFICATION PROBLEM AT THE WAREHOUSE MODELLED AS A MULTI-KNAPSACK

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**Purpose:** Appropriate product categorisation in warehouses is an issue facing most warehouses and distribution centres around the globe today. The ABC classification scheme aids in determining the most vital values at the warehouse. ABC classification reduces the effects of excess, end-of-life, or huge volumes of phase-out products.
**Design/methodology/approach**: ABC classification is a method for classifying products according to their relevance. Products are divided into three categories using the ABC analysis, with category "A" items being the most important, category "B" as medium important and category "C" items being the least important for the distributor. This research model the ABC classification problem as a multi-knapsack and provides an example of commercial and non-commercial solver usage that enables distributors to categorise assortment according to the ABC classification.
**Findings:** Proposed approach enables the distributor to arrive at the best possible outcomes.
**Research limitations/implications**: The main limitation of this research is that it does not take into consideration constraints that show that some products cannot be quickly categorised or placed on the shelves because of the availability of storage equipment or warehouse personnel at the time of classification should be considered. Further research may be done on these issues.
**Practical implications:** Performance comparisons between the proposed approach and the traditional ABC classification method provided by the distributors are conducted.
**Originality/value:** The main contribution is the improvement of the classification method used in warehouses these days. The proposed approach allows assigning an optimal product mix to ABC categories.

**Keywords:** ABC classification; multi-knapsack; distribution centre; warehouse.

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

## 1. Introduction

Assortment planning models in the literature and decision selection problems like category management concentrate on the selection of goods in a single category. In other words, variety within a category influences demand contingent upon store visits but has no relation to store choice. However, if the shop cuts diversity across the board based on single category analysis, the business loses appeal, and some consumers may migrate to other merchants, which would decrease customer foot traffic. This concern is especially pertinent to basket consumers since they may buy their entire basket from another vendor if they cannot locate the item they are looking for in one category (Cachon, Kök, 2007).

Each store offers a unique selection. All variations in demand can be taken into account in this situation, but maintaining tailored assortments is expensive.

Since small businesses have close relationships with their consumers, they are able to understand their requirements, purchasing patterns, and seasonal income patterns, which are reflected in the decisions they make regarding their stores (Koul, Jasrotia, 2019).

Cachon and Kok (2007) claimed that each consumer type in their model shop choice is based on the diversity of a particular category, which they refer to as the lead category (Cachon, Kok, 2007).

Rodríguez et al. (2017) considered the following issues given by consumer preferences for the attribute values that might be assigned to the product (i.e., its potential features), the attribute values of goods sold by their rivals, and the attribute values that each producer can use depending on, for example, technological constraints, legal considerations, or the availability of resources.

Three problems that are fundamental to any marketing management process are formalised, and their computational complexity is examined by Rodríguez et al. (2017):

- maximise the number of clients by choosing the product's attributes,
- determine whether there is a workable strategy that ensures the reach to a specific average number of customers before a deadline,
- determine whether there is a workable strategy that ensures the reach of the maximum customer traffic before the cutoff date of the product's characteristics (Rodríguez et al., 2017).

Firms can no longer rely on the old sales performance techniques as technology and organisational structures get more complicated, the competition for product differentiation increases and customers become product masters. Organisations must evaluate existing approaches, retest presumptions, and apply innovative solutions to meet today's expectations (Forum Europe Ltd, 1997).

As an alternative, a shop can use a centralised regime to decide on categories for the whole store. Cachon and Kök (2007) demonstrated that category management never comes up with the best answer and offers both less selection and more expensive rates than ideal (Cachon, Kök, 2007).

The Pareto Principle is the foundation of the well-known classification method known as ABC analysis, which helps businesses decide which goods should be managed as priorities in their inventory. Modern operations management and supply chain literature that covers this subject concentrate on using cost value as the only criterion for categorisation. Jemelka et al. (2016) contended that in order to survive, organisations and supply chains today must be able to offer the right items quickly to relatively niche consumers. This concentration on a single criterion is necessary since there are global suppliers, intermediaries, and buyers, and product lives are shortening quickly (Jemelka et al., 2016).

There are several relatively easy and inexpensive strategies to manage inventory effectively, but some of them are underutilised. It includes the assortment ABC analysis. According to such analysis, the inventory is classified into three categories – Category A, Category B, and Category C. A method that assigns products based on how often they are purchased is used in this class-based storage assignment policy. The method's goal is to store rapidly moving goods close to the delivery zone. The main limitation of the existing approach is that the solution is not optimal.

In this research, we modelled the ABC classification problem as a multi-knapsack problem which differs from the basic multi-knapsack problem having additional bin cost variables in the objective function. The multi-knapsack problem is the problem of assigning a subset of items to the number of distinct knapsacks in a way that the total profit sum of the selected items is maximised without exceeding the capacity of each of the knapsacks (Pisinger, 1999).

The main contribution is the possibility to assign an optimal product mix to ABC categories which improves the solution used in the warehouses at the moment. The next contribution is the demonstration of solver usage as an optimisation engine for solving warehouse tasks. Therefore, we use commercial and non-commercial solvers to solve the warehouse product classification problem optimally.

The work is presented as follows. In Section 2, the relevant literature review. Section 3 presents the definition, notation and mathematical formulation for the ABC assortment classification problem. In Section 4, we briefly describe the input data for the experiment. Section 5 presents the computational experiment. Final comments and possible research directions are given in Section 6.

## 2. Related literature

### 2.1. Assortment problem

The measurements of the assortment — assortment width and assortment depth — are used to categorise the products offered in a warehouse and the retail sector. The assortment depth represents the diversity of certain product groupings, whereas the assortment breadth describes the range of various goods.

A wide selection can add value for customers by facilitating shopping. While going too far too soon can be perilous, sticking too closely to the current assortment and image may unfairly restrict the retailer's ability to innovate (Danneels, 2003). The capacity of a retailer's selection policy to successfully develop its significance and appeal to customers over time depends on the logic and sequencing of that policy (Ailawadi, Keller, 2004).

Profitable retail assortment optimisation necessitates the capacity to acquire up-to-date information about product performance across the company, as well as the ability to assess current and historical revenues and profits with trends and execution versus target. Only then can merchants use benchmarking to optimise their selection.

Cachon et al. (2005) created two search models. In general, the independent assortment search model assumes that each retailer's selection is distinct; therefore, if the search option is selected, the consumer expects to see several varieties when searching. Therefore, the consumer's anticipated value from search is unrelated to the retailer's selection (because search yields different variants no matter which variants the retailer carries) (Cachon et al., 2005).

The overlapping assortment model is the name given to the second search model created by Cachon et al. (2005). There are only a few goods on the market in this instance. Because there are fewer potential new versions for the consumer to see if the search is chosen, growing the retailer's selection now decreases the value of the search. A deeper assortment enhances the chance a buyer purchases some variety because it decreases the value of search, which is a significant impact that is not reflected by the no-search model (Cachon et al., 2005).

Researchers have documented the impacts of cross-selling products. It is well-accepted that there is a correlation between buying consumer goods from different categories that complement one another or act as substitutes for one another (Urban, 1998; Seetharaman et al., 2005; Raeder, Chawla, 2011; Oestreicher-Singer et al., 2013).

When there are several things to exhibit but little available shelf space, the issue gets more challenging. Retailers are therefore being forced to create effective decision support systems to control product availability due to low profits, the increasing demand for operational efficiency, and an ever-increasing focus on the needs of the consumer (Hübner, 2017).

Hariga et al. (2007) assert that inventory control, shelf space allocation, product selection, and item display area selection are essential procedures that significantly affect the financial operation of business owners. In order to avoid sub-optimality, the decision-making process for

various operations should be specifically connected. However, this integration, along with the inherent non-linearity of relevant mix models, will raise the complexity notably for real-world applications (Lotfi, Torabi, 2011).

Several recent works examine assortment selection and stocking decisions for a group of interchangeable items in a single category (e.g., van Ryzin, Mahajan, 1999; Mahajan, van Ryzin, 2001; Smith, Agrawal, 2000; Kok, Fisher, 2007; Hübner, Schaal, 2017), while other publications solely examine stocking decisions (Netessine, Rudi, 2003; Yücel et al., 2009).

Retailers may improve store groups and drive appropriate assortments by form, shop, department, and category by starting product assortment optimisation process flow using current behavioural-based shopping clustering data. Retailers may get rid of duplicates and underperforming. Stock Keeping Units (SKUs) with different retail assortment planning strategies. They prevent out-of-stocks and overstock, boost supply chain efficiency and forecast accuracy, and, most importantly, raise customer happiness and profitable revenue growth.

Simonson (1999) focused on the ways in which retailers can influence purchase decisions with the help of product assortment:

1. Customers typically evaluate only a group of the available products, with no regard to the entire assortment. Therefore retailers can influence which product groups should be evaluated together and create such groups to achieve their goals.
2. If the assortment is constant, the retailer can change the manner in which the products are displayed.
3. The assortment preferences could be manipulated by the marketing mix variables such as sales promotions. Therefore the retailer could continue achieving the sales goals (Simonson, 1999).

Sales companies must be prepared to review their fundamental strategies, reevaluate generally held presumptions, and incorporate fresh approaches to the ever-evolving problem of selling in order to meet the needs of the modern marketplace. Forum Europe Ltd (1997) presented the results of the research into sales productivity. Their goal was to create a foundation for improving a business' sales efforts.

Modern retail faces constant issues of managing space and selection in diverse shop layouts. Supported by information and communication technology, retail sectors are progressively resorting to e-retailing (and its variants such as retail through social networks and mobile shopping), which permits considerable overcoming of the restrictions of space and selection. Nonetheless, the vast majority of retail sales continue to take place in stationary retail formats, where suppliers (manufacturers and distributors/wholesalers) try to tackle the persistent challenge of a trade-off between limited space for product demonstration/sale and a diverse range of items (Dujak et al., 2016).

### 2.2. Assortment substitution

Substitution is a crucial factor in assortment planning. Customers can choose an alternative product if one they'd prefer isn't available (or choose not to buy any other product). Typically, there is only one round of replacement allowed, so if a client cannot find both her original pick and her alternative choice, the sale is lost (Corsten et al., 2018).

Subject to a maximum number of distinct assortments, assortments can range from store to store. When the customer's initial preference is not known, Fisher and Vaidyanathan (2009) introduced a model of substitution behaviour and took into account the impact of substitution while selecting assortments for the retail chain. To estimate the demand for attribute levels and replacement probabilities, they used the sales history of the SKUs that the retailer carried. They then extrapolate this information to estimate demand for any potential SKU, even those that the shop does not presently carry. The researchers provided a number of different criteria for selecting SKUs (Fisher, Vaidyanathan, 2009).

Fisher and Vaidyanathan (2014) developed a method for determining the best assortments, which includes a demand model, an estimation strategy, and assortment selection heuristics. Substitution is quantifiable, varies greatly, and significantly affects the ideal assortment (Fisher, Vaidyanathan, 2014).

The assortment planning problem for a single store using the exogenous demand model was modelled by Hübner et al. (2016) and Kök and Fisher (2007). Furthermore, it's frequently believed that substitution only occurs between items belonging to the same category.

On the one hand, Hübner et al. (2016) suggested using a stochastic news vendor model for perishable and non-perishable goods that simultaneously optimises assortment and order sizes under storage constraints, and that makes it possible to solve retail-specific specific problems using an optimal procedure or a near-optimal solution heuristic procedure for large problem cases. They consider product categories that are collectively delivered just once throughout a sales period, such as daily, every other day, just once during a season, etc.

On the other hand, Huh et al. (2016) discovered that buyers are likely to stay inside a category even though they believe the substitute product to be inferior to the original. According to their hypothesis, cross-category substitutes are paradoxically more rewarding than within-category substitutes due to their greater likeness to desired stimuli. Sloot et al. (2005) analysed switching categories and concluded that this tendency was minor. They examined the effect of product-, store-, situation-, and consumer-related variables in their study.

Campo et al. (2004) examined how consumers respond to unexpected, transient out-of-stocks (OOS), as contrasted to permanent assortment reductions (PAR). They compared and contrasted OOS and PAR reactions, as well as the underlying causes of each, and then empirically tested our theories in two different product categories. Their findings suggested that store losses in the event of a PAR could be significantly greater than those in the event of a stock-out for the same item (Campo et al., 2004).

If a customer's first choice product isn't offered by a retailer, they might choose to buy nothing or another item that is close enough to their top choice to make them eager to buy it. Both assortment optimisation and estimate must take into account the probability of substitution. In order to estimate substitution probabilities, it is necessary to separate sales of an SKU to customers who most favoured that SKU from sales to customers who preferred a different SKU but made a substitution when their favoured SKU was not available in the selection (Fisher, Vaidyanathan, 2014).

### 2.3. ABC classification

The majority of organisations today struggle with properly managing their inventory. When distributors are juggling a variety of consumer demands, it can be challenging to keep the optimum level of inventory at the warehouse. Nevertheless, the distributor will be able to manage assortment effectively if he has a strong inventory control system.

With the economy's recent rapid growth, citizens' way of life and level of consumption has quickened, and demand for retail services is rising as well. People have progressively started to do their grocery shopping at chain stores. Activity-based classification (ABC) is used in some supermarkets' warehouses. The primary method for classifying commodities in storage is the ABC method. Lin and Ma (2021) provided a novel method based on ABC classification, specifically for a niche market like chain supermarkets, in order to address the drawbacks of conventional classification techniques. (Lin, Ma, 2021).

Customers' perceptions of the variety of goods and services that a retailer provides in one place have a big impact on the image of the business. The advantages of a large selection are obvious. First, the retailer's salience increases with the breadth of the product selection since there are more scenarios in which the consumer may remember and consider the merchant. Salience is the most fundamental component of a brand. Second, the ease of one-stop shopping made possible by a wide product selection is more crucial than ever for today's time-pressed consumer (Messinger, Narasimhan, 1997; Ailawadi, Keller, 2004), which puts pressure on merchants to expand their selection. Third, consumers frequently browse at multiple stores; they might choose to buy a certain category in the store they are now visiting rather than another one depending on the in-store selection and marketing mix activities. Retailers with a wider selection benefit from the fact that unplanned purchases make up a sizeable amount of consumers' overall shopping baskets (Ailawadi, Keller, 2004).

Retailers have the option to differentiate their product lines by offering things that are exclusive to the market, but doing so can make pricing comparisons more difficult or, in the worst-case scenario, impossible. Where the potential financial rewards from discovering a lower price far outweigh the expenses of search, the consequences of a one-time search for an item (for example, the purchase of a big appliance) on retailer decisions regarding price and assortment are particularly applicable (Stassen et al., 1999).

The design of the warehousing and handling system goes through a number of steps, starting with the definition of the system limitations and requirements, and concluding with the evaluation of the preferred design. The goal of data analysis is to provide the basis for the designer's suggestions for appropriate operational systems and techniques, layouts, furnishings, technology, workforce levels, and pricing. There are numerous ways to exhibit and analyse data, including graphs, charts, statistical analysis, tables, drawings, and networks (De Koster et al., 2017).

Based on the Pareto principle, which claims that 20% of people are responsible for 80% of the impacts, ABC analysis is a straightforward method of classifying materials in terms of value and quantity. The Pareto principle for inventory management states that 20% of SKUs use 80% of the total annual cost. SKUs are categorised based on their Annual Usage Value, as determined by the ABC analysis.

- A class: the highest annual consumption value.
- B class: the medium consumption value.
- C class: the lowest consumption value (Mor et al., 2021).

The XYZ analysis is a method for allocating products according to changes in demand. The goal of the XYZ analysis is to organise the products according to their consumption in order to determine the best inventory plan. The following are the classification procedures:

- X class: the minimal variance.
- Y class: some variance.
- Z class: the most variation (Mor et al., 2021).

FSN analysis is a method of classifying inventory items as groups according to the rate of movement in the warehouse. Such classification is given as:

- F class: fast-moving.
- S class: slow-moving.
- N class: non-moving (Mor et al., 2021).

Presenting sales amounts, picking accessions, and inventory levels throughout the entire spectrum of SKUs in descending order of magnitude is one really helpful analytical tool. Pareto analysis, ABC analysis, or the 80/20 rule are other names for this technique. The results of 80/20 analysis, more frequently than not, show that around 20% of the stock range accounts for roughly 80% of the total inventory, 80% of the picking efforts and 80% of the sales. In order to create solutions that are appropriate for the material being held and handled, the designer is able to categorise and identify the considerably relevant SKUs in the range of items as well as identify various characteristics for various areas of the item range (De Koster et al., 2017).

The methodology presented in the study by Mor et al. (2021) can be used to identify the parts that will become obsolete in an automobile spare parts warehouse. The authors proposed a framework based on ABC-XYZ and FSN analysis to prioritise the spare parts based on their criticality, and inventory management techniques are used to reduce costs (Mor et al., 2021).

An effort was made to utilise lean concepts to increase the effectiveness of a manufacturing industry warehouse's operations as part of a continuous improvement approach. By using appropriate inventory models, such as ABC analysis, inventory can be managed more effectively. Baby et al. (2018) showed the sales warehouse as a representation of a number of problems with product delivery to clients. The authors aimed to improve warehouse operations by offering lean alternatives. Wastes are classified into transportation, inventory, waiting, delay, space, movement, overproduction, and defect waste groups. Wastes are discovered using lean technologies. Value stream mapping was utilised to track waste, and by switching to a U-shaped flow pattern and completing ABC inventory analysis, the majority of operational wastes, such as long order picking times, delayed vehicle loading, and incorrect storage, are avoided. Depending on ABC inventory analysis, the new inventory arrangement places products in order of their contribution to sales. Most warehouse operations have at least a 40% improvement (Baby et al., 2018).

Truly benefit is mostly dependent on quick order fulfilment; hence slow order picking deters customers. By creating a dynamic class-based storage assignment algorithm that puts quickly moving goods on lower shelves and closer to the shipping area, the goal of this project by McInerney and Yadavalli (2022) was to boost warehouse throughput. An ABC class-based storage policy was used in place to achieve this. The preferred storage locations are given to the A-class products, the second-best storage locations to the B-class products, and the remaining storage spaces to the C-class products (McInerney, Yadavalli, 2022).

Because sometimes nearby containers are not available, similar products are frequently stored in separate locations. Additionally, when the default container is empty, the computer system does not direct pickers to alternative containers. Pickers then report inaccurately that certain items are out of stock. There would be fewer needless restocks and order delays if the products were distributed according to a storage policy that placed them in close proximity to default and secondary containers (McInerney, Yadavalli, 2022).

The relocation of stock sections and the reduction of forklift handling distances were studied by Jemelka et al. (2016). Forklift tracks can be shortened by analysing the stock in accordance with the turnover of the raw materials and dispersing the storage areas in accordance with the ABC technique based on the turnover. The authors also included a comparison of the original 12-section plan based on the actual experience of warehouse operators and the computed solution based on the raw material cycle using the ABC approach (Jemelka et al., 2016).

Li et al. (2016) developed an integrated mechanism for optimisation purposes based on the ABC categorisation and the mutual compatibility of products and presented a novel dynamic storage assignment problem. A data mining method known as the "product affinity-based heuristic" was created for computing pairwise associations between products.

Incoming SKUs are distributed among the available locations according to random storage procedures. Class-based storage assignment methods place SKUs in regions designated for their corresponding classes based on their demand rates and ABC classification. By reducing the necessary travel lengths, the suggested storage assignment approach aims to optimise the order pickup procedure (Li et al., 2016).

Designing a warehouse and handling system involves more than just producing a simple drawing that specifies the dimensions and locations of racks or other storage spaces, handling areas, aisle runs, and vehicle charging points. In addition to that, it specifies things like the unit loads (like pallets), operating systems, equipment types and quantities, service and ancillary activities, communication and information systems, organisational structure, number of employees, and associated operating and capital costs. The external layout and the necessary room for vehicle access, parking, and manoeuvring, as well as for site security, parking, and any other operations, should also be indicated (De Koster et al., 2017).

Among the present issues at the warehouse are the poorly planned warehouse layout and the close proximity of the shelves, which made it impossible for the warehouseman to control the inventory of the goods. Due to overproduction, the overstocked supply typically arises at the end of the year (Hanafi et al., 2019). Hanafi et al. (2019) rearranged the facility layout depending on demand using the ABC classification approach.

The system that may reduce the total costs to the supplier meets one of the best requirements for a trustworthy supply management system. The entire cost is determined by the cost of storage, the cost of orders, and the cost of inventory shortages. On the other hand, only quantitative and qualitative factors are taken into account while making decisions in traditional supply control management (Hanafi et al., 2019).

### 2.4. A traditional method of ABC classification

The ABC classification method is a useful tool for identifying key products within the warehouse. From the standpoints of manufacturing, inventory control, revenue-generating, and sales generation, it is very important to categorise the products.ABC categorisation adds the most value to the business.

Companies shouldn’t allot the same amount of resources to each product in a warehouse because not all of them generate the same revenue and profitability. The ABC analysis is a method of inventory classification that divides the products into three categories: A, B, and C, according to their revenue.

Since there is no perfect universal classification, the appropriate one must be selected based on the specifics of each organisation. In the ABC system, there are four primary classification categories for product references:

- Classification of ABC products by rotation.
- Classification of ABC products by unit cost.
- Classification of ABC products by total inventory value.

- Classification of ABC references by use and value (AR Racking, ABC Inventory Method in the Warehouse: Origin, Characteristics and Advantages, https://www.ar-racking.com/en/news-and-blog/storage-solutions/quality-and-security/abc-inventory-method-in-the-warehouse-origin-characteristics-and-advantages).

Category A: Goods falling under category A are the most valuable and important items. About 20% of all products make up segment A products, which generate 80% of the company's revenue. It is regarded as a niche market with few products but high sales (Deskera; https://www.deskera.com/...).

Being the priority references category, the corporation must commit more resources to it to carry out, periodically and frequently, more extensive and complicated stock controls. A company will incur significant losses if there is an inventory issue with category A products, such as a stock shortage or depletion. To expedite the order preparation process, category A products in the ABC model must be placed in easily accessible locations adjacent to the dispatch area. This must be taken into account in order to create the warehouse plan and properly organise all of the stock. Products in this category can be kept in storage facilities with easy access to unit loads or, when appropriate, in automated storage facilities to reduce the time it takes to load and unload cargo (AR Racking, ABC Inventory Method in the Warehouse: Origin, Characteristics and Advantages, https://www.ar-racking.com/en/news-and-blog/storage-solutions/quality-and-security/abc-inventory-method-in-the-warehouse-origin-characteristics-and-advantages)

Category B: Products in category B are slightly more expensive than those in segment B. It controls 30% of the market for goods and generates 15% of the revenue. In addition, although there are more items in this category, they are less useful (Deskera; https://www.deskera.com/...).

Any reference that falls into the category that lies between A and C should have its status frequently examined in case it needs to be changed to either A or C in the future. After organising and reserving the finest spots for the A references, they will be placed in the warehouse's most direct and accessible locations. Typically, category B products are kept in intermediate levels with convenient access to some unit loads but not always (AR Racking; https://www.ar-racking.com/...).

Category C: Products falling under category C are more numerous but less effective at bringing in revenue. Comparatively to categories A and B, category C has the highest stock ownership at 50% but only produces 5% of the revenue (Deskera; https://www.deskera.com/...).

Due to their low demand and limited turnover in the warehouse, these products should only receive the barest minimum of resources. Inventory control may be occasional, employ basic techniques, be situated in the warehouse remote from the dispatch location, at greater or lower accessibility levels, and be sufficient to prevent obsolescence or expiration issues. Category C references must be evaluated to determine whether investing resources in storage and stock is desirable for the organisation, as storage costs may end up being more than the income realised through marketing (AR Racking; https://www.ar-racking.com/...).

To sum it up, A represents the most vital items, B indicates moderately necessary commodities, and C indicates the least critical inventories. Any organisation determines how the ABC categories are divided, but the percentages should be roughly 80%, 15%, and 5%. In the ABC analysis, "A" stands for the most significant inventory, "B" for moderately necessary inventory, and "C" for the least important inventory (AR Racking; https://www.ar-racking.com/...; Cips; https://www.cips.org/...; Deskera; https://www.deskera.com/...; EazyStock, Drakeley; https://www.eazystock.com/...; Katana; https://katanamrp.com/...).

ABC classification is performed according to the following steps:

1. Calculate sales/profit/consumption of each product during the investigated period.
2. List the products in descending order based on their sales/profit/consumption value.
3. Sum up the number of items sold and the sales/profit/consumption value.
4. Calculate the cumulative percentage of items sold and the cumulative percentage of the sales/profit/consumption values.
5. Determine the thresholds for splitting the data into categories A, B and C. The threshold for determining the ABC split groups will be unique to the company and the offered assortment. In this research, we set 80%/15%/5% for categories A, B and C (EazyStock, Drakeley; https://www.eazystock.com/...)

## 3. Problem definition and formulation

$P$ - the total number of products.

$B$ - the total number of categories.

$i$ - product index, $i = 1,...,P$.

$j$ - category index, $j = 1,...,B$.

$v_i$ - value of the product $i$.

$c_j$ - cost of the category $j$.

$W_j$ - capacity of the category $j$.

Decision variable:

$$x_{ij} = \begin{cases} 1, & \text{if product } i \text{ is assigned to category } j \\ 0, & \text{otherwise} \end{cases}$$

There is a number of products $P$ at the warehouse. The products must be classified into $B$ categories (such as A, B, C) according to their rotation in the warehouse. The most demanded products and, therefore, those products that generate the most movements in the warehouse should be assigned to category A, and those with hardly any rotation to the last category (e.g. C). The demand or value of the product is characterised by $v_i$. Each category $j$ has its capacity according to the Pareto principle $W_j$. The costs resulting from product storage and

moving from the warehouse are characterised by $c_j$. Generally, the storage costs for the lowest category (e.g. C) can be even higher than the profitability obtained from their marketing. The lowest costs are in the first category A.

The goal is to assign products to the categories so that distributor's profit is as much as possible.

The model can then be formulated as follows:

$$\max \sum_{i=1}^{P} \sum_{j=1}^{B} x_{ij} v_i (1 - c_j) \tag{1}$$

subject to:

The number of products in each category cannot exceed the available category capacity:

$$\forall (j)[\sum_{i=1}^{P} x_{ij} \leq W_j] \tag{2}$$

(category capacity)

Each product must be assigned to one category.

$$\forall (i)[\sum_{j=1}^{B} x_{ij} = 1] \tag{3}$$

(product to category assignment)

## 4. Experimental data

For the experiment, we used the "Online Retail II UCI", which is a real online retail transaction data set of two years provided by Kaggle (Kaggle; https://www.kaggle.com/...).

This "Online Retail II" dataset includes every transaction made by a UK-based, registered, and non-store online retailer between December 1, 2009, and December 9, 2011. The company primarily offers distinctive gifts for all occasions. The company has a large number of wholesalers as clients.

Attribute information:

- Invoice number. Nominal, which is uniquely assigned to each transaction.
- Product (item) code. Nominal, which is uniquely assigned to each distinct product.
- Product (item) name. Nominal.
- Quantity. Numeric. The quantities of each product (item) per transaction.
- Invoice date and time. Numeric. The day and time when a transaction was generated.
- Unit price. Numeric. Product price per unit in sterling.
- Customer number. Nominal, which is the number uniquely assigned to each customer.
- Country name. Nominal. The name of the country where a customer resides.

The first six attributes are essential for the current research.

We transformed the data into a structure presented in Figure 1. The information about the products and invoices is needed for the research.

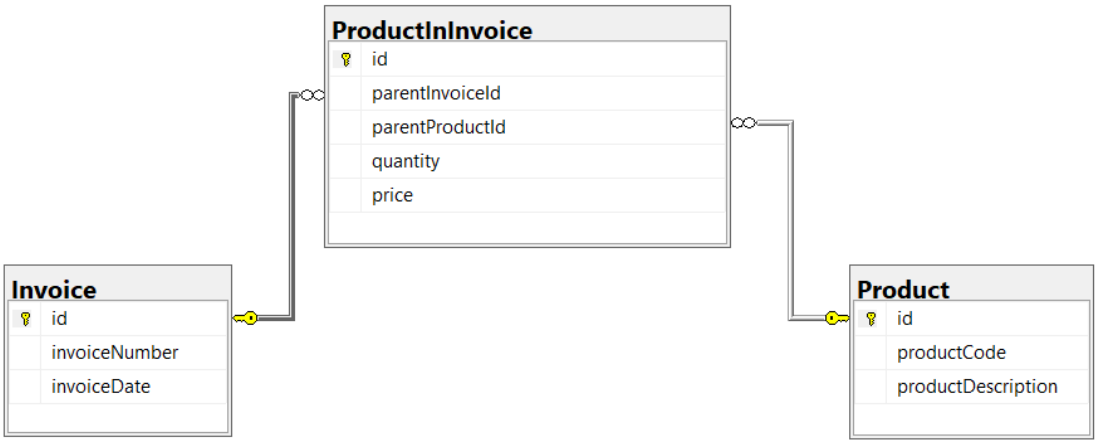


**Figure 1.** Database diagram based on the downloaded data.

Source: own elaboration.

The dataset could be explained as follows. There is a number of products that the company offers in the assortment. There is a number of invoices with the dates on which the products were sold or returned. In one invoice, there could be many different products. Products can be sold or returned within the invoices.

Table 1 **Błąd! Nie można odnaleźć źródła odwołania.**explains the input data. There were 8196 products and 46 373 invoices between 01.01.2010 and 31.12.2011. The average number of products in an invoice was 43, with minimum and maximum values of 1 and 2544, accordingly. Invoices reported the number of sold (8158) and returned (5090) products which gave the 22 053 839 sold product quantities and 846 360 product quantities. For the analysis, we chose the 2-year timeframe from 01.01.2010 to 31.12.2011.

**Table 1.**
*Statistics on the input data*

| Parameter | Value |
|---|---|
| The total number of products | 8196 |
| The total number of invoices | 46 373 |
| The minimum number of products in invoices | 1 |
| The average number of products in invoices | 43 |
| The maximum number of products in invoices | 2544 |
| The total number of products in invoices which were sold | 8158 |
| The total number of products in invoices which were returned | 5090 |
| The sum of quantities of products in invoices which were sold | 22 053 839 |
| The sum of quantities of products in invoices which were returned | 846 360 |
| Timeframe of analysed sales data in invoices | 01.01.2010 – 31.12.2011 |

Source: own elaboration.

## 5. Experiment

The goal of the computational experiment was to test if the optimal solution could be found by commercial and non-commercial solvers and compare it to the solution made by the distributor evaluation using a real-size database.

For the experiments, the database was built in MS SQL using:

- SQL Server 2019.0150.2000.05.
- SQL Server Management Studio v18.12.1.
- SQL Server Management Studio 15.0.18424.0.

The main program, which used libraries for solvers, was written in C# using:

- Microsoft Visual Studio Community 2019
- Version 16.8.2.
- VisualStudio.16.Release/16.8.2+30717.126.
- Microsoft .NET Framework.
- Version 4.8.03752.

The computer parameters are:

- Processor: AMD Ryzen 5 1600 Six-Core Processor 3.20 GHz.
- System type: 64-bit Operation System, x64-based processor.
- RAM: 16GB.
- Operation system: Windows 10.

We modelled the assortment categorisation problem as a multiple knapsack problem, and we used both the free-of-charge MIP solver and the CP-SAT solvers to solve it. Next, we used the commercial CPLEX solver. Later provided the comparison of the optimal solutions found by the solvers with the practical distributor's solution.

Google OR-Tools is an open-source software suite for optimisation used for tackling the world's known problems in vehicle routing, flows, integer and linear programming, and constraint programming (https://developers.google.com/optimization). Using such libraries, optimisation problems could be modelled and solved in C++, Python, C#, or Java. We used C# for dealing with all solvers.

Table 2 reports the time required for product categorisation by solvers and by the distributor. The table also provides us with the information to determine which solver will earn the best results for the warehouse. We had 39 test instances. Among them, there were 24 instances which represented 1 month, 8 instances which represented 3 months, 4 instances which represented 6 months, 2 instances for 1 year and 1 instance for the whole 2-year period. The average number of products for 1 instance was 5153 with its minimal and maximal values 3797 and 8196 accordingly. We analysed only the transactions with sales during the selected period, i.e. the products that were not returned or sold were not taken into account. This is done only for the experiment in different instances. Otherwise, the products without sales will be assigned to category C. We didn't want to disturb our results with such cases. In practice, the widest

period (e.g. a year) is selected, and all products are categorised, even the products with a lack of sales.

CPLEX solver was the fastest solver, which found the solution on average in 0.11 seconds, with its fastest and longest time at 0.07 seconds and 0.22 seconds, accordingly. MIP solver and the CP-SAT solvers executed comparably, founding the solution on average in 1.98 seconds for MIP and 2.32 seconds for CP-SAT. The minimum and maximum solution time vary from 1.18 seconds to 4.39 seconds for MIP. The minimum and maximum solution time vary from 1.51 seconds to 3.85 seconds for CP-SAT. The solution found by the distributor in SQL was the slowest and, on average 3.28 seconds. As it could be observed, for SQL, the time step was 1 second, while for solvers, it was more precise.

**Table 2.**
*Product categorisation solution time*

| Dates | Start date | End date | Number of products | MIP time [s] | CP-SAT time [s] | CPLEX time [s] | SQL time[s] |
|---|---|---|---|---|---|---|---|
| 1 month | 01.01.10 | 31.01.10 | 5 019 | 1.89 | 2.19 | 0.14 | 3.00 |
| | 01.02.10 | 28.02.10 | 4 752 | 1.80 | 2.06 | 0.09 | 4.00 |
| | 01.03.10 | 31.03.10 | 5 284 | 2.09 | 2.30 | 0.11 | 3.00 |
| | 01.04.10 | 30.04.10 | 4 776 | 1.95 | 1.99 | 0.09 | 4.00 |
| | 01.05.10 | 31.05.10 | 4 770 | 1.80 | 1.97 | 0.09 | 4.00 |
| | 01.06.10 | 30.06.10 | 4 887 | 1.80 | 2.34 | 0.14 | 3.00 |
| | 01.07.10 | 31.07.10 | 4 749 | 1.92 | 2.46 | 0.08 | 3.00 |
| | 01.08.10 | 31.08.10 | 4 831 | 1.84 | 2.12 | 0.10 | 3.00 |
| | 01.09.10 | 30.09.10 | 4 904 | 1.72 | 2.28 | 0.11 | 3.00 |
| | 01.10.10 | 31.10.10 | 5 080 | 1.86 | 2.15 | 0.10 | 4.00 |
| | 01.11.10 | 30.11.10 | 5 312 | 1.97 | 2.40 | 0.12 | 4.00 |
| | 01.12.10 | 31.12.10 | 4 861 | 1.58 | 2.29 | 0.09 | 3.00 |
| | 01.01.11 | 31.01.11 | 4 445 | 1.56 | 1.88 | 0.09 | 4.00 |
| | 01.02.11 | 28.02.11 | 4 125 | 1.45 | 2.42 | 0.09 | 3.00 |
| | 01.03.11 | 31.03.11 | 4 315 | 1.44 | 2.69 | 0.09 | 3.00 |
| | 01.04.11 | 30.04.11 | 4 267 | 1.56 | 1.85 | 0.09 | 3.00 |
| | 01.05.11 | 31.05.11 | 4 186 | 1.43 | 1.80 | 0.08 | 4.00 |
| | 01.06.11 | 30.06.11 | 4 386 | 1.51 | 2.12 | 0.10 | 3.00 |
| | 01.07.11 | 31.07.11 | 4 463 | 1.57 | 2.02 | 0.10 | 3.00 |
| | 01.08.11 | 31.08.11 | 4 334 | 1.41 | 1.81 | 0.08 | 4.00 |
| | 01.09.11 | 30.09.11 | 4 470 | 1.45 | 1.92 | 0.09 | 3.00 |
| | 01.10.11 | 31.10.11 | 4 532 | 1.53 | 1.93 | 0.10 | 3.00 |
| | 01.11.11 | 30.11.11 | 4 631 | 1.62 | 2.01 | 0.10 | 4.00 |
| | 01.12.11 | 31.12.11 | 3 797 | 1.18 | 1.51 | 0.07 | 3.00 |
| 3 months | 01.01.10 | 31.03.10 | 6 074 | 2.69 | 2.71 | 0.12 | 3.00 |
| | 01.04.10 | 30.06.10 | 5 737 | 2.41 | 2.69 | 0.12 | 3.00 |
| | 01.07.10 | 30.09.10 | 5 758 | 2.47 | 2.56 | 0.13 | 3.00 |
| | 01.10.10 | 31.12.10 | 5 807 | 2.28 | 2.68 | 0.13 | 3.00 |
| | 01.01.11 | 31.03.11 | 5 125 | 1.94 | 2.26 | 0.11 | 4.00 |
| | 01.04.11 | 30.06.11 | 5 247 | 1.97 | 2.31 | 0.10 | 3.00 |
| | 01.07.11 | 30.09.11 | 5 084 | 1.92 | 2.28 | 0.11 | 3.00 |
| | 01.10.11 | 31.12.11 | 5 008 | 1.48 | 2.22 | 0.11 | 3.00 |
| 6 months | 01.01.10 | 30.06.10 | 6 517 | 2.90 | 2.76 | 0.15 | 3.00 |
| | 01.07.10 | 31.12.10 | 6 348 | 2.54 | 2.78 | 0.14 | 3.00 |
| | 01.01.11 | 30.06.11 | 5 759 | 2.38 | 2.52 | 0.14 | 3.00 |
| | 01.07.11 | 31.12.11 | 5 486 | 1.58 | 2.42 | 0.13 | 3.00 |

Cont. table 2.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 year | 01.01.10 | 31.12.10 | 7 317 | 3.50 | 3.32 | 0.20 | 3.00 |
| | 01.01.11 | 31.12.11 | 6 329 | 2.73 | 2.65 | 0.14 | 3.00 |
| 2 years | 01.01.10 | 31.12.11 | 8 196 | 4.39 | 3.85 | 0.22 | 4.00 |
| Min | | | 3 797 | 1.18 | 1.51 | 0.07 | 3.00 |
| Avg | | | 5 153 | 1.98 | 2.32 | 0.11 | 3.28 |
| Max | | | 8 196 | 4.39 | 3.85 | 0.22 | 4.00 |

Source: own elaboration.

All solvers found optimal solutions for all instances. Comparing solvers' performance, it could be noted that the value of the objective function was the same for all solvers, the number of products in each category was the same for all solvers, while the value for different categories for one selected instance differed for solvers. All products were assigned to one of the categories by all solvers.

Table 3 **Błąd! Nie można odnaleźć źródła odwołania.**reports the comparison of the solution found by the distributor to the optimal solution found by the solvers. The profit ratio calculated by the total profit found by the distributor divided by the total found by the solver was, on average, 99.9994%. For 17 instances of 39 ones, the solution found by the solver was better than the distributor's solution.
This difference is, on average, 0.00128% and varies from 0.00002% to 0.00650%. Not so much, but in large warehouses or distribution centres, even such profit ratio difference provides for savings. So solver usage is advisable for large problem instances.

**Table 3.**
*Performance of the distributor's method*

| Dates | Start date | End date | Profit ratio | Solvers were better |
|---|---|---|---|---|
| 1 month | 01.01.10 | 31.01.10 | 100.0000% | |
| | 01.02.10 | 28.02.10 | 99.9940% | 0.00599% |
| | 01.03.10 | 31.03.10 | 99.9977% | 0.00227% |
| | 01.04.10 | 30.04.10 | 100.0000% | |
| | 01.05.10 | 31.05.10 | 100.0000% | |
| | 01.06.10 | 30.06.10 | 100.0000% | |
| | 01.07.10 | 31.07.10 | 99.9992% | 0.00075% |
| | 01.08.10 | 31.08.10 | 100.0000% | |
| | 01.09.10 | 30.09.10 | 99.9985% | 0.00147% |
| | 01.10.10 | 31.10.10 | 99.9999% | 0.00006% |
| | 01.11.10 | 30.11.10 | 100.0000% | |
| | 01.12.10 | 31.12.10 | 99.9998% | 0.00015% |
| | 01.01.11 | 31.01.11 | 99.9997% | 0.00033% |
| | 01.02.11 | 28.02.11 | 99.9999% | 0.00013% |
| | 01.03.11 | 31.03.11 | 100.0000% | |
| | 01.04.11 | 30.04.11 | 99.9935% | 0.00650% |
| | 01.05.11 | 31.05.11 | 100.0000% | |
| | 01.06.11 | 30.06.11 | 100.0000% | |
| | 01.07.11 | 31.07.11 | 100.0000% | |
| | 01.08.11 | 31.08.11 | 100.0000% | |
| | 01.09.11 | 30.09.11 | 100.0000% | |
| | 01.10.11 | 31.10.11 | 100.0000% | |
| | 01.11.11 | 30.11.11 | 99.9998% | 0.00024% |
| | 01.12.11 | 31.12.11 | 99.9967% | 0.00332% |

Cont. table 3.

| | | | | |
|---|---|---|---|---|
| 3 months | 01.01.10 | 31.03.10 | 99.9999% | 0.00007% |
| | 01.04.10 | 30.06.10 | 100.0000% | |
| | 01.07.10 | 30.09.10 | 99.9998% | 0.00017% |
| | 01.10.10 | 31.12.10 | 100.0000% | 0.00002% |
| | 01.01.11 | 31.03.11 | 100.0000% | |
| | 01.04.11 | 30.06.11 | 99.9999% | 0.00006% |
| | 01.07.11 | 30.09.11 | 100.0000% | |
| | 01.10.11 | 31.12.11 | 99.9999% | 0.00014% |
| 6 months | 01.01.10 | 30.06.10 | 99.9998% | 0.00018% |
| | 01.07.10 | 31.12.10 | 100.0000% | |
| | 01.01.11 | 30.06.11 | 100.0000% | |
| | 01.07.11 | 31.12.11 | 100.0000% | |
| 1 year | 01.01.10 | 31.12.10 | 100.0000% | |
| | 01.01.11 | 31.12.11 | 100.0000% | |
| 2 years | 01.01.10 | 31.12.11 | 100.0000% | |
| Min | | | 99.9935% | 0.00002% |
| Avg | | | 99.9994% | 0.00128% |
| Max | | | 100.0000% | 0.00650% |

Source: own elaboration.

## 6. Conclusion

Distribution expectations on the profitability of the warehouse or distribution centre have increased; this means that they are now more educated and tend to increase savings and increase the gained profit. Therefore they are interested in methods of assortment categorisation, which allow them to achieve their goals and to be better than their competitors.

According to the industry, the kind of items, or the particular requirements of the warehouse, there are different ways to categorise or define the importance of a product for a corporation. Wrong product categorisation could lead to low profits because of increased costs of picking. By changing the category of the product, the distributor's revenue might potentially increase, and the product picking costs may be decreased. In other words, changing product categories at the warehouse and distribution centre may help a company to achieve higher results.

This research shows how commercial and non-commercial solvers could be used for assortment categorisation and what profitability could be achieved compared to the distributor's categorisation method. The proposed approach to model assortment categorisation problem as a multi-knapsack one and usage of solvers provides businesses with the right tools to make appropriate decisions and increase their sales.

The results showed that for 17 instances from 39 ones, the solution achieved found by the solver was better than the wholesaler's solution on an average of 0.00128%. This difference varied from 0.00002% to 0.00650% for the rest instances. There is no big difference with the optimal solution on paper, but in large warehouses or distribution centres, even a small

percentage improvement provides wholesalers with savings. In larger warehouses the performance of the proposed ABC classification method can be increasingly significant.

A complete assortment optimisation tool should integrate assortment optimisation, connection visibility, and quality measurement capabilities. Distributors who use such technology in their business expect to gain a competitive edge. Distributors can increase the profitability of the assortment and clearly define its category of it by integrating automation as proposed in this research.

Each classification has a precise area. Keeping track of the ABC classification is crucial since the demand for certain products can vary. ABC analysis could be counter-productive. Not all enterprises might choose to categorise their product line using this method. Any company that fails to plan and put in a classification system will not have efficient management over its inventory management, and hence its gained profits will be reduced. The ABC classification allows for efficient stock management and a focus on important stock lines.

The main limitation of this research is not taking into account constraints which indicate that some products cannot be placed on the shelves immediately or some of them cannot be classified immediately. Moreover, the availability of storage equipment or warehouse staff in the classification moment should be taken into account. These issues may be the subject of further research.

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# MICROPAYMENTS IN GAMES USING THE FIFA SERIES AS AN EXAMPLE - FUN OR E-GAMBLING ACCESSIBLE TO CHILDREN? DISCUSSION AROUND CONTROVERSY AND REGULATION

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**Purpose:** The study's main objective was to identify the risks associated with game developers' mechanisms to define the micropayment system, using the example of EA Sports' practices in the FIFA series of games. The specific objectives were: to define the form in which micropayments occur in games of the FIFA series, to determine the factors that affect the attractiveness of micropayments to players, and to define the similarities between loot boxes and gambling games.
**Design/methodology/approach**: The authors highlighted the payments used by game developers available from within the app, their characteristics and the juxtaposition of these mechanisms with those used in gambling. Then, using desk research analysis, the financial benefits of using this system for the developers of the FIFA series were analyzed, as well as the identified potential risks of these practices. The authors based their considerations on Polish and foreign literature, studying academic articles, books, reports, and chapters from monographs and electronic sources. The following professional, scientific databases were used to gather scientific literature: Google Scholar, ResearchGate and ScienceDirect.
**Findings:** Micropayments are an essential source of additional revenue for game developers. Not only do they effectively engage players, but the value of additional in-game purchases often exceeds the product's original price (i.e. the full-priced game). The term micropayments, in this case, is already used conventionally - it is widespread for some in-game purchases to be as much as hundreds of zlotys. Because of their apparent similarities to gambling, loot boxes, or boxes with randomized prizes, are controversial - so much so that countries such as Belgium are considered gambling and do not allow for young people. Typical users of micropayments in games are minors, who are more easily influenced by the persuasion practised by game developers, especially in multiplayer games, where a competitive element and additional content can improve a player's performance.
**Social implications:** Due to mechanisms using microtransactions, companies can profit significantly from selling complementary content after the revenue from product sales has already been generated. Loot boxes engage players, but they also raise a lot of controversy and doubts due to their disturbing resemblance to gambling.

**Originality/value:** The treatment of issues treating the phenomenon of micropayments in online games is based on the literature on the subject, Polish and foreign, enriching the existing body of scientific work on the gaming industry, signalling the authors' contribution to the development of the discipline of management and quality sciences. The article is primarily addressed to researchers and scholars dealing with e-gaming in the context of its various dimensions. The work may also interest students of marketing, psychology and pedagogy. In addition, the article is valuable for parents and guardians of children and adolescents who spend time on online games to outline the problem of micropayments in games. The article's value is a comprehensive discussion of gambling, micropayments and "loot box" mechanics about the controversies and regulations surrounding them.

**Keywords:** micropayments, games, gaming, FIFA, EA Sports, gambling, loot box.

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

## 1. Introduction

Gaming is a required field which developed from simple arcade games to enormous productions that have become popular worldwide (Kent, 2010). Video games owe their popularity mainly to the phenomenon of transmedia and the usage of convergent narratives, which stand for a large variety of communication methods – the games do not only experience the written story but also the one visible and readable. In games classified as transmedia stories, the story is told by one medium and developed by others (Boczkowska, 2014).

Nowadays, games are not only targeted at a single player, but many of them allow some forms of competition, primarily online, connecting gamers from all over the globe. It is trendy in games such as football or basketball that simulate sports competition through the screen. In games partly or generally based on competition between players, in-app payments often occur.

Micropayments have been a subject of discussion for years that becomes more lively as the popularity of micropayments in apps and games, all mobile, computer and console, keeps rising. However, small payments are made within the used app (Zakonnik, 2007). Industry sources present microtransactions as a part of the game, considering both free-to-play (the ones that can be played for without initial payment) and a great deal of big-budget productions. Due to micropayments, the player can unlock some extra, usually hard-to-obtain, content. The purchase can be performed in two ways: buy the content for real money or the exceptional balance with a premium currency that lets them purchase within the game (GRYOnline.pl, 2013).

The discussion around in-game payments is mainly about their potential dangers. First, there goes the lack of justice in competition, where purchasing additional content affects the player's performance. The second is subsidizing a product the player has already paid for it. This situation takes place in the case of games that are not free to play. The third and most

disturbing aspect is the randomness of some mechanics, which can carry the hallmarks of gambling (loot boxes).

The main objective of this article is to present the issues accessible within the literature on the characteristics of micropayments in games using the example of EA Sports' practices in the FIFA game series and the potential dangers arising from them. The specific objectives are to analyze the microtransactions used by developers within the FIFA game series, to identify the factors determining the attractiveness of micropayments to players and their impact on the functioning of the community, and to define dangerous mechanics for minors, show the similarities between loot boxes and gambling games. The authors highlighted existing and planned legal restrictions on using micropayment systems in games. They discussed the phenomenon of gambling as one of the behavioural addictions and highlighted its various dimensions.

## 2. Methodology

The authors used the *desk research* method. They reviewed the literature on micropayments in electronic entertainment, including primary games in the FIFA series created by the EA Sports studio. The bibliography includes 41 items, covering scientific articles, books, reports, and chapters from monographs and electronic sources - mainly from 2016-2023. The following scientific databases were used to gather the literature: Google Scholar, ResearchGate and ScienceDirect.

## 3. Gambling as a behavioural addiction phenomenon and its various dimensions

The word "gambling" originally derives from the Arabic as "az-zahr," meaning "game of dice" or "dice" for this game. In Old French, the word appeared as "azard" or "azart," meaning blind luck, chance, or good fortune. The phrase "gambling" was understood as surrendering to the decisions of fate, entrusting the game's results to the simple chance, giving up the possibility of consciously influencing the course of events, or, finally, allowing the risk (Wilk, 2012).

Currently, in the Polish language, gambling takes on two meanings. First, it means all games of chance, including betting, poker, or slot machines. Second, gambling is also a risky venture, the outcome of which is difficult to predict. Games of chance, the outcome of which depends solely on chance and which may result in monetary or material winnings, further include contests and lotteries of Totalizator Sportowy, scratch cards, number games, dice games, bingo

games, roulette, text message contests, card games, lotteries (Borecki, 2018). In doing so, it is worth pointing out the differences between gaming and gambling. Gaming as a form of casual fun not involving the loss of a large sum of money is not bad. It becomes dangerous when one loses control over one's behaviour and can lead to disrupted family and social relations, professional problems, loneliness and significant material losses (Gontarz, 2019).

According to the classification of gambling, one can distinguish (Woronowicz, 2017): recreational gambling - which is a pastime, a form of leisure activity, and risk gambling - where the negative consequences of gambling are still small enough that the gambler can deal with them on their own; problem gambling - here the first more serious negative consequences of gambling already appear; pathological gambling (otherwise known as compulsive, addictive or problem gambling (Banaszak, 2014; Tucholska, 2008) – which stands for addiction with all its consequences. Pathological gambling is a behavioural addiction compulsion to perform a particular activity that destroys the functioning of the addict and those around them (Kaczmarek, Laere, 2019).

The literature distinguishes determinants of the development of pathological gambling, which are the following factors: familial/genetic, sociodemographic (age, gender, ethnicity, type of gambling), subjective (personality, biochemical reactions, cognitive processes, mental states), religious/spiritual (Tucholska, 2008). According to (Panasiuk, Panasiuk, 2016), a large percentage of gamblers, especially adolescent and middle-aged men, reveal a tendency to abuse psychoactive substances, such as alcohol, drugs, nicotine, or anabolic steroids, which eventually leads to addiction to them. Combining pathological gambling with another harmful addiction or bad habit, such people often commit criminal and delinquent acts or engage in self-aggressive and self-destructive activities, such as self-harm or suicide attempts.

In turn, the determinants of e-gambling, by (Lelonek-Kuleta et al., 2020), are gender, age, population, place of residence, education, and monthly family income. Men are more likely to gamble than women. In terms of age, the youngest group (under 29) is much more likely to gamble online than older people (over 50). As for the place of residence, practising e-gambling is much less common among those living in urban areas than those living in rural areas. Education also plays a significant role in online gambling, with those with primary education showing higher activity than those with vocational education. Finally, those with low monthly family incomes are significantly more likely to devote their time to online gambling than those earning more than 3000. The researchers (Lelonek-Kuleta et al., 2020) also highlight the frequency of Internet use as a concurrent element with online gambling. Those who use the Internet more frequently tend to engage more in e-gambling.

According to (Lelonek-Kuleta, Bartczuk, 2021), psychological factors, including motivation and coping strategies, play a key role in explaining problematic esports betting. The authors also noted that e-gambling activity is associated with other forms of gambling and playing video games in the context of gaining an advantage through payment. Moreover, the intensity of pathological e-gambling increases with involvement in other types of online

gaming. Interestingly, in the group of people actively involved in intensive esports betting, some of them do not experience its negative consequences. According to the study, this situation is because the protective factor for these individuals turned out to be committed coping strategies.

## 4. Micropayments and characteristics of the "loot box" mechanics

Effective electronic payment systems determine the development of e-commerce. Large-scale payments use credit/debit cards, while small-scale e-commerce is limited by the nature of existing e-payment (or otherwise "micropayment") systems (Baddeley, 2004). According to (Carat, 2002), micropayment systems represent e-payment solutions that allow payments of up to five euros. A similar definition of micropayments is given by (Hernandez - Verme & Valdes Benavides, 2013), according to which it is an online or mobile real-time or deferred financial transaction with a value of fewer than five euros that initiates the immediate delivery of a digital good in the form of news content, online music, movies or TV shows. On the other hand, according to (Herzberg, 2002), micropayments are defined as charging amounts less than (or close to) the minimum credit card transaction fees - which are around 20 cents. (Nguyen, 2006) states that micropayments are low-value electronic payments that do not use a digital signature to authenticate each payment made – the same as the case of high-value payments. Payment authentication is inaccurate for micropayments due to the high computational and processing cost for the bank compared to the value of the payment.

On the other hand, micropayments are the name used colloquially for payments in games of various amounts, but the division by the range of these amounts used by (Zakonnik, 2007) helps determine the scale of the phenomenon. A distinction is thus made between:

- milipayments - up to 1 zloty,
- micropayments - above a zloty to 100 zloty,
- mini-payments - above PLN 100 to PLN 1,000,
- macro-payments - above PLN 1,000.

We can still look at micropayments from an industry-specific point of view - a micropayment is considered a small payment for additional content in a game, which can give a wide range of interpretations towards this mechanic since under the word small can be completely different amounts perceived subjectively as not high. Micropayments, however, are made through a store implemented into the game, so the user does not have to log into additional platforms. The offer must also be some premium product - that is, it must be difficult to access, or its acquisition method is time-consuming - the payment can significantly accelerate the player's goal or improve his gameplay experience (GRYOnline.pl, 2013).

At this point, it is worth mentioning a mechanism that affected the market even before the popularization of smartphones - in Japan, in free-to-play mobile games (the user can enjoy the game for free), unique monetization mechanisms called *Gacha* or *Gachapon* were introduced. The name comes from toy slot machines housed in unique balls - after inserting a coin and turning the mechanism, the customer receives a random toy. *Gacha-Pon* refers to the sound the device makes when the mechanism moves. Some toys differed in their rarity, for example - and the whole thing contributed to its adaptation in Japanese F2P games, where it was henceforth possible to land additional content for the game. The whole concept differs from American and European productions' ideas - the player does not pay for content but rather for a lucky draw that may allow him to get the prize of his dreams - in real or virtual currency. In the case of micropayments, which are traditional for the European or American markets, the player instead buys specific additional content with specified features (Josef et al., 2018).

The feature of micropayments is primarily their convenience since acquiring an electronic product does not require complicated transfers - most often, it is done by using the payment method assigned by default to the user's account or e-transfer through an intermediary platform. As a result, the purchase requires virtually no effort.

The number of microtransactions (such as Pay2Win), a business model where players can buy virtual items using micropayments, has increased significantly in recent years. This situation involves the purchase of specific virtual goods in the game, such as weapons, capes, pets, cards, and characters using real money. However, other types of microtransactions have also emerged, one of which is loot boxes (or loot crates (Josef et al., 2018)) also referred to as chests or boxes, where players use real currency to purchase a random virtual item in the game (González-Cabrera et al., 2022).

Lootboxes are one of the most controversial microtransactions in online games. First, mainly because of the randomness with which players earn valuable rewards. Moreover, secondly, because of the perceived psychological effects of the business model behind this mechanism. The high probability of receiving duplicate and low-value rewards encourages players to purchase loot boxes to earn more valuable or useful rewards. In addition, the loot box environment, which contains lights and sounds, is exciting, which translates into buying loot boxes, which also seems exciting and appealing. The randomness of the contents of the virtual loot boxes, the possibility of winning game-changing items, and the experience of the psychological thrill of anticipation and winning all tap into the same psychological characteristics and financial risks of traditional gambling, contributing to excessive gaming behaviour and psychological overinvestment in video games. Therefore, the similarities between loot boxes and traditional forms of gambling create severe and long-lasting psychological and financial risks, especially among minors, who are more susceptible to such risks (Derrington et al., 2021).

Virtual reward crates take different forms - some we can buy with real money (and these raise the most objections), and some the player can obtain using in-game currency. An additional division is a possibility of selling content - some models allow the exchange of acquired content for in-game currency and even sale for real money, while others do not provide such options. It is challenging to identify which ones pose the greatest threat to players (Zendle et al., 2020). We can therefore differentiate them according to the following characteristics (Zendle et al., 2020):

- paid or free crate openings: some games allow only or almost only crates purchased with real money (e.g. *Counter-Strike: Global Offensive*), while others, in addition, also offer crates for game progress (e.g. *FIFA* or *Overwatch*);
- the possibility of monetizing game content: in some productions, it is allowed to sell content acquired by the player for real money (for example, on a particular exchange), whereas in others, it is not by the rules of the game and the creators do not provide such a solution - in the face of these restrictions, players often sell accounts or use unofficial marketplaces called grey market;
- Pay2Win model: we can distinguish loot boxes into those whose purchase provides or can provide an advantage over other players, for example, by enabling faster gameplay progress (e.g., the card game *Hearthstone*), while in others, they perform cosmetic or even decorative functions - such as unique skins for characters or games, backgrounds, visual effects (e.g., the previously mentioned *Counter-Strike: Global Offensive*);
- use of in-game currency: Another feature is the currency the player uses to make loot box payments. We distinguish between mechanisms in which the purchase is made directly using the actual currency and those in which the purchase is made through payment in in-game currency - but this is often an indirect purchase with real money, as the player buys the in-game currency and then the loot box with it. The currency, in many cases, can be acquired by the player as the game progresses;
- crate and fundamental mechanics: an emerging solution is also a mechanic in which the player can acquire content crates as the game progresses, while they can be opened with a key. The key is often challenging to obtain or purchasable with real money or in-game currency;
- presentation of possible rewards before opening the loot box: some crates present the contents in the front of the player only after opening. However, there are also mechanisms in which the player can preview potential content before opening the loot box - for example, a range of rare items that the player can draw (though not necessarily) upon opening - this can be a form of roulette, for example, in which the player can see near-winners - items close to the one drawn - giving the player hope that the next prize might be more valuable since it was so close;
- exclusive content: most loot boxes owe their appeal to exclusive items that cannot be obtained elsewhere in the game. However, this is not a standard in all games but a common practice.

Loot boxes contribute to the development of the concept of games as services. As the name implies, a game product is a commodity with a specific set of features the player pays for and can use in a specific way. Game as a service (GaaS) is a term that refers to a type of game distribution oriented to maximize monetization over time. The goal is not to sell the product once but to provide ongoing support from the developer long after the game's release so that the player makes additional purchases - through micropayments, paid add-ons and even subscriptions - and so that the player base is steady or growing and keeps the community alive, generating substantial revenue (GRYOnline.pl, 2020). The trend is so strong that it no longer applies to free-to-play games but also to high-budget AAA productions and regular buy-to-play games.

## 5. Micropayments in the FIFA series

The *FIFA* game series has been the most famous soccer simulator for years and is one of the most popular sports series in gaming history. It is counted among Electronic Arts' extensive portfolio as a game by their EA Sports brand. However, it was announced that the International Federation of Football (FIFA) would not sign the game starting with the next release due to the failure to grant a further license. The developers did, however, announce a continuation of the series under a new name – *EA Sports FC* (GRYOnline.pl, n.d.).

The FIFA Ultimate Team mode is a vital element of the series, attracting players for years, which first appeared in the *FIFA '09* edition. It allows players to create the football team of their dreams, which can be "managed" correctly for their purpose. This situation can be achieving league promotions in online play, recreational play against AI-controlled opponents, participating in Championships with players worldwide, completing challenges, trading players and opening packs with players and other feature cards (Siuda, 2021). An example of a squad in *FIFA Ultimate Team* is shown in Figure 1.


**Figure 1.** An example of a squad in FIFA Ultimate Team.

Source: (EA SPORTSTM FIFA 23, 2023).

There are several ways to acquire players (and content for upgrading them, coaches, stadium elements and the like), which have varying values - bronze, silver and gold cards and unique cards. Footballers, because they are the key value here, can be acquired by the player as follows:

- by performing appropriate tasks in *Ultimate Team* mode,
- by achieving corresponding results in online competition against other players or AI (*Squad Battles*, *Division Rivals*, *FUT Championships*),
- through the transactions on the internal transfer market,
- by buying content packs with *FIFA Coins* or the particular currency *FIFA Points*.

The developers list several methods of acquiring coins (used to operate in the transfer market and buy the aforementioned "packets") and *FIFA Points*. Coins can be obtained by:

- playing matches in *Ultimate Team*,
- earning rewards in online competition modes against other players or AI,
- selling cards on the transfer market.

The *FIFA Points* particular currency can be purchased with real money in the in-game store, the store dedicated to the platform the player is using (PC, consoles), in stationery stores as top-up cards and in other trusted stores (Electronic Arts Inc., 2023).

The most popular option for acquiring footballers in the game is to open packs - they are available as prizes for *FIFA Coins* and *FIFA Points*. However, to get them without additional financial outlay, the player must perform a relatively large number of activities in the game and, above all - regularly. Therefore, a commonly used alternative is buying packs with real money. Micropayments in *Ultimate Team* bring considerable profits to EA, as evidenced by annual financial reports (Armughanuddin, 2019).

An analysis was made of the micropayments present in the FIFA game, highlighting the characteristics discussed in Chapter 4, as shown in Table 1.

**Table 1.**
*Characteristics of microtransactions in the FIFA game*

| | |
|---|---|
| paid and free box openings | There are two types of openings in the game - both for real money and for currency acquired in the game. |
| the possibility of monetizing the game content | The developers do not allow a legal form of monetization of content; only sometimes is there the possibility of exchange for in-game currency. |
| Pay2Win | This controversial matter cannot be stated outright because a higher number of paid packets opened does not guarantee an improvement in a player's performance or even obtaining top players. However, it statistically increases the likelihood of obtaining valuable rewards, such as coveted unique cards. |
| use of in-game currency | Both funds earned within the game (FIFA Coins) and those purchased with real money (FIFA Points) are used. |
| crate and key mechanics | The mechanics do not apply to the FIFA series. |
| showing possible rewards before opening the loot box | There is the case with packages purchased with FIFA Points. The player can sometimes preview the entire package contents and, in other cases - the probability of obtaining rewards of a given rarity and value. |
| exclusive content | An element of randomness characterizes packs, although in theory, prizes can also be won without additional financial outlay - packets containing exclusive items are unlikely to occur. The exception is promotional content, which can be purchased with FIFA Points or coins, although then the exact content of the package is known. |

Source: own study based on: (Zendle et al., 2020).

The very high revenue is encouraging the developers to continue this practice. As the sources point out, despite the emerging criticism, FIFA Ultimate Team profits are increasing significantly yearly. Figure 2 illustrates the net profit generated by selling additional content in *FIFA Ultimate Team* from 2018 to 2021.

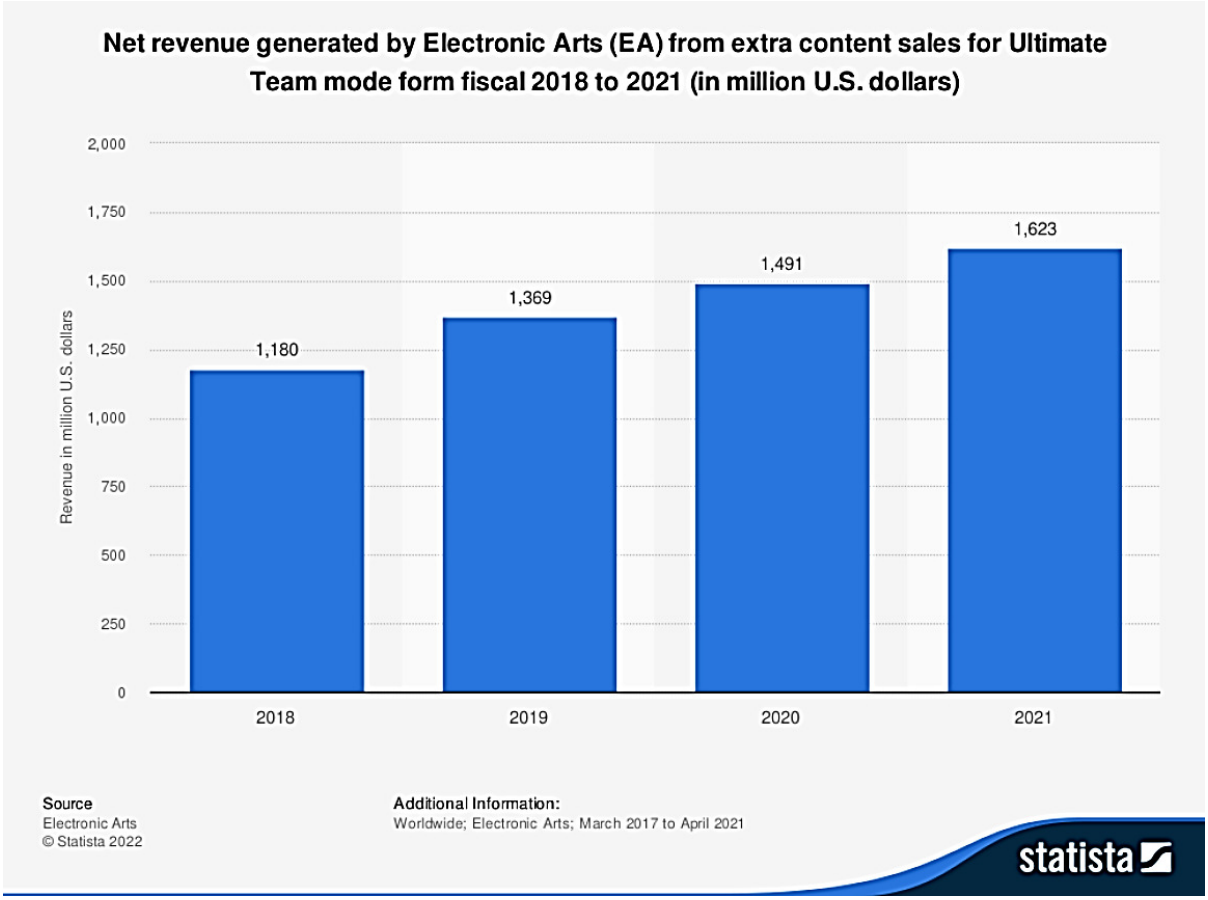


**Figure 2.** The net profit generated by the sales of additional content in FIFA Ultimate Team from 2018 to 2021.

Source: Clement, 2022.

The *FIFA* game is dedicated to players as young as 3 years old, which may raise some doubts - the prices of single packs of *FIFA Points* within the 2022 game reach up to PLN 439.00. In addition, when opening the packs, the player may notice a resemblance to a gambling game - including randomness, stimulating visual and sound effects and the likelihood of winning unique content. The whole thing becomes beautiful not only for adults but also for underage players. In *FUT*, the player realistically has only a tiny chance to get valuable content, and the whole mechanism is confusingly similar to casino games. The controversial issue remains that the players are dominated by underage users, who are much more susceptible to the adverse effects of online gambling (Lemmens, 2022). Developers, however, do not apply any significant restrictions to protect the youngest, which is widely criticized. Figure 3 shows the available *FIFA Points* packages in *FIFA 23*, including promotions for subscribers to EA Play, a paid service that allows favourable access to EA's game catalogue.

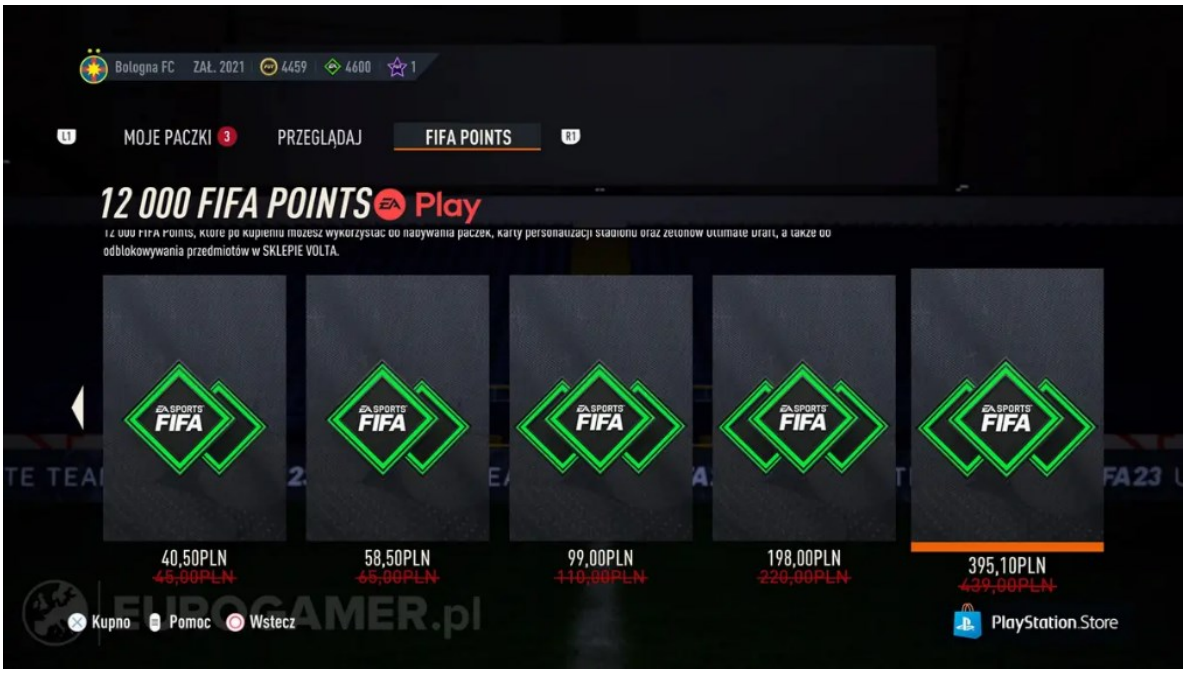


**Figure 3.** Paid card packs in FIFA 23.
Source: Wańtuchowicz, 2022.

## 6. Controversy and regulation around loot boxes

Loot boxes have been causing controversy over their mechanics for years. According to psychologist Claire Murdoch, who works for the NHS in England, loot boxes damage children's psyches and addict them to gambling. In her opinion, the sale of games that allow the purchase of random loot should end as soon as possible, reducing children's exposure to the love of gambling in adulthood (Nic, 2020). In turn, according to the authors of the 2022 report, loot boxes cause financial and emotional harm to younger players. This harm consists of using credit cards without parental knowledge to acquire socially valuable items; remorse over subsequent spending; and frustration over the lack of a dream item in a loot box (Ash et al., 2022). The same authors have made several recommendations in this regard. First, the gaming industry should have independent regulations. Second, paid reward systems in digital games should be regulated. Third, in-game accounts, parental controls and purchase systems should be standardized. Finally, tools should be implemented to make it easier for players to track and manage their spending across video games and platforms (Ash et al., 2022).

Further recommendations have been made regarding reducing the risk of switching from playing video games to gambling (Wieczorek & Dąbrowska, 2021). In their report, these authors first point to the need for a prevention strategy that raises awareness and informs and educates about gambling and gambling disorders and the links to playing video games. Second, game operators should place greater emphasis on social accountability for marketing strategies

that result in increased game sales. Third, stricter age verification measures should be introduced. Finally, parents must also take responsibility for allowing their children to play social games and supervise all apps installed on children's phones (Wieczorek, Dąbrowska, 2021).

In 2018, the Belgian Gaming Commission (Commission des Jeux de Hasard) stated unambiguously that loot boxes were gambling and banned their use. Despite the objections of major game developers, the ability to purchase real-money loot boxes from Belgian versions of games by some of the most prominent players in the market was eventually removed (Olejnik, 2019). On the other hand, Australian lawmakers plan to introduce a law restricting access to games with loot boxes. At issue is a situation that, under the relevant law, would require developers of video games with loot boxes to label them as available only to adults. The proposed law stipulates that games containing loot boxes will be labelled as R18+ and thus easily identifiable by parents or guardians. On the other hand, if the publisher does not agree to label a game appropriately, it cannot be sold in stores (Pławecki, 2022).

Also, console manufacturers: Sony, Microsoft and Nintendo are working on their regulations to control game spending more. These regulations would mainly inform players about the chances and probability of hitting a valuable item in chests (Portal Bukmacherski Spryciarz, 2022).

A critical classification cataloguing games in terms of their content and level of adaptation to the age of players is PEGI (Pan European Game Information). The PEGI system, which is valid in Europe and Poland, consists of two levels of information (Dębski, Bigaj, 2020; PEGI, n.d.):

1. **Age designations** - five categories (+3, +7, +12, +16, +18) that suggest the minimum age of the audience to which a digital game is suited. The lower the category, the less likely the game contains elements that may cause fear in young viewers. Then, expose them to the sight of violence or vulgar language; encourage gambling behaviour; expose them to sexual content and nudity; show situations of drug use, alcohol consumption or smoking; expose them to scenes containing stereotypes of an ethnic, religious, nationalistic or other nature that may constitute a type of content inciting hatred.
2. **Content descriptors_**- eight symbols indicating potentially undesirable elements, such as foul language, discrimination, drugs, fear, gambling, sex, violence, and in-game purchases, which a product may contain.

Every game officially released in Poland contains PEGI designations, which, in the physical version, can be found, among other things, on the box, so you can get acquainted with them before making a purchase. It is worth paying attention to the digit indicating the permissible age and additional descriptors (Dębski, Bigaj, 2020). Unfortunately, all games are not assigned descriptive categories (Grajewski, 2023).

## 7. Limitations

This article has several limitations. First, the literature review was based only on three selected scientific databases, Google Scholar, ResearchGate and ScienceDirect, which may have limited the number and value of search results for relevant items. Second, the literature search used specific keyword combinations with Boolean operators, which may have resulted in the omission of other scientific items in a given database. Selected industry reports and electronic sources were used for the subject matter covered to supplement the analysis.

Despite the identified limitations of the study, this article may form the basis for a more extensive study in the future, which could include other entities/facilities that use micropayments. In addition, this paper may be the beginning of a series of articles on the issue of micropayments in gaming, emphasizing the regulatory issues surrounding loot boxes.

## 8. Conclusions and recommendations

The main objective of the article was to identify the risks associated with the mechanisms used by game developers to define the micropayment system using the example of EA Sports' practices in the FIFA series of games, as well as the specific objectives that have been achieved.

Through a literature review on the subject, the authors' findings indicate that loot boxes are still popular - especially among children and teenagers despite the controversy surrounding them. Despite their randomness, or perhaps mainly because of it, the loot box environment seems extremely exciting to players, translating into the act of buying them. The article also points out the similarity of loot boxes to traditional gambling, posing severe and long-lasting psychological and financial risks - especially among minors.

An alarming practice is that a soccer simulator such as the FIFA series promoted as a game suitable for children and young people, bases its financial success on high-risk microtransactions (the rewards are often inadequate to the funds invested), which bear the apparent hallmarks of gambling. The revenue from in-game purchases has increased yearly, exceeding the profits from selling a full-priced product such as a boxed or electronic game.

Several practical implications have been developed based on the analyzed content of academic and industry items. First, regulations based on the PEGI classification provide an opportunity to avoid or move away from the phenomenon of micropayments. Second, it is possible, and indeed desirable, to introduce secure financial instruments to assist players in managing their spending in games. This situation could solve the problem of uncontrolled and sudden purchasing actions using parents'/guardians' payment cards. Third, it would be necessary to regularly make parents/guardians of minors aware, through dedicated training

courses, seminars, and conferences, of the factors that most determine their vulnerability to e-gambling. Demographic (gender, age, education, income, wealth), behavioural (frequency of Internet use), as well as psychographic (personality, interests, cognitive processes, mental states) and religious/spiritual factors, should be mentioned here. Finally, it would be appropriate to look at the problem of micropayments in a broader context, not only pejoratively, but also as a sign of the times, a trend in developing the concept of games as services, to which loot boxes are a significant contributor.

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# KEY INDICATORS AS A SOURCE OF ANALYSIS OF THE LEVEL OF PROGRESS OF SUSTAINABLE DEVELOPMENT

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**Purpose:** The purpose of the study was to analyze the importance of the issue and the level of sustainable development in the context of the functioning of Poland and Slovakia against the background of the European Union, based on a system of indicators, and to analyze the level of implementation of selected sustainable development goals by these countries.
**Design/methodology/approach**: The research process was based on the diagnostic survey method. The techniques used for data collection were content analysis and desk research. The study covered the years 2000-2021.
**Findings:** Both in theory and in practice, a problem has been recognized, namely that the surveillance methods developed are fraught with various disadvantages (e.g., standardization or uniformity of data for all EU countries). Within the framework of each of the examined indicators (from the area of SDG7, SDG8, SDG9), Poland showed a rise in the ranking of EU member states between 2000 and 2021. Slovakia, on the other hand, only in relation to the indicator of ross domestic expenditure on R&D by sector (SDG9) showed a decline in placement.
**Research limitations/implications**: A limitation of the study's implementation is the potential constraints on the availability of the data needed to calculate indicators to monitor the degree to which the Sustainable Development Goals are being met.
**Practical implications:** The results of the research will positively influence the planning of further activities by both the analyzed countries, Poland and Slovakia. The results of the research provide constructive information that may prove useful for the development of future strategic plans related to the implementation of the goals of the concept of sustainable development.
**Originality/value:** The study fills a research gap in the field of comparative analysis of selected spectra of Poland and Slovakia against the background of the European Union in the context of the implementation of sustainable development goals (Development Agenda 2030).

**Keywords:** sustainability, sustainability management, key indicators, monitoring indicators.

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

## 1. Introduction

The processes of globalization, industrialization and dynamic economic development have contributed significantly to the destruction of the environment. Progressive climate change, which is the result of greenhouse gas emissions in the perspective of years, will have an adverse impact on the development of countries and the functioning of society (Hajduk-Stelmachowicz, 2014; Pacana, Czerwinska, 2017). The answer to such circumstances is the implementation of the premises of the concept of sustainable development in the area of macro and microeconomic functioning. The essence of the idea of sustainable development concerns the sustainable reduction of economic and social disparities and the protection of the environment (Kusljic, 2022; Vig, 2022). Enterprises wishing to maintain a stable position in the EU market must take care of the appropriate level of competitiveness. One of the fundamental conditions for mature competition has become the formulation and implementation of developmental strategies that take into account pro-environmental activities. This is important because the development of manufacturing companies is largely conditioned by the performance of activities that do not relate to caring for the environment (Fljtikova et al., 2023; Dagbanja, 2022). In highly developed countries, manufacturing companies do not identify legal restrictions (or other tools) to protect the environment as a form of state restructuring against manufacturing industries, but rather as a zone of competitiveness (Benavides-Sanchez et al., 2022; Grebski et al., 2022; Trąpczyński et al., 2019).

The purpose of the study was to analyze the importance of the issue and the level of sustainable development in the context of the functioning of Poland and Slovakia against the background of the European Union, based on a system of indicators. An additional objective is to analyze the level of implementation of selected sustainable development goals from the 17 Sustainable Development Goals (SDGs) adopted in New York at the 2015 Sustainable Development Summit by Poland and Slovakia. The study covered the years 2000-2021, and the research process was based on a diagnostic survey method. The techniques used for data collection were content analysis and desk research.

## 2. Issues and stages of sustainable development emergence

There are many definitions of sustainable development in the literature, as the issue is inherently multidimensional. Basically, sustainable development refers to development in which a state of balance is achieved between three main dimensions, that is, economic, social and environmental (Shilla et al., 2020; Lazar et al., 2021). On the economic dimension, balance means striving for steady economic development. Balance on the social dimension indicates

the protection of public health and social integration. And with regard to the environmental dimension, it means an emphasis on striving to care for and protect natural resources and the environment in such a way as to enable future generations to meet their needs (Staniszewska et al., 2020; Hajduk-Stelmachowicz, 2017).

Sustainable development is the subject of a considerable amount of both theoretical and practical analysis. The complexity of the concept contributes to the fact that there is no single, leading and universally accepted definition. There is also a lack of consensus on the issue of measuring the determinants of sustainable development and measuring the level of implementation of the idea. The progressive development of the idea of sustainable development has been closely linked to the need to effectively address climate change (Anstorga, Valdes, 2021; Ulewicz, Blaskova, 2018). The stages of the emergence of the concept of sustainable development are shown in Figure 1. Milestones (shaded boxes - Figure 1) in the implementation of the concept are considered to be: 1992 Earth Summit, Millennium Declaration, 2002 Johannesburg Summit and 2012 Rio de Janeiro Summit, 2030 Development Agenda (Transforming Our World) (Fonseca et al., 2020).

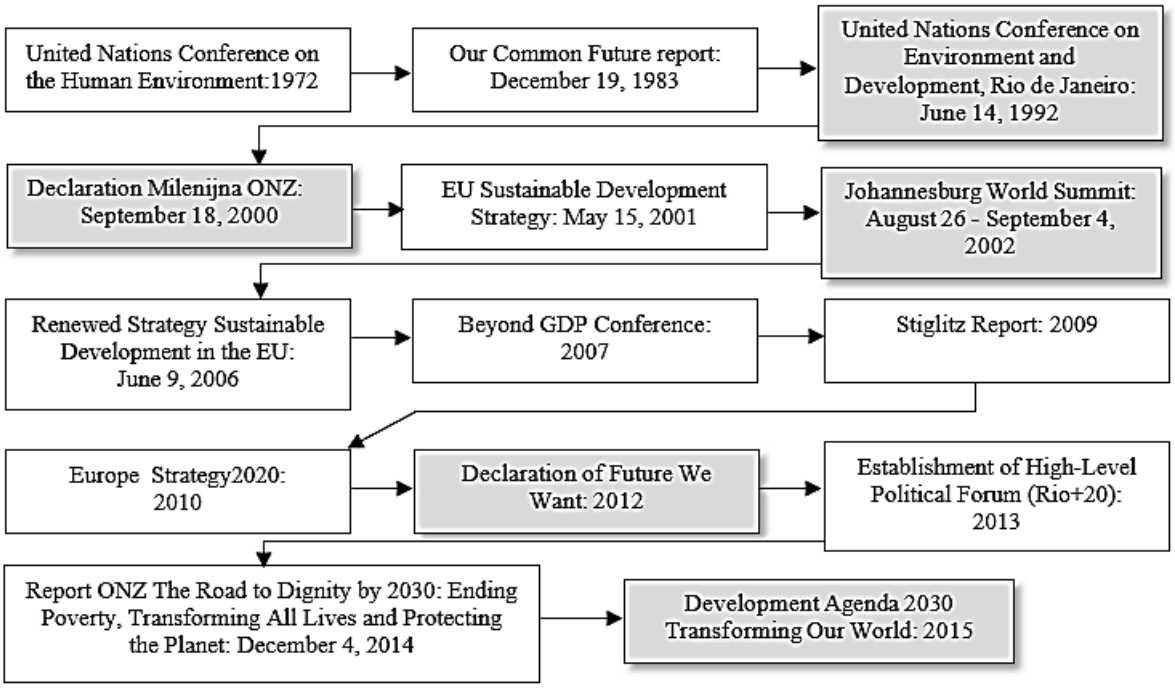


**Figure 1.** The stages of formation of the concept of sustainable development are presented.

Source: own compilation based on: Misztal, A., (2019). Zrównoważony rozwój przedsiębiorstw a Stopień Rozwoju społeczno-Gospodarczego. Studia i Prace Kolegium Zarządzania i Finansów, nr 174, s. 33-45. https://doi.org/10.33119/SIP.2019.174.2.

Implementing such a multifaceted concept and monitoring the level of its implementation requires a clear definition of the method of measurement and indication of measures. The implementation of the goals and targets is monitored worldwide by appropriate indicators (Bassen et al., 2023; United Nations Statistics Division, https://unstats.un.org/…, 19.04.2023).

## 3. Sustainable development indicators

Sustainability indicators are a fundamental tool for monitoring the progress of the concept's implications. They enable the development of a statistical picture of the country from the perspective of implementing a new development paradigm (Bassen et al. 2023). However, there is no universally accepted definition of the term "indicator". Usually, the terms "indicator" and "gauge" are terms that appear interchangeably in the literature. However, it should be noted that the feature of the indicator is the comparability of its results, which allows for indicating the position of a given variable/object in relation to other variables/objects (Czerwińska, 2020). In this approach, the indicator is a function of one or more features (for example, odor emission per km2 - the indicator is a function of feature 1: odor emission and feature 2: area) (Czerwińska et al., 2020a).

The beginning of the creation of a set of sustainable development indicators concerns the concretization of this idea of enterprise development. Indicators are developed in order to supervise the implementation of planning documents (for example: policies, programs, strategies) created successively at the local, regional, national and European Union levels (Sakharov, Andronova, 2022). Determining the progress of the implementation of the assumptions of the development concept is possible thanks to the concretization of the sustainable development paradigm by identifying: development principles (basic selection of indicators), goals (positive target states) and orders (economic, social, environmental, institutional and political) (Peng, Zhang, 2022).

The principles of sustainable development are the main verifier of the implementation of the declaration of the development idea contained in the documentation (policy objectives, strategies, programmes). The basic principle is the principle of intergenerational justice – "All future generations have the right to live and enjoy all the environmental values they know, just as you do, or even better" (Dyatlov, Selishcheva, 2020; Trusina, Jermolajeva, 2021). With regard to the selection of indicators, particular importance can be attributed to the sets of rules that have been defined at the various stages of the implementation of the concept of sustainable development (Figure 1) (Balas, Molenda, 2016).

Further levels of specifying the idea of sustainable development, which can be measured with the use of indicators, are in the form of patterns. This applies to governance and development goals. The relationships and connections between the fundamental categories for measuring the implementation of sustainable development are presented in Figure 2.

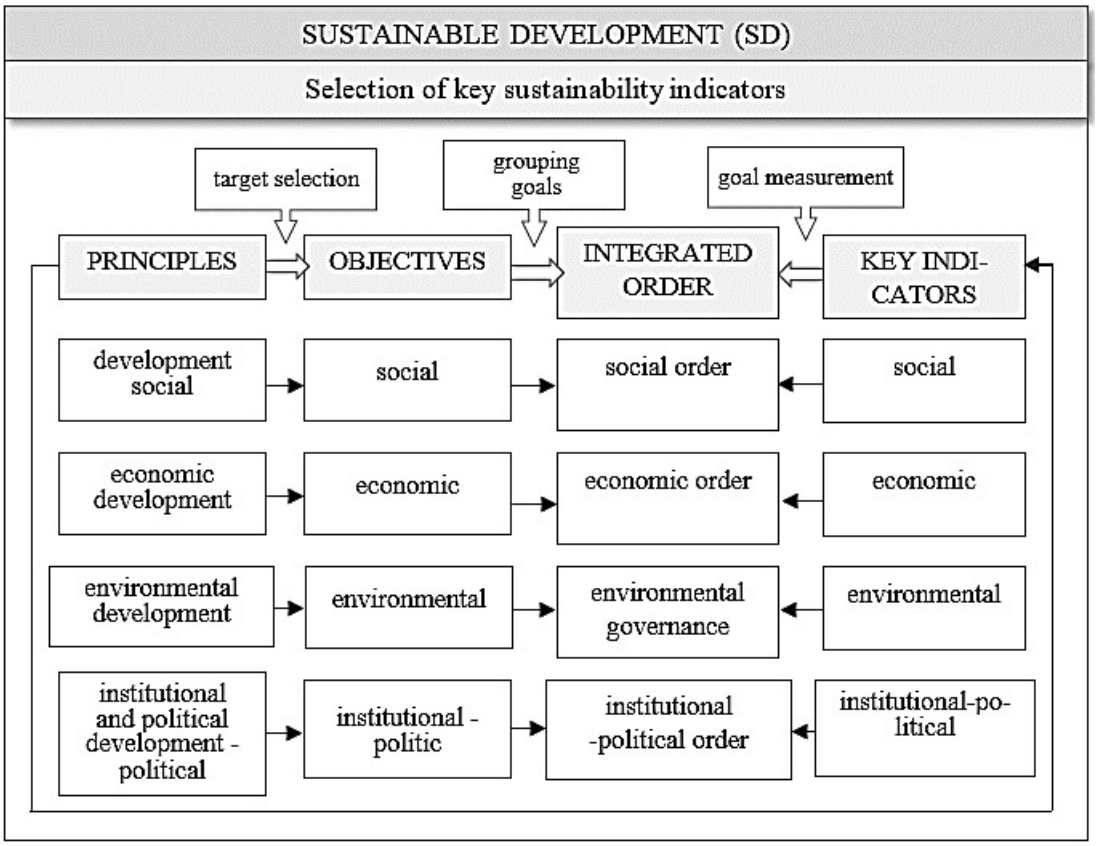


**Figure 2.** The idea of creating and selecting national sustainable development indicators in the context of ensuring integrated governance.

Source: own compilation based on: Wskaźniki Zrównoważonego Rozwoju Polski, 2011, s.16.

It should be noted that in the understanding of sustainable development as an interdisciplinary category, the role of the link that simplifies the interpretation and understanding of this idea is played by integrated governance (Figure 2). It forces one to respect the interdisciplinary approach, since without such a grasp of the concept it is difficult to understand the main meaning of the idea of development. Integrated order is defined as a positive target state of developmental change (like a goal) that integrates the component orders in a non-contradictory and coherent way (Pondel, 2021). The literature on the subject indicates that sustainable governance is a benchmarking way of presenting a development pattern, i.e. a target arrangement of sustainable development (Gunnarsdottir et al., 2021). The constructive basis for the formation of integrated order is determined by a system of strategic goals with social, economic, environmental and institutional-political specificity. The achievement of the indicated goals understood as positive, target states in a clearly specified time perspective is monitored by indicators of sustainable development. Therefore, when selecting these indicators, governance should be integrated through the use of composite indicators for more than one governance (Balas, Molenda, 2016).

## 4. Research methodology

Implementation of the research to achieve the stated goal of the study required structured undertakings. Figure 3 shows the stages in the implementation of the study.

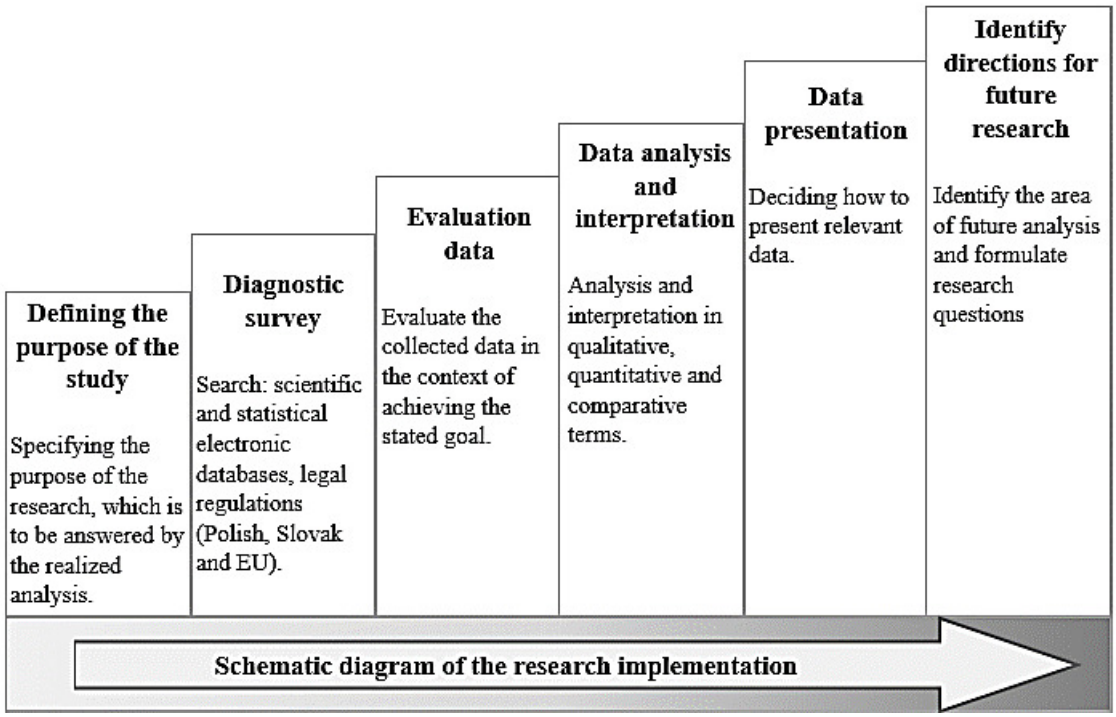


**Figure 3.** Idea diagram of the implementation of the study.

Source: own study.

The stages of research implementation consist of six stages: defining the purpose of the research, collecting data, evaluating data, analyzing and interpreting data, presenting data, and determining directions for future research (Figure 3). A synthetic description of each stage is as follows:

- defining the purpose of the research - the purpose of the research was not only to learn about reality, but also to assess it and, against this background, to draw general conclusions relevant not only for the studied collective (Poland, Slovakia and the European Union), but also for other countries in similar conditions;
- diagnostic survey - the creation of a comprehensive, representative and at the same time key set of data to be analyzed during the implementation of further stages. The data collection process was based on content analysis and desk research against electronic statistical and scientific databases and legislation relevant to the purpose of the study;
- data evaluation - involves evaluating the collected data in the context of specific needs and criteria related to the purpose of the study;
- data analysis and interpretation - making sense of the collected data;

- presentation of data - the stage is concerned with deciding how to organize the data and extract those data that will be included in the study;
- defining directions for future research - defines the area for further scientific inquiry, based on primary research.

The developed model for analyzing the degree of fulfillment of the goals of sustainable development of Poland and Slovakia against the background of the European Union allows the implementation of effective diagnostic studies.

## 5. Analysis of the degree of implementation of the concept of sustainable development of Poland and Slovakia

The 2030 Agenda for Sustainable Development sets out 17 Sustainable Development Goals (SDGs) and associated 169 tasks (targets) to be achieved by the world by 2030. They address achievements in 5 areas - the so-called 5xP: people, planet, prosperity, peace, partnership. The goals cover a wide range of challenges, such as poverty, hunger, health, education, gender equality, climate change, sustainable development, peace, social justice (Sustainable Development Goals, http://www.un.org.pl/, 19.04.2023). They replaced the Millennium Development Goals, which were to be achieved by 2015.

Due to the comprehensiveness of the issue and volume limitations, the study analyzed selected indicators of sustainable development that testify to the level of implementation of the development concept in Poland and Slovakia.

The analysis included selected indicators from the Sustainable Development Group 7 (SDG7), which SDG 7 implies providing general access to modern energy services, improving energy efficiency, as well as increasing the share of renewable energy. Because the European Green Deal recognizes energy efficiency as a key means of reducing cross-sectoral greenhouse gas emissions, the first indicator examined is the primary energy consumption rate. The indicator measures the level of a country's total energy demand excluding non-energy use of energy carriers. The values of the primary energy consumption indicator obtained by the analyzed countries against the EU are shown in Figure 4.

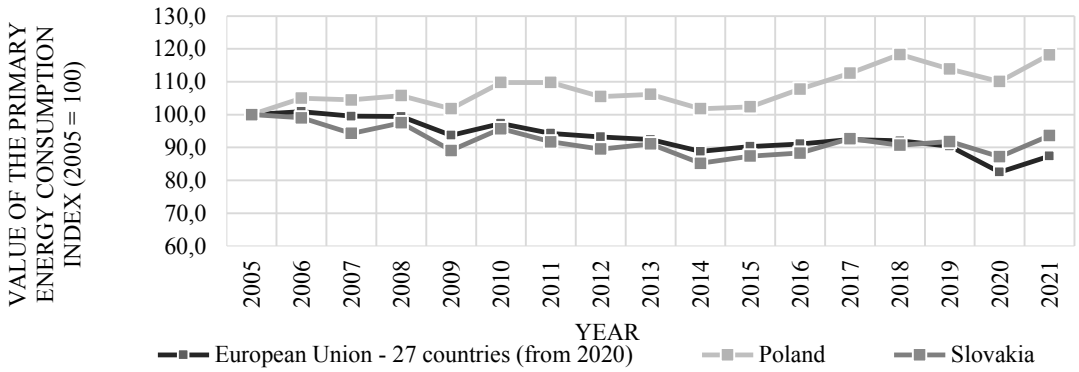


**Figure 4.** Dynamics of the primary energy consumption index for Poland and Slovakia against the EU. Source: own compilation based on: https://ec.europa.eu/eurostat access: 19.04.2023.

As agreed, the EU aimed to improve energy efficiency by 20% by 2020, in line with the Europe 2020 strategy, and by at least 32.5% by 2030, as regulated by the revised Energy Efficiency Levels Directive. From 2005 to 2020, the EU has reduced primary energy consumption by 17.5%, thus falling short of its target. Slovakia, on the other hand, has reduced consumption by 12.8% since that time frame. Poland is a country that has failed to reduce the value of primary energy consumption. In this country, consumption has increased by 10%, a negative result indicating the need for radical action. In order to transition to an affordable, reliable and sustainable energy system, Poland should improve access to clean energy research and focus its efforts on promoting investments in energy infrastructure and clean energy technologies. In relation to other EU countries, Poland ranked 22 in 2021, while Slovakia ranked 10.

Another indicator to be analyzed, energy productivity, is also included in SDG7. The indicator determines the amount of economic output produced per unit of gross available energy. Gross available energy is understood as the amount of energy products that are necessary to meet the demand of all entities within the analyzed geographic area. The value of economic production is presented in units of euros, which are chained to volumes up to the reference year (which was considered 2010) at exchange rates in effect from 2010, or it is expressed in units of PPS (purchasing power standard). The first way of expressing the value of the indicator is used to observe the change over time relative to a specific area. The second way of presenting the value, on the other hand, allows comparisons to be made between member states in a given year. The values of the energy productivity index by the analyzed countries against the EU are shown in Figure 5.

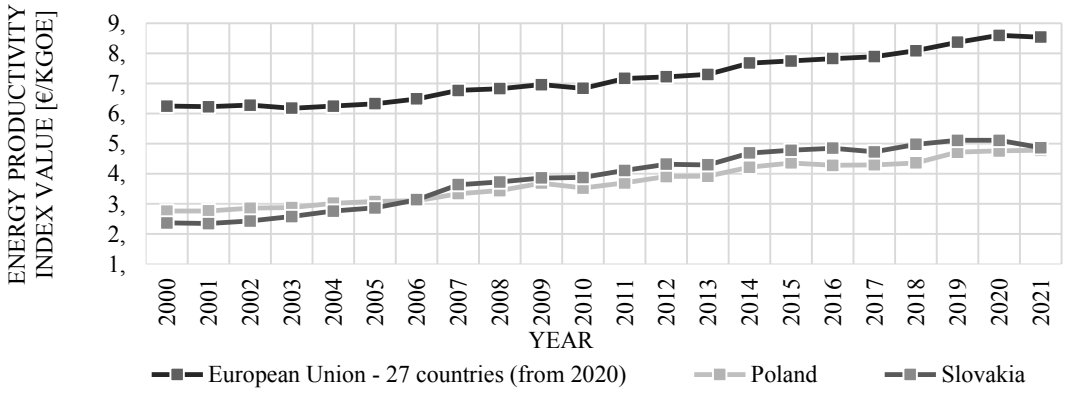


**Figure 5.** Dynamics of energy productivity for Poland and Slovakia against the EU.
Source: own compilation based on https://ec.europa.eu/eurostat access: 19.04.2023.

Based on the results of the study illustrated with Figure 4, one can see an upward trend in the value of the energy productivity index in Poland, Slovakia and the EU. The increase in the value of the indicator for Poland in the considered period was 73.2% (from the value of 2.76 €/kgoe in 2000 to 4.78 €/kgoe in 2021), while in Slovakia an increase in the value of the indicator of 105.4% was observed (from the value of 2.37 €/kgoe to 4.87 €/kgoe in the studied period). From 2006 to the end of the analyzed period, the values of the energy productivity indicator for Slovakia exceeded the values of the indicator achieved by Poland. In 2021, the difference in the level of energy productivity was less than 2%. In relation to other EU countries, Poland rose from 27th position (2000) to 25th (2021), while Slovakia rose from 29th position (2000) to 23rd (2021). The results show that the countries surveyed are steadily achieving the goals of providing affordable and clean energy and ensuring and promoting sustainable consumption and production patterns. The Erupean Union showed the smallest value of the growth rate of the energy productivity index - the value for the period under review was 36.6%.

The real GDP per capita indicator was also selected for analysis. This indicator is used to monitor progress in achieving Sustainable Development Goal Number 8 - SDG8 - Decent Work and Economic Growth. The goal is embedded in the European Commission's Priorities of the European Green Deal. SDG 8 promotes the importance of continuous economic growth and associated high levels of economic productivity. SDG8 also recognizes the creation of well-paid jobs of high quality and the achievement of global prosperity. The indicator values obtained by the analyzed countries against the EU are shown in Figure 6.

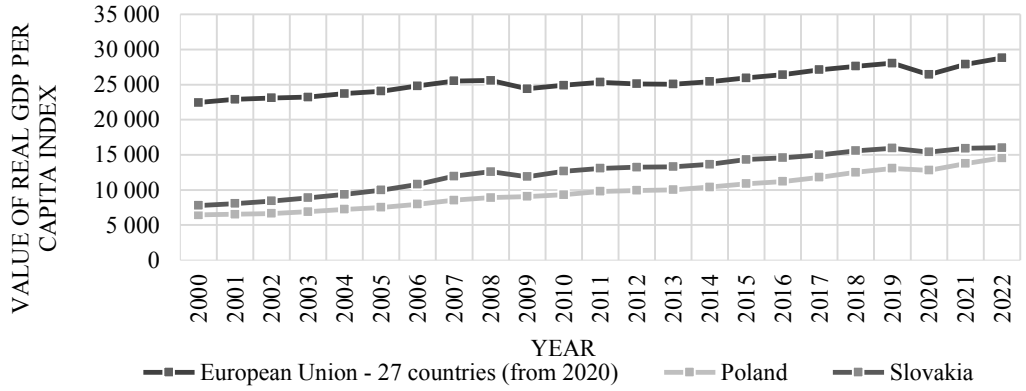


**Figure 6.** Dynamics of real GDP per capita for Poland and Slovakia against the EU.

Source: own compilation based on https://ec.europa.eu/eurostat access: 19.04.2023.

During the period 2000-2022, positive trends can be observed related to the growth of the real GDP per capita index in Poland, Slovakia and the EU. During the period under review, the values of the index in Poland increased by 125.7% (from 6,450 to 14,560 euros), in Slovakia by 105.8% (from 7,780 to 16,010 euros). In contrast, the EU-27 achieved an increase of 28.4% (from 22,450 to 28,810 euros). Despite the fact that in every year under review the value of the analyzed indicator in Slovakia was higher than in Poland, Poland is characterized by a significantly higher growth rate of real GDP per capita. In relation to other EU countries, Poland rose from 27th position (2000) to 25th position (2021), while Slovakia rose from 25th position (2000) to 23rd position (2021).

Within the framework of SDG9 - Innovation and Industrial Infrastructure, a balanced indicator of Gross domestic expenditure on R&D by sector was analyzed. SDG 9 encourages the creation of resilient yet sustainable infrastructure and urges inclusive and sustainable industrialization. It also emphasizes the importance of research and innovation to identify sustainable solutions to challenges at three key levels: social, economic and environmental. The indicator is used to keep a constant check on the implementation of progress in creating resilient infrastructure, promoting inclusive and sustainable industrialization and fostering innovation. The cited rationale is related to the European Commission's priorities under "An economy that serves people" AND "Europe for the digital age." The level of fulfillment of the sustainable development premise in relation to the indicator of gross domestic expenditure on R&D by sector is illustrated in Figure 7.

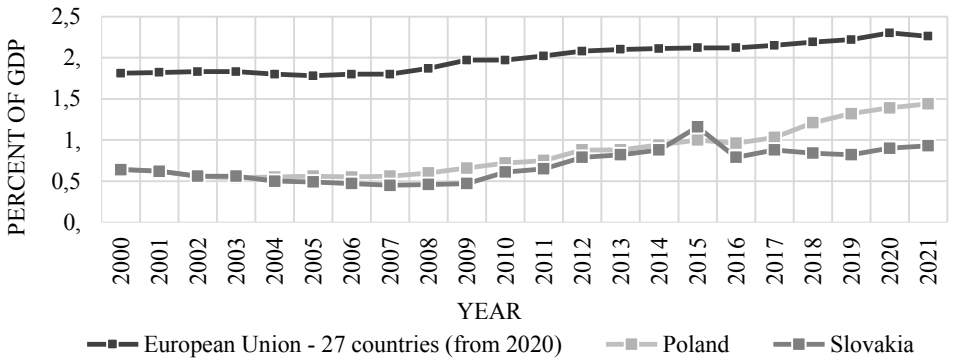


**Figure 7.** Dynamics of gross domestic expenditures on R&D by sector for Poland and Slovakia in comparison with the EU.

Source: own compilation based on https://ec.europa.eu/eurostat access: 19.04.2023.

The European Union has long set a goal of increasing R&D intensity to 3% of GDP. This goal was reaffirmed in the November 2021 Council Recommendation on the Pact for Research and Innovation in Europe. The value of the index of gross domestic expenditure on R&D by sector in 2021 was 2.26%, indicating an increase in the level of investment by 24.9% with respect to 2000. Since 2016, Poland has shown considerable dynamism - the increase in the value of the index reached 50% and in 2021 it was 1.44%. With respect to Slovakia, the highest value of the indicator was observed in 2015 - 1.16%. In 2016 there was a significant decrease (0.79%) and from 2019 an upward trend is visible. In relation to other EU countries, Poland from the 18th position (2000) reached the 17th position (2021), while Slovakia from the 19th position (2000) reached the 25th position (2021).

As presented through the study of selected indicators of sustainable development, the analysis of the situation of Poland and Slovakia in the context of meeting the assumptions of sustainable development is a complex process. The analyzed countries differ in the level of economic development, which has a direct impact on the bluntness of implemented improving and often radical changes in the social, environmental and economic areas. The Joint Europe 2020 Strategy and the 2030 Agenda for Sustainable Development set ambitious goals. However, it should be remembered that the significantly different economic levels of the countries of the community affect the different bluntness of countries' readiness for change.

## 6. Summary and conclusions

The issue of sustainable development is one of the overarching goals of the European Union. The progress of member countries in achieving the Sustainable Development Goals is constantly monitored using a set of indicators. The number of dimensions that are evaluated (economic, social and environmental dimensions) and the level of detail of the analyses carried out contribute to the fact that more than a hundred synthetic indicators are used for monitoring.

The purpose of the study was to analyze the importance of the issue and the level of sustainable development in the context of the functioning of Poland and Slovakia against the background of the European Union, based on the system of indicators. An additional objective is to analyze the level of implementation of selected sustainable development goals from the 17 Sustainable Development Goals (SDGs) adopted in New York at the 2015 Sustainable Development Summit by Poland and Slovakia.

As a result of the analysis of available scientific studies and data, it was found that both in theory and in practice a problem was recognized, namely that the developed surveillance methods are burdened with various inconveniences. An example of an inconvenience could be the standardization or unification of data for all Eiropean Union countries. These methods are also burdened with subjectivity and a certain generalization. However, the need for monitoring and systematic implementation of in-depth analysis of data and information on the progress of sustainable development implementation in member countries is undeniable.

The paper outlines the essence of sustainable development indicators and presents selected indicators under the three categories of sustainable development goals. Attention was paid to area 7 - affordable and clean energy, 8 - decent work and economic growth, and 9 - industry innovation and infrastructure. The indicators analyzed in relation to Poland's and Slovakia's performance against the progress of the European Union were primary energy consumption (SDG7), energy productivity (SDG7), real GDP per capita (SDG8) and rross domestic expenditure on R&D by sector (SDG9). Within each of the indicators examined, Poland has shown a rise in the ranking of EU member states over the analyzed period. Slovakia, on the other hand, only in relation to the indicator of rross domestic expenditure on R&D by sector (SDG9) showed a decline in placement.

The comparative analyses conducted in the article, as well as the analyses of the dynamics of change of selected indicators, indicate differentiated trends in the member countries in all areas studied.

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# E-LEARNING AS A SYSTEM FOR DISSEMINATING KNOWLEDGE ABOUT SUSTAINABILITY DEVELOPMENT MANAGEMENT IN A CHEMICAL ENTERPRISE

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**Purpose:** The aim of the article is to show e-learning as a system for disseminating knowledge about managing the sustainable development of chemical organizations.
**Design/methodology/approach**: A qualitative methodology was selected, which enables the study of the importance of an e-learning platform in managing knowledge about sustainable development in a chemical enterprise.
**Findings:** Literature studies allowed to development of the concept of an e-learning platform, the components of which are the processes of searching, discounting, and protecting knowledge about sustainable development, necessary for effective management in a chemical company.
**Originality/value:** Disseminating knowledge about sustainable development among employees of a chemical company is of practical importance. This article aims to fill a research gap in the field of acquiring, discounting, and protecting knowledge using an e-learning platform.

**Keywords:** E-learning, knowledge management, sustainability development, a chemical enterprise.

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

## 1. Introduction

Contemporary organizations, especially chemical enterprises, face new challenges resulting primarily from the rapid development of information technology and the dissemination of the concept of knowledge management. Knowledge and its management are the key factors for the success of enterprises operating on the market today. One of the main characteristics of good management from the point of view of building unique competitive advantages is the company's ability to learn and transfer knowledge, especially in the area of sustainable development of the

organization. Nowadays, knowledge is becoming - on a micro-scale - a priority production factor and - on a macro scale - a determinant of technical progress. Sustainable development, although defined in various ways, can generally be understood as a relatively permanent process, based on stable and diverse foundations, bringing benefits not only to the organization itself and its creators or owners but also to the broadly understood environment. Sustainable development of organizations is a method of management in which economic, environmental, and social issues related to their functioning are taken into account simultaneously and equally.

The chemical industry, as one of the first branches of the national economy, started to implement the assumptions of conducting activities based on the search for solid attitudes of "sustainable development", leading to achieving profits while maintaining justice, a sense of security, and durability of ecological functions. Sustainability has been widely recognized as a core function of any chemical company. The products of the chemical industry are an inseparable part of social development, the approach of producers, both in terms of responsibility for the products themselves and for the production process, is changing towards increasing responsibility for employees and the natural environment.

Introducing modern programs and projects regarding environmental management in a chemical company and implementing clean and safe technologies requires launching the processes of searching for knowledge and its discounting in the process of communicating and educating employees.

Managing such development requires not only efficiency and accuracy in fulfilling the manager's functions and tasks but above all comprehensive observation of reality, analysis of processes taking place in every area of the organization's functioning, and creative use of resources and creating new concepts and trends for the organization's development. One of the tools enabling creative management of the organization's resources is e-learning.

The aim of the article is to show e-learning as a system for disseminating knowledge about managing the sustainable development of an organization.

## 2. E-learning as an instrument for disseminating knowledge in the organization

The dynamically changing reality poses new challenges to modern organizations. Globalization of markets, knowledge-based economy, information society, and increase in the level of competitiveness - these are the key factors determining the preservation and functioning of communities, businesses, and customers. The dissemination of new ICT technologies causes changes not only in the functioning of enterprises, but also in organizational structures, causing a new division of tasks, responsibilities, and competencies, and thus - proves the important role of education in the organization's strategy. There is no universal definition of e-learning.

Generally, they can be characterized as a controlled method of transferring knowledge (usually remotely), based on electronic media. E-learning is generally classified in three ways (Goyal et al., 2021):

- partial classroom learning - with this type of learning, the traditional classroom environment is provided to students as an infrastructure tool, and the rest is remote learning,
- distance learning - is a method of full distance learning with limitations of spatial and time units,
- smart distance learning anytime, anywhere (smart distance learning) - is the concept of teaching and learning methodology within this classification is further divided into different categories such as asynchronous and synchronous learning, blended learning, distance learning or Classroom 2.0, and intelligent learning.

Both e-learning and blended learning evolve from a new idea to a widespread, practical, and rational way of education. Blended learning training is defined as a combination of traditional and electronic training (blended learning), subject to various forms of education depending on the specificity of the subject (training content). Modern e-learning is conducted online or off-line in the internal network of the training institution (intranet) or via an external network (Internet), and recently also via mobile telephony (m-learning, mobile learning), often with the use of additional resources on information carriers (CD-ROM, DVD, etc.). In other words, e-learning and blended learning are "a modern way of transferring knowledge, controlling the learning process and obtaining feedback on assimilation.

The rapid development of the Internet and the progressing computerization of society enabled the creation and dissemination of the so-called e-learning platforms, i.e. software sets enabling online classes and remote service of trainees. E-learning platforms are extensive applications that facilitate the creation, conduct, and administration of educational courses. These are de facto integrated sets of tools to achieve more specific related goals with teaching, in particular course management and course resources. In principle, there is no consensus as to what specific functions an e-learning platform must perform. IT companies offering the purchase and implementation of solutions in the field of e-learning platforms literally define the e-learning platform as the so-called smart wardrobe, equipped with many clever shelves and drawers in which you can arrange various things. Some have encrypted locks and only those in the know have access to these places. Most importantly, however, every access to this secret "closet" is logged. Opening each drawer by users leaves a virtual "track" (*Co to jest platforma e-learningowa*…, 2023).

From the point of view of effective organization management, the e-learning platform should be considered as a component of knowledge management consistent with the sustainable development strategy adopted in the organization.

The concept of sustainable development implemented by organizations in the knowledge environment is part of the model of holistic knowledge management (SET KM Model), based on three pillars: (1) the organization's strategy, i.e. the strategic organizational concept of awareness, knowledge, and learning; (2) an environment for creating, sharing and using knowledge, depending on the organization and its partners, and objective factors; (3) knowledge tools conducive to effective management processes, including knowledge diffusion. The concept of sustainable development becomes particularly important in the era of knowledge society and economy because knowledge is the driving force for the universal development of individuals, organizations, and the entire economy. Knowledge is an intangible asset that plays a key role in the success or failure of any organization (Ooi, 2014, pp. 5167-5179). Organizations treat it as an instrument that enables them to compete effectively in the market (Mothe et al., 2027, pp.1-21).

A.M. Dereń, et al. (2022, pp. 1-16) proposed the concept of an e-learning platform dedicated to an industrial organization operating in conditions of sustainable development. The adopted concept is based on five coherent elements: a system of knowledge exchange in the field of sustainable development, a database of development problems, a database of development products, a recruitment system, a motivation system, and a database of employee experience. This concept not only provides broadly understood employee development but can also be a system for presenting, testing, and reporting knowledge. The recommended e-learning platform not only enables the management of talents and employee experience but is also a communication tool enabling the exchange of knowledge. The process of knowledge exchange is related to its acquisition, discounting, and protection.

## 3. A system of acquiring, discounting, and protecting knowledge in a chemical enterprise

Nowadays, knowledge, information, and data are the key strategic resources of every business organization. It is assumed that knowledge is confirmed belief. It is about beliefs and expectations. It is a function of a particular attitude, perspective, or intention, and it is about actions. It is context-dependent and relative (Lipczyński, 2014, p. 48). On the other hand, information captured as streams of messages is an instrument for discovering and building knowledge (Nonaka and Takeuchi, 2000a, pp. 80-81). Information transforms into knowledge when, in the process of interpretation, it gives context and is "anchored" in beliefs and human involvement (Nonaka et al., 2000b, p. 7). Data, on the other hand, are individual facts, statistics, or information, often digital.

Figure 1 shows the system of acquiring, discounting, and protecting knowledge in the organization as the key components of the e-learning platform for the exchange of knowledge in the organization. The purpose of this exchange is to increase the productivity of knowledge.

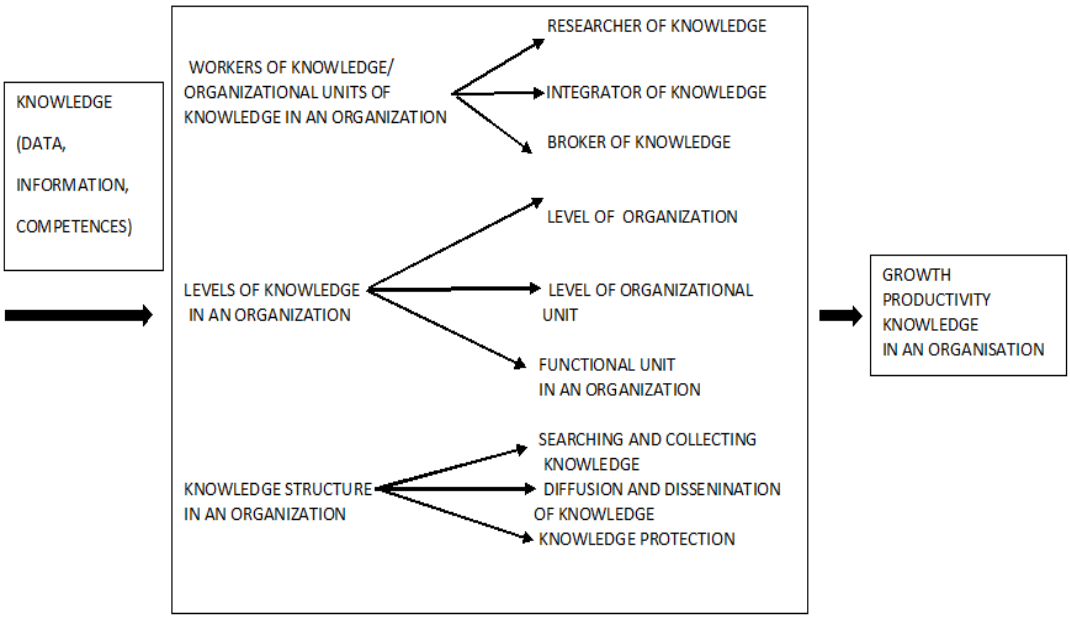


**Figure 1.** Acquiring, discounting, and protecting knowledge in a chemical enterprise.
Source: own study.

Knowledge productivity is the ratio of the effects to the expenditure incurred to obtain knowledge. In order to evaluate inputs, the indicator of the current state of resources and the costs of modifying knowledge resources should be determined. G. Probst et al. (2002) define the state of resources as employee skills, key competencies, connections with the knowledge environment, quality, and a number of competence centers and patents.

The exchange of knowledge is preceded by its acquisition. It is a process of knowledge flow from the organization's environment to its interior, as well as a process during which employees acquire knowledge from internal sources, i.e. from their co-workers, from documentation and databases, available books and magazines, and the media.

For this purpose, it is necessary to distinguish the levels of knowledge management in the organization (as a whole), in its organizational units, and in the performed functions, e.g. production, marketing, and innovation.

As part of the knowledge acquisition process, a number of sub-processes can be distinguished, such as knowledge discovery, knowledge generation, knowledge acquisition, identification of the necessary knowledge and knowledge gaps, identification of knowledge users, knowledge localization - identification of internal and external sources of knowledge and ways of obtaining it, evaluation of knowledge, knowledge assimilation - integration of external knowledge with internal knowledge, knowledge mapping, structuring and organizing knowledge (Wyrozębski, 2014, pp. 42-53).

Acquisition of knowledge can also take place by extracting it from competitors' products or processes conducted by them, for example by benchmarking. In addition, the acquisition of knowledge is also carried out through participation in training, conferences, and symposiums, as well as in an informal way during contact with other people. Social media are also an important source of knowledge, especially in terms of information on potential opportunities and threats.

Acquisition of knowledge also takes place through the purchase of advice and studies from consulting companies, especially in a situation where own human resources do not promise rapid development. However, the knowledge acquired in this way is not unique. This is the nature of knowledge created in an organization.

An active approach to knowledge acquisition involves searching the internal and external environment. This is about filtering and evaluating potential opportunities from outside the enterprise, including related and emerging technologies, new markets, and services, including those that can be exploited by combining them with existing employee competencies. Recognizing an opportunity in practice means a process of painstaking penetration of the environment carried out on several levels. It can be an operational-level initiative where marketing and technology managers learn about developments in their fields; it can also be a top-down initiative where subsidiary managers or professional equity funds are advised to monitor and invest in potential opportunities (Tidd, Bessant, 2011, p. 737).

The acquired knowledge should be discounted, i.e. its value must be used in the organization. This requires the codification of knowledge, i.e. giving it an appropriate organizational form, and facilitating access to it by employees who need it at a given moment. Codification of knowledge in its entirety is not always possible. Hence the need to create the so-called corporate guides or knowledge maps. They allow you to divide all your knowledge into three categories:

- basic (core) knowledge, necessary for the functioning of the company "here and now",
- advanced knowledge, allowing to create of competitive advantage in the market,
- innovative knowledge, allowing to distance competitors (Kłusek-Wojciszke, Łosiewicz, 2009, p. 145).

The e-learning platform enables effective discounting of knowledge by:

- converting data and information into knowledge, e.g. by identifying patterns,
- transforming texts into knowledge by means of syntheses, comparisons, and analyses,
- preserving individual knowledge into group knowledge, i.e. passing it on to employees,
- involving employees in knowledge, e.g. in the form of seminars, workshops, and training,
- connecting employees with other employees by creating professional and specialized thematic groups,
- integration of knowledge with knowledge by identifying and interacting with different fields of knowledge, e.g. in joint projects.

Knowledge discounting takes place with the active participation of knowledge researchers, knowledge brokers, and knowledge integrators. They form a group that bonds learning on an individual and corporate level. The functioning of this group facilitates the sharing and transfer of knowledge in the enterprise.

For the processes of transferring and discounting knowledge in an enterprise, its protection is of great importance. Knowledge is a strategic resource of every organization and a basic element of business processes.

The criteria for evaluating knowledge as a protected value, in its general stock, depend, among others, on factors such as:

- level of novelty,
- creative contribution,
- scientific, implementation, and market attractiveness, completeness,
- susceptibility to development,
- inspiring development,
- the ability to keep secrets,
- the cost of production or purchase,
- economic and non-economic benefits possible to obtain temporary and in the future,
- expected period of use,
- competitiveness in relation to existing knowledge, both protected and unprotected (Kotarba, 2006, p. 226).

The catalog of features indicated above is not complete, but it is a reference point for assessing the value of knowledge possessed by the company and implementing appropriate safeguards. Organizational knowledge protection should include the following areas:

- controls on the acquisition, production, and processing of information and knowledge,
- secure distribution of the resources in question,
- monitoring the "ways" of information and knowledge in the structure of a given organization,
- - staff training in security procedures (Materska, 2005, p. 17).

In the opinion of G. Probst et al. (2002) the protection of knowledge is to protect organization against the loss of this valuable resource and its unauthorized use experiences and information by competitors. Increasing awareness in the field of protection knowledge requires launching the process of its identification, building a strategic architecture and programming the company's goals, defining growth parameters and priorities development of new activities, developing a clear way of allocating resources supplying knowledge creation processes (Sołek, 2012, p. 93).

## 4. Conclusion

The concept of sustainable development is particularly important in the era of knowledge society and economy, because knowledge is a factor in the development of individuals, organizations and the entire economy. The concept of sustainable development implemented by companies in the chemical industry is part of the knowledge management model, based on the acquisition, discounting and protection of knowledge. A practical tool for implementing this knowledge management model is the e-learning platform recommended by the authors. Building and implementing an e-learning platform is a change that needs to be properly communicated and carried out in the organization. It is a process that should be preceded by a detailed strategic analysis in several key areas: business needs resulting from the emergence of the problem, its solution, analysis of recipients and stakeholders or partners (PESTEL analysis) and available resources. The e-learning platform is an innovative method of knowledge sharing and a stimulator of human resources development in the company, adapted to the individual capabilities of a given employee. Effective implementation of the skills development strategy in the organization requires the use of a modern e-learning platform that offers a sufficiently wide range of functionalities. The platform will largely automate the repetitive tasks of HR departments, enable tracking of training progress made by employees of the organization and will identify possible gaps in knowledge and competences, both in the individual and team dimension.

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# CSR COMMUNICATION IN SOCIAL MEDIA – CASE STUDY GRUPY AZOTY ZAK S.A.

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**Purpose:** Communication is a vital tool in the process of building and shaping social relations, which affects the image and reputation of companies, including chemical companies. Communication, carried out in various ways, is a complex and dynamic process. In the context of social relations, communication is the basic tool and way of transmitting and receiving information. The aim of the conducted research was to evaluate the existing communication system in selected social media channels implemented by a chemical company in the context of corporate social responsibility. The article presents the communication processes in Grupa Azoty as a case study in social media in correlation with social responsibility activities.
**Design/Methodology/Approach:** The article applies a case study of Grupa Azoty ZAK S.A., along with the analysis of statistics collected from selected communication channels of Grupa Azoty ZAK S.A. In addition, direct interviews were conducted with employees of the organizational unit supervising communication processes to supplement the analysis.
**Findings:** The interpretation of the indicators described for the purposes of this article proves, among other things, that there is a mutual dependence between CSR activities and communication in social media. The research showed that CSR posts are among the most popular publications, and the analysis of the characteristics of post themes shows the audience's interest in multimedia-based CSR-related posts. Furthermore, the research proves that CSR communication depends on the geopolitical situation, current topics arousing the greatest interest among the general public, and the world situation.
**Research Limitations/Implications:** The analysis is based on a single case study.
**Practical Implications:** Those responsible for communication in the organization should be aware of the needs and expectations of the local community, which affect the level of interest in the publication's topics, translating into a positive image of the company involved in activities that are very important from the point of view of the local community.
**Social Implications:** Shaping social attitudes, building relationships that affect the image of a chemical company in social media is, therefore, an important and significant tool in broad and complex communication processes. Constant monitoring of statistical indicators of message recipients is a necessary activity to draw conclusions and recommendations for future actions. Companies can assess which communication channels to develop to adapt to global trends, how to attract new recipients, and how to build identity with the brand.
**Originality/Value:** The presented research results concern the communication processes carried out in social media in the context of corporate social responsibility - a topic that is not widely studied.

**Keywords:** Communication, Social Media, Corporate Social Responsibility.
**Category of the paper:** Research paper.

## 1. Introduction

Communication is a vital tool in the process of building and shaping social relations, which affects the image and reputation of companies, including chemical companies. Conducted in various forms, communication is a complex and dynamic process that involves multiple layers and constitutes an action. In the context of social relations, communication serves as the fundamental means of transmitting and receiving information. It is impossible to avoid speaking, writing, gesturing, or thinking - all these forms of communication underpin social systems and form the basis of social relations. Innovations in the field of communication have enabled the use of various transmission media, with the Internet offering the most communication opportunities through images, sound, visual effects, and social media. These platforms provide unprecedented possibilities for rapid transmission, fostering mutual connections and communication networks that contribute to the development of emotions and social relations.

## 2. Defining Communication in Correlation with Social Media

Until recently, communication was primarily associated with transmitting and receiving information through verbal and non-verbal means. However, with the development of the Internet, the possibilities have expanded, and various tools for building personal relationships have emerged.

In the literature on "communication", the term frequently appears in searches, and numerous publications aim to define the concept. Effective communication is said to occur when the recipient interprets the message according to the intended communicative intention (Błaszczyk, 2005). Authors of scientific publications concur that communication processes involve social relationships and mutual exchanges of information (Adler, 1986), as well as the selection of transmitted and received messages (Ross, 1983). The Internet has played a significant role in shaping social relationships, and with its development, social media has emerged. Initially, it seemed that social media would primarily serve as a tool for social communication between individuals, facilitating pleasant online meetings and nurturing social ties. However, companies soon recognized their strong social interaction potential and the opportunities they provide for building brand image, creating communities around them that acknowledge the benefits of using the brand (Brzozowska-Woś, 2013).

Social media has thus become immensely important, often defined as a "natural, unrestricted form of information exchange on the network between individuals with common interests" (Gogołek, 2010) or simply as a channel of communication, "a set of technologies for initiating communication and content transmission between people, their friends, and the social networks to which they belong" (Treadaway, Smith, 2011). Social media involves the exchange of opinions, observations, information, shared experiences, and impressions by its users. Such message exchanges contribute to building emotions in social relationships. Companies readily capitalize on this factor, as research indicates that positive emotions associated with a brand (Brzozowska-Woś, 2013) are the most prevalent factor conditioning brand liking, which in turn, impacts the positive brand image on social media. Importantly, there are also dependencies between effective internal communication and employee identification with the company, i.e. strengthening employee loyalty with the company (Cybulska, 2011).

## 3. Research Methodology

To gain deeper insights into the communication activities of a chemical enterprise on social media, this article presents a case study of Grupa Azoty ZAK S.A. For research purposes, the main trends in the communication of a chemical organization were examined by analysing statistics collected from the company's Facebook, LinkedIn, Twitter, and YouTube profiles in 2018-2022, as these are the communication channels utilized in Grupa Azoty ZAK S.A.'s operations. Additionally, the research process employed direct interview techniques, and qualitative data collected (posts, information about supported events, photo materials) gathered from interviews with employees coordinating and supervising the communication processes related to building brand image were analysed. These interviews aimed to interpret the existing data and systematize the knowledge pertaining to the discussed phenomenon. For this purpose, interviews were conducted with five employees from the Communication and CSR Office. Three people deal with activities related to external and internal communication of the company, and their responsibilities include, among others, creating press releases, information and promotion, administration of the company intranet, administration of company channels on social networks and cooperation with the media. The other two people are responsible for the implementation of CSR activities, i.e. tasks related to creating a positive image, organization of promotional events, activities in the areas of sponsorship and charity, tasks related to employer branding as part of internal and external communication, including the implementation of scholarship programs.

In addition, a literature review and reports on communication trends in social media were reviewed.

## 4. Trends in communication in social media

With the growing popularity of the Internet, it has become an opportunity for entrepreneurs to improve the image of their companies, brands, organizations or products. Many international reports show a steady increase in interest in the Internet. Already 5 years ago, 57% of the world's population had an Internet connection, of which 45% had access to social media, and the number of business pages was also growing - in 2018 there were 80 million, currently 4.95 billion users (Kemp, 2019). Trends in social media are constantly changing - innovation, keeping up with new developments, and developing their communication strategy on them. The scope of reports on Digital Poland that examine social media trends on the Polish market focuses on measuring the growth of the number of Internet users and individual communication channels, factors influencing trends, popularity rankings of social media, and the time users spend on the Internet (Empemedia, 2023). Reports show that geopolitical events around the world affect the situation in shaping trends. In 2002, factors such as the war in Ukraine and the influx of refugees to Poland could partially explain the 8.5% increase in the population of Internet users in Poland, almost 3 million people. Research shows that the number of social media users is constantly growing. The number of Polish social media users per person is also increasing, which in 2022 was 72%, or 27 million people - compared to 2018 (Empemedia, 2022), when 16.3 Poles over 1 year old used social media (Majchrzyk, 2018). Research shows a steady upward trend. However, the time that Poles spend on the Internet is decreasing. In 2022, Poles spent 5 minutes less time online every day than the previous year (time), and even 10 minutes less time on social media. Among the available communication channels, the reports show the real presence of Poles, which indicates that the most users have Facebook (17.65 million). The next important channels are Instagram (10.1 million), LinkedIn (4.6 million), Snapchat (4.9 million), Pinterest (4.2 million), and Twitter (only 2 million) (Empemedia, 2022). An interesting fact in Polish trends is the lack of YouTube in the top popular social media channels. Despite the lack of popularity, research shows that Polish Internet users spend the most time here - over 23 hours per month (Polewko, 2022). Companies are aware that conducting promotional activities in social media is not the same as controlling previously more frequently used mass media (press, radio, television), as well as initially internet advertising. Social media users have been given new tools to create their own online networks, which can spread messages and information on their own and manipulate emotions. Thus, skilful use of social media by companies has become not only an opportunity, but a necessity, and if organizations want to build their own image on the Internet, they must constantly research and monitor trends, as well as develop their own online channels, taking into account the needs of their target audience among social media users. The most important initial action should be a thorough and skilful planning of activities, knowing their target group, setting goals, and selecting appropriate tools and communication channels (Brzozowska-Woś, 2013).

## 5. Analysis of research results

Analysis of Communication Activities in Grupa Azoty ZAK S.A.

In Grupa Azoty ZAK S.A., the communication strategy is based on the needs of the audience. The literature also mentions the concept of an information gap or a hope gap, which arises when recipients seek ways to fill the gap with the expectation of receiving information (Błaszczyk, 2005).

For this reason, in 2019, the audience was preliminarily identified based on the implemented social media channels, and communication assumptions and content were tailored to them. To increase the effectiveness of communication on social media, the company carried out an initial verification and determination of similarities between audience groups in correlation with social media channels. They classified the audience by gender, location of origin (where they live), experience, and social relationships. The similarity of content and the likelihood of "likes" were then matched, indicating the audience's interest in the topic, and translated into the message's reach.

The communication goal in Grupa Azoty ZAK S.A. is to establish complex relationships by responding to needs and sending messages related to both the company and society's needs. In order to send messages, create publications, and develop content according to the adopted communication policy, the company makes choices about content, appropriate words, and their connections, which together form a message for the recipient. The difficulty in building messages lies in formulating them in a way that ensures they are understood and received according to intentions and established interpretations (Olechnicki, Załęcki, 1997). The literature suggests the appropriate selection of channels for the message. However, the company determined that not only is the channel itself important, but also its audience. For this reason, the company adopted communication assumptions tailored to specific channels in social media and identified types of audience.

To present individual communication channels, the author of the article first identified the main tools used in external communication, based on the basic division of the website www.zak.grupaazoty.com and social media platforms. Social media plays a role in the organization as the company's business card, a platform for exchanging messages, and an ongoing dialogue with stakeholders. The company has its own profiles on four channels:

1. Facebook - facebook.com/GrupaAzotyZAK.
2. Twitter - twitter.com/GrupaAzoty_ZAK.
3. LinkedIn - linkedin.com/company/18058551.
4. YouTube - youtube.com/user/GrupaAzotyZAK.

In Grupa Azoty ZAK S.A., communication activities are based on a carefully prepared communication plan. Initially, the company attempted to analyse and define the main groups of communication recipients within the created social media profiles as part of the prepared plan. The analysis and main groups of message recipients are shown in Table 1.

**Table 1.**
*Recipients of individual social media channels in Grupa Azoty ZAK S.A.*

| Facebook | Twitter | LinkedIn | YouTube |
|---|---|---|---|
| **Employees** | Media | Employees | |
| **Local community** | Industry organisations | Industry organisations | Local community |
| **Beneficiaries of CSR programmes** | Shareholders | Customers, suppliers, competitors | Industry organisations |
| **Opinion-forming environment** | State and local government administration | Scientific and research community | Scientific and research community |
| **Grupa Azoty companies** | Customers, Suppliers, Competitors | Grupa Azoty companies | Grupa Azoty companies |

Source: Own elaboration based on research results.

As you can see, each of the communication channels has different groups of recipients, hence the communication assumptions must also be different. As a member of the Grupa Azoty capital group, the company's communication activities are in a constant process of consolidation, which also applies to communication activities. These activities are the result of the jointly developed Grupa Azoty Group Strategy by specialists from all Grupa Azoty companies. The author describes the consolidation processes that result in the development of Grupa Azoty's communication policy more broadly in the literature (Drozdowicz-Tomaszek, 2021, 2022). Communication lines for the main areas of business, charity, social responsibility, sponsorship, and tradition were systematized in the company's regulations. The organization divided the assumptions into internal and external communication as part of the communication processes, with social media included in the external scope.

In the age of tremendous social media popularity, companies must develop assumptions that aim not only to interest the audience in the message and build relationships that strengthen the positive image of the company but also to avoid behaviours that cause undesired consequences for reputation or image deterioration. Organizations should include in their communication plans the prediction of potential threat directions, a holistic approach to current and future threats requiring constant monitoring and relationship management, trend analysis, and the development of tools enabling a rapid response to users' undesired behaviours (Szwajca, 2017).

Communication assumptions are therefore an important element of the adopted communication plan. This is also confirmed by other studies carried out in the area of human resources, which concern the need to separate groups of employees according to the scope of information needs, drawing up a detailed program for the use of means of communication to take into account information needs (Olsztyńska, 1999).

Therefore, communication assumptions are an important element of the adopted communication plan. By identifying the recipient group in existing social media profiles, the organization adjusted the messages to its intentions, which aim to build positive emotions among social media users. The content was based on basic assumptions and intentions adapted to individual channels, which is clearly shown in Table 2.

**Table 2.**
*Communication assumptions in Grupa Azoty ZAK S.A.*

| Facebook | Twitter | LinkedIn | YouTube |
|---|---|---|---|
| **Shaping the Company's reputation as:** | **Building the Company's image as:** | **Search and establish business contacts** | **Support for communication on other SM channels** |
| the most important company in the region | Innovative enterprise | Interest of potential Customers, Suppliers | **Building the company's image through:** |
| a good employer | Communicating consciously | Emphasizing the Company's position on the markets | Presenting the aesthetic values of the company |
| A secure business in the neighborhood | Broad-minded | Positioning of company know-how: employees as experts | Video appeal |
| **Strengthening loyalty by:** | **Building corporate identity through:** | Presentation of marketing, research and scientific activities, innovations | |
| emphasizing direct and indirect links between the local environment and the Company; | Targeting information through interactions | **Strengthening loyalty and building corporate identity:** | |

Source: Own elaboration based on research results.

The most common assumption, according to Table 2, is building the image and shaping the reputation of the company. Analysing the content of current posts and shared communications on each social media channel, the author of this article identified several main publication patterns and the most commonly used topics of posts.

On the organization's profile created on Facebook/Facebook/GrupaAzotyZAK, the following published topics were identified, which included:

1. Job offers.
2. Important events and corporate programs.
3. Current business activities, such as concluding cooperation agreements or other significant events in the company's industry.
4. Press releases on important events related to organization, ownership supervision, implementation of strategies, and investment plans.
5. Information related to corporate social responsibility: donations and support for local, regional, and supra-regional initiatives; successes and achievements of social program beneficiaries; information on local and regional patronages and events.
6. Successes and achievements in the field of sponsorship, including the excellent results of the Grupa Azoty ZAKSA Kędzierzyn-Koźle volleyball team.
7. Scientific research activities, including speakers' participation in conferences, cooperation with educational institutions, schools, and research institutes.
8. Information on internal communication and employee integration activities.
9. Information regarding the activities of government and local authorities.

Profile of Grupa Azoty ZAK S.A. on Twitter stands out with a different theme, mainly including information on important corporate events and programs related to various companies within Grupa Azoty and current business activities. Additionally, the published content includes media messages featuring members of the board and representatives of the company, as well as press releases. A key and characteristic feature of this channel is the speed of reaction, hence the publications also include live broadcasts and reports from so-called breaking news, such as online transmissions from press conferences or events.

LinkedIn is a channel dedicated mainly to employees and employer branding, so it is not surprising that the most frequent communications are job offers and information on employees' achievements, information about the company's life, volunteering, and other employee activities. Publications mainly focus on business and industry events, as well as broadly defined research and development activities based on personal experiences. These include, among others, the participation of speakers in conferences, scientific presentations, cooperation with educational institutions such as universities, high schools, as well as research and development institutes. This channel also communicates most frequently about innovations.

YouTube, as a channel supporting all the above-mentioned communication tools, enriches the publication theme with video materials from interviews conducted, reports on the implementation of investment tasks - the construction of installations, and reports from corporate events. In the archival materials on the company's profile, we can find videos documenting, among other things, the launch of installations, visits of representatives of government administration, or other important public figures. You can listen to interesting interviews on fertilizer production topics, learn about the history of the company, promotional videos, but also entertaining materials on employee integration activities: songs or videos from team-building events.

## 6. Discussion

Analysing selected statistical data from one of the social media platforms operated by the company partially addresses the article's goal, which is to present the communication process in social media in correlation with social responsibility business activities. Detailed data is confidential to the company. The description of selected data presented in this article aims to outline general assumptions that the chemical organization follows in social responsibility business communication.

The interpretation of indicators described for this article demonstrates, among other things, that there is a mutual relationship between CSR activities and communication on social media. Since 2018, statistics have shown that the range of publications is increasing, but their dynamics and the number of achieved likes are decreasing. In terms of communication processes,

companies compete in finding creative topics that may interest their audiences. However, in relation to global trends that show widespread and growing use of social media, but decreasing time that Internet users spend online, regarding adaptation to the expectations of the audience, the Azoty Group is achieving less interaction for social media posts.

Shaping social attitudes, building relationships that affect the chemical company's image on social media is an important and essential tool in wide and complex communication processes. Continuous monitoring of audience statistical indicators of messages is a necessary activity to draw conclusions and recommendations for future actions. Companies can assess which communication channels to develop to adapt to global trends, how to attract new audiences, and how to build identity with the brand. The Grupa Azoty ZAK profile is operated according to the trends observed on the social media market. Research for this article proves the existing relationships between social communication, CSR, and professional sports. In order to acquire new audiences, build brand identity, and improve reputation in local communities, businesses should adjust to the current geopolitical situation both globally and locally and increase the number of publications regarding their implemented social initiatives.

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# SUSTAINABLE SOCIAL DEVELOPMENT MANUFACTURING ENTERPRISES IN SELECTED COUNTRIES CENTRAL AND EASTERN EUROPE

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**Purpose:** The main aim of this paper is to assess the impact of macroeconomic conditions on the social development of manufacturing enterprises in selected countries of Central and Eastern Europe.
**Design/methodology/approach**: Due to the implemented goal, the following research hypothesis was formulated as follows: Macroeconomic factors are statistically significant for the social development of manufacturing enterprises in Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia. Due to the implemented research issues, the paper was divided into two main parts. The first part presents selected theoretical problems related to social development. The second part contains the methodology and the results of the study and a summary. In the analysis, we used synthetic indicators of social development of enterprises and synthetic macroeconomic indicators. The relationship between variables was measured using the Pearson's linear correlation index and the method of least squares.
**Findings:** The results of the study indicate that in all analyses countries there is a statistically significant relationship between the indicator of social development and the indicator of macroeconomic development. The highest level of impact of macroeconomic factors on the social development of manufacturing enterprises in the countries of Central and Eastern Europe is recorded in Estonia, while the lowest in Lithuania.
**Research limitations/implications**: Research limitations result from the analysis of a deliberately selected case, which does not allow for formulating general conclusions. Nevertheless, the article refers to sustainable development of manufacturing enterprises.
**Practical implications:** The information contained in the publication may be of interest to business representatives, students and doctoral students of technical, economic and social faculties; analysing the impact of sustainable social development on the operations of manufacturing enterprises in the national and international dimension.
**Originality/value:** The publication covers the topic of sustainable social development of manufacturing enterprises in the macroeconomic aspect. Interdisciplinary research combining the areas of management and quality science with economics and finance.

**Keywords:** Central and Eastern Europe, manufacturing enterprises, sustainable social development.

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

## 1. Introduction

Development is a complex and multidimensional category. It is a process of long-term and targeted quantitative and qualitative changes. Development is extremely important for enterprises because it enables them to survive and operate in a competitive market. It leads to changes in the level and structure of company components.

Business development has many faces. Over the years, the approach to doing business has undergone significant transformations. Nowadays, it is believed that in addition to making a profit, enterprises should also pursue economic and social goals. Processes such as globalization, computerization and increasing public awareness of the negative aspects of doing business require changes in the management of the development of modern enterprises. An increase in the level of competitiveness requires adaptation to changing market conditions. Contemporary enterprises are obliged to support the development of employees, improve the quality of life of local communities or protect the environment (Vare, Scott, 2007; Ciegis, Zeleniute, 2008; Duran et al., 2015; Misztal, 2018).

The concept of sustainable development is gaining importance. It involves the implementation of economic, social and environmental goals. This approach leads to the emergence of a number of benefits for the company and its environment. The goal of enterprises is not only to maximize profit, but also to environmental protection and to improve the conditions and quality of employees' work, care for their health and intellectual development (Dernbach, 2003; Prugh, Assadourian, 2003; Blewitt, 2008; Stoddart, 2011; Slimane, 2012; Barbosa et al., 2014; Emas, 2015).

The main aim of this paper is to assess the impact of macroeconomic conditions on the social development of industrial enterprises in selected countries of Central and Eastern Europe. The following research hypothesis was formulated as follows: Macroeconomic factors are statistically significant for the social development of manufacturing enterprises in Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia in the period from 2012 to 2022.

The first part of the paper is devoted to theoretical considerations regarding the social development of enterprises and its determinants. The second, main part presents the results of the study on a group of industrial enterprises in the period from 2012 to 2022. The analysis was based on data from Eurostat. Statistical dependence was examined using Pearson's linear correlation index and the method of least squares.

## 2. Motivation and purpose

The conducted analysis showed that the most important parameters of the project implementation The development of modern enterprises depends on a number of factors, including globalization, the development of modern information and communication technologies, changes in approach to management processes (Vare, Scott, 2007; Ciegis, Zeleniute, 2008; Duran et al., 2015; Misztal, 2018). Enterprises always operate in a specific external environment. The environment gives them opportunities and possibilities, but at the same time sets requirements and limitations (Mitek, Miciula, 2012).

Currently, one of the most popular approaches to business management is the idea of sustainable development. The term has several meanings, it is flexible and open to interpretation (Prugh, Assadourian, 2003; Blewitt, 2008; Barbosa et al., 2014). Most definitions underline the need for a compromise between the needs of the present and future generations (Dernbach, 2003; Stoddart, 2011; Slimane, 2012; Emas, 2015).

Sustainable development of enterprise can be understood as a:

- "meeting the needs of a firm's direct and indirect stakeholders (...) without compromising its ability to meet the needs of future stakeholders as well" (Dyllick, Hockerts, 2002),
- "achieving success today without compromising the needs of the future" (Boudreau, Ramstad, 2005),
- "keep the business going", "future-proofing" (Colbert, Kurucz, 2007),
- "take decisions considering the common value" (Porter, Kramer, 2007),
- "a holistic approach of thinking of business which seeks to integrate consideration of the three aspects of sustainability – social, environmental and economic (Oželienė, 2017)".

Sustainable development can be considered from three perspectives: economic, social and ecological. From an economic point of view, companies are focused on maximizing profit, increasing productivity and profitability. From an ecological perspective, companies take action for reduction of emissions and pollution, smart use of resources, biodiversity, security ecosystems, protection of natural resources, recycling, the use of environmentally friendly production. Social activities focus on respect of the human rights, health protection, social security, employee satisfaction, investments in employee coaching and development (Grudzewski et al., 2010; Grabara et al., 2015; Misztal, 2018; Kowalska, Misztal, 2019).

The social development of an enterprise can be understood as taking actions for the development of employees and local communities. It has two dimensions, identified with the impact of enterprise management on the external environment and the interior of the organization. The impact on the company's environment depends on its size, scale and type of business. It should be emphasized that the external environment has a key impact on the

development of the enterprise. It creates opportunities and prospects for development, on the other hand, it can generate restrictions and barriers. The impact of enterprises on local communities is associated with the creation of new jobs and financial support for local social initiatives. In the internal context, development should be equated with improving the conditions and quality of employees' work (Mitek, Miciuła, 2012; Misztal, 2019).

Undoubtedly, the implementation of the concept of sustainable development of enterprises has many features in common with corporate social responsibility (Taylor, 2003; Sheridan, Milgate, 2005; Goel, Ramanathan, 2014). The role of corporate social responsibility in the enterprise management process is to fully accept economic, social and environmental factors. These aspects go beyond typical business activities. They make it possible to meet the expectations of the company and its environment (Biadacz, Wysłocka, 2016; Musiał, Kubacki, 2017). Corporate Social Responsibility values focus on responsibility towards employees, towards the client, towards the natural environment, towards the local population (Kożusznik, 2005). Enterprises that implement the triad of economic, social and environmental goals act responsibly and consciously (Ferrell et al., 2016). It seems right to say that Corporate Social Responsibility is focused on providing the best conditions for the development of society. The goal is to improve the quality of life (Turban, Greening, 1996; Papke, Wooldridge, 2008; Phillips et al., 2018).

Social development has quantitative and qualitative features. Due to the implemented issues and the purpose of the study, as well as the availability of statistical data, the authors assumed that social development should be equated with such categories as: wages and salaries, social security costs, total number of employees in a country, turnover per person employed, apparent labor productivity, gross value added per employee, growth rate of employment, number of persons employed per enterprise, investment per person employed.

Social development of an enterprise depends on several factors that can be divided into two groups (Lorenc, Sorokina, 2015; Trojanowski, 2015):

- macroeconomic conditions such as: level of the country's economic development, macroeconomic stability, stability of legal regulations, support for pro-ecological activities, ecological awareness of people,
- microeconomic conditions such as: financial situation of enterprises, profitability, productivity, product quality, environmental awareness of the management staff, type of business activity, opportunities and prospects for further operations, accumulated human capital, innovation, information technologies.

Development is determined by internal factors on which the enterprise has an impact and external factors determined by the level of socio-economic development of the country. The basic indicators for the assessment of macroenvironment can be included: gross domestic product (GDP), trade balance, research and development expenditure, unemployment rate, harmonized index of consumer process (HICP).

## 3. Methodology

The main aim of the study is to assess the impact of macroeconomic factors on the social development of manufacturing enterprises in selected countries of Central and Eastern Europe. Countries, base on which the study is conduct: Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia and Slovenia, their common feature is accession to the European Union on the 1th of May, 2004. Due to the desire for a comprehensive approach to the analyse issues, the research covered all economic entities of the section C (manufacturing, conducting their activities in selected countries of Central and Eastern Europe in the period from 2012 to 2022). The survey is based on statistical data from Eurostat.

The research hypothesis is formulated as follows: Macroeconomic factors has a statistically significant impact on the manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022.

The assessment of the impact of macroeconomic factors on the social development of manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022 is carried out in four stages.

Preparation, analysis and assessment of a synthetic indicator of social development of manufacturing enterprises and a synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022).

Based on the partial indicators (selected for availability and comparability in terms of time), a synthetic indicator of social development of manufacturing enterprises (SI soc) and a synthetic macroeconomic indicator (SI macro) of selected countries of Central and Eastern Europe (2012-2022) are determined. The components of synthetic indicators are divided into stimulants and destimulants.

Components of the synthetic indicator of social development of manufacturing enterprises in selected countries of Central and Eastern Europe: stimulants: wages and salaries [million euro], social security costs [million euro], total number of employees in a country, turnover per person employed [thousand euro], apparent labor productivity [thousand euro], gross value added per employee [thousand euro], growth rate of employment [%], number of persons employed per enterprise, investment per person employed [thousands euro]; destimulants: personnel costs [million euro].

Components of the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe: stimulants: gross domestic product (GDP) [million euro], trade balance [million euro], research and development expenditure [million euro]; destimulants: unemployment rate [percentage], harmonized index of consumer process (HICP) [percentage].

Indicators are normalized based on the following formulas (Dziekański, 2014):

Stimulants:

$$S = (x_{ij} - \min x_i)/(\max\{x_i\} - \min\{x_i\}) \quad (1)$$

Destimulants:

$$D = (\max\{x_i\} - x_{ij})/(\max\{x_i\} - \min\{x_i\}) \quad (2)$$

where:

S, D: normalized value of a characteristic for the examined unit,

x_ij: value of the j-th feature for the examined unit,

max: the maximum value of the j-th feature,

min: the minimum value of the j-th feature.

The synthetic indicator of the social development of manufacturing enterprises and a synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022) are created assuming the same impact of the indicators on the value of the aggregate measure based on the formula (Nowak 1995):

$$Sj = 1/n \sum_{i=1}^{n} S_{ij} \quad (3)$$

where:

S_j: aggregate metric for j-th year,

N: number of indicators used in the model.

Analysis of the impact of the time variable (t) on the synthetic indicator of social development of manufacturing enterprises and the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022) - the use of the Ordinary Least Squares Method.

Research on the relationship between the synthetic indicator of the social development of manufacturing enterprises and the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022) using the Pearson's linear correlation analysis and Ordinary Least Squares Method, assuming that, the explained variable is the synthetic indicators of the social development of manufacturing enterprises of selected countries of Central and Eastern Europe, the explanatory variable is the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe.

## 4. Results

The risk analysis of the construction project was carried out using the capabilities of the Risky Project The research is based on manufacturing enterprises operating in selected countries of Central and Eastern Europe in the period from 2012 to 2022 (Czechia, Estonia, Hungary, Latvia, Lithuania, Poland, Slovakia, Slovenia). In 2012, 318604 manufacturing enterprises are operating in selected countries of Central and Eastern Europe, while in 2018 415803 - an increase of 971799 enterprises (Table 1).

**Table 1.**
*Research sample*

| Country | Number of manufacturing enterprises | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** |
| Czechia | 151753 | 156209 | 167344 | 173519 | 173889 | 167688 | 170041 | 172054 | 175425 | 175894 | 179059 |
| Estonia | 5478 | 5441 | 5468 | 5563 | 5927 | 6381 | 6613 | 7053 | 7259 | 7507 | 7686 |
| Hungary | 56346 | 52710 | 52163 | 51521 | 49798 | 47475 | 47614 | 49310 | 49951 | 50809 | 51086 |
| Latvia | 7488 | 7521 | 7872 | 7737 | 8981 | 9537 | 9806 | 10523 | 11090 | 10921 | 11011 |
| Lithuania | 15768 | 12849 | 12485 | 13729 | 15133 | 16120 | 17975 | 19398 | 19969 | 20268 | 20855 |
| Poland | 56346 | 52710 | 52163 | 51521 | 49798 | 47475 | 47614 | 49310 | 49951 | 50809 | 51086 |
| Slovakia | 8081 | 8044 | 70271 | 70294 | 66683 | 63208 | 64297 | 63969 | 68413 | 72563 | 75506 |
| Slovenia | 17344 | 17172 | 17113 | 17012 | 17182 | 18148 | 18561 | 18853 | 19074 | 19376 | 19514 |
| ∑ | 318604 | 312656 | 384879 | 390896 | 387391 | 376032 | 382521 | 390470 | 401132 | 408147 | 415803 |

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

On the basis of selected partial indicators illustrating the social development of manufacturing enterprises, a synthetic indicator of the social development of manufacturing enterprises of selected countries of Central and Eastern Europe (2012-2022) is determined. Integrated indicators can take values from 0 to 1, the higher the indicator level, the higher the degree of development. The average value of the synthetic indicator of the social development of manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022 is in the range 0,52-0,59 (standard deviation 0,13-0,21), while the middle value (median) of this indicator is in range 0,52-0,64. The highest value of the synthetic indicator of the social development of manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022 is observed in Hungary (2022) - 0,88, while the lowest in Hungary (2013) - 0,10 (Table 2).

**Table 2.**
*A synthetic indicator of the social development of manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022*

| Country | Indicator | Year | | | | | | | | | | | Descriptive statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | **2012** | **2013** | **2014** | **2015** | **2016** | **2017** | **2018** | **2019** | **2020** | **2021** | **2022** | **Mean** | **Median** | **Min** | **Max** | **SD** |
| Czechia | SI soc | 0,58 | 0,13 | 0,35 | 0,51 | 0,50 | 0,51 | 0,64 | 0,73 | 0,72 | 0,76 | 0,81 | 0,57 | 0,58 | 0,13 | 0,81 | 0,19 |
| Estonia | SI soc | 0,48 | 0,16 | 0,32 | 0,60 | 0,64 | 0,67 | 0,66 | 0,62 | 0,66 | 0,77 | 0,82 | 0,58 | 0,64 | 0,16 | 0,82 | 0,18 |
| Hungary | SI soc | 0,49 | 0,10 | 0,41 | 0,57 | 0,49 | 0,55 | 0,69 | 0,79 | 0,70 | 0,82 | 0,88 | 0,59 | 0,57 | 0,10 | 0,88 | 0,21 |
| Latvia | SI soc | 0,55 | 0,14 | 0,44 | 0,53 | 0,64 | 0,56 | 0,55 | 0,54 | 0,54 | 0,62 | 0,65 | 0,52 | 0,55 | 0,14 | 0,65 | 0,13 |
| Lithuania | SI soc | 0,51 | 0,24 | 0,42 | 0,62 | 0,59 | 0,57 | 0,57 | 0,64 | 0,63 | 0,69 | 0,73 | 0,57 | 0,59 | 0,24 | 0,73 | 0,13 |
| Poland | SI soc | 0,55 | 0,27 | 0,36 | 0,55 | 0,48 | 0,54 | 0,62 | 0,69 | 0,70 | 0,73 | 0,77 | 0,57 | 0,55 | 0,27 | 0,77 | 0,15 |
| Slovakia | SI soc | 0,52 | 0,17 | 0,42 | 0,45 | 0,46 | 0,49 | 0,59 | 0,72 | 0,68 | 0,72 | 0,77 | 0,55 | 0,52 | 0,17 | 0,77 | 0,17 |
| Slovenia | SI soc | 0,65 | 0,18 | 0,42 | 0,55 | 0,49 | 0,48 | 0,59 | 0,63 | 0,70 | 0,67 | 0,70 | 0,55 | 0,59 | 0,18 | 0,70 | 0,15 |

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

In the analysed period, in all selected countries of Central and Eastern Europe, the synthetic indicator of social development of manufacturing enterprises is characterized by an upward trend (parameters before the time variable ($t$) are positive). The highest development tendency of the synthetic indicator of the social development of manufacturing enterprises in selected countries of Central and Eastern Europe is recorded in Hungary - the coefficient before the time variable is 0,057,$R^2 = 0{,}740$, while the lowest in Latvia - the coefficient before the time variable is 0,024,$R^2 = 0{,}329$ (Table 3).

**Table 3.**
*Parameters for equating the trend line for synthetic indicator of social development of manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2023:* $y = \propto_0 + \propto_1 t$

| Dependent variable (SI soc) | OLS | Coefficient | SD | P- value | $R^2$ |
|---|---|---|---|---|---|
| Czechia | Constant | 0,276 | 0,082 | 0,008 *** | 0,643 |
| | Time | 0,049 | 0,012 | 0,003 *** | |
| Estonia | Constant | 0,296 | 0,076 | 0,003 *** | 0,665 |
| | Time | 0,047 | 0,01 | 0,002 *** | |
| Hungary | Constant | 0,245 | 0,077 | 0,011 ** | 0,740 |
| | Time | 0,057 | 0,011 | 0,001 *** | |
| Latvia | Constant | 0,378 | 0,079 | 0,001 *** | 0,329 |
| | Time | 0,024 | 0,012 | 0,065 * | |
| Lithuania | Constant | 0,372 | 0,057 | 0,0001 *** | 0,62 |
| | Time | 0,032 | 0,008 | 0,004 *** | |
| Poland | Constant | 0,331 | 0,056 | 0,0002 *** | 0,715 |
| | Time | 0,040 | 0,008 | 0,001 *** | |
| Slovakia | Constant | 0,278 | 0,064 | 0,001 *** | 0,713 |
| | Time | 0,045 | 0,009 | 0,001 *** | |
| Slovenia | Constant | 0,365 | 0,08 | 0,001 *** | 0,43 |
| | Time | 0,030 | 0,012 | 0,029 ** | |

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

Based on selected partial indicators illustrating the macroeconomic situation, a synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022) is determined. The average value of the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe in the period from 2012 to 2022 is in the range 0,46-0,60 (standard deviation 0,07-0,19), while the middle value of this indicator is in the range 0,39-0,58. The highest value of the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe in the period from 2012 to 2022 is observed in Poland (2021) - 0,84, while the lowest in Czechia (2013) - 0,27 (Table 4).

**Table 4.**
*A synthetic macroeconomic indicator of selected countries of Central and Eastern Europe in the period from 2012 to 2022*

| Country | Indicator | Year | | | | | | | | | | | Descriptive statistics | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | 2020 | 2021 | 2022 | Mean | Median | Min | Max | SD |
| Czechia | SI macro | 0,42 | 0,27 | 0,28 | 0,42 | 0,42 | 0,42 | 0,48 | 0,60 | 0,70 | 0,72 | 0,70 | 0,49 | 0,42 | 0,27 | 0,72 | 0,15 |
| Estonia | SI macro | 0,47 | 0,45 | 0,44 | 0,66 | 0,57 | 0,53 | 0,53 | 0,60 | 0,56 | 0,56 | 0,62 | 0,55 | 0,56 | 0,44 | 0,66 | 0,07 |
| Hungary | SI macro | 0,45 | 0,34 | 0,33 | 0,37 | 0,33 | 0,44 | 0,53 | 0,67 | 0,71 | 0,68 | 0,72 | 0,51 | 0,45 | 0,33 | 0,72 | 0,15 |
| Latvia | SI macro | 0,58 | 0,42 | 0,47 | 0,54 | 0,56 | 0,58 | 0,70 | 0,71 | 0,61 | 0,69 | 0,72 | 0,60 | 0,58 | 0,42 | 0,72 | 0,10 |
| Lithuania | SI macro | 0,51 | 0,36 | 0,29 | 0,42 | 0,47 | 0,59 | 0,70 | 0,71 | 0,61 | 0,58 | 0,76 | 0,55 | 0,58 | 0,29 | 0,76 | 0,14 |
| Poland | SI macro | 0,44 | 0,37 | 0,35 | 0,34 | 0,38 | 0,42 | 0,54 | 0,72 | 0,79 | 0,84 | 0,78 | 0,54 | 0,44 | 0,34 | 0,84 | 0,19 |
| Slovakia | SI macro | 0,32 | 0,32 | 0,31 | 0,35 | 0,44 | 0,44 | 0,49 | 0,61 | 0,65 | 0,79 | 0,70 | 0,49 | 0,44 | 0,31 | 0,79 | 0,16 |
| Slovenia | SI macro | 0,32 | 0,33 | 0,39 | 0,37 | 0,31 | 0,28 | 0,45 | 0,60 | 0,70 | 0,61 | 0,65 | 0,46 | 0,39 | 0,28 | 0,70 | 0,15 |

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

In the analysed period, in all selected countries of Central and Eastern Europe, the synthetic macroeconomic indicators characterized by an upward trend (parameters before the time variable (*t*) are positive). The highest development tendency of the synthetic macroeconomic indicator of selected Central and Eastern European countries is recorded in Poland - the coefficient before time variable is 0,053, $R^2$ = 0,770, and the lowest in Estonia - the coefficient before time variable is 0,013, $R^2$ = 0,370 (Table 5).

**Table 5.**
*Parameters for equating the trend line for synthetic macroeconomic indicator in selected countries of Central and Eastern Europe in the period from 2012 to 2022:* $y = \propto_0 + \propto_1 t$

| Dependent variable (SImacro) | OLS | Coefficient | SD | P- value | $R^2$ |
|---|---|---|---|---|---|
| Czechia | Constant | 0,231 | 0,047 | 0,001 *** | 0,818 |
| | Time | 0,044 | 0,007 | 0,0001 *** | |
| Estonia | Constant | 0,468 | 0,038 | 6,360 *** | 0,370 |
| | Time | 0,013 | 0,006 | 0,047 ** | |
| Hungary | Constant | 0,254 | 0,055 | 0,001 *** | 0,749 |
| | Time | 0,042 | 0,008 | 0,001 *** | |
| Latvia | Constant | 0,450 | 0,039 | 1,120 *** | 0,667 |
| | Time | 0,025 | 0,006 | 0,002 *** | |
| Lithuania | Constant | 0,331 | 0,064 | 0,001 *** | 0,618 |
| | Time | 0,036 | 0,009 | 0,004 *** | |
| Poland | Constant | 0,227 | 0,065 | 0,007 *** | 0,770 |
| | Time | 0,053 | 0,010 | 0,001 *** | |

Cont. table 5.

| | | | | | |
|---|---|---|---|---|---|
| Slovakia | Constant | 0,200 | 0,036 | 0,001 *** | 0,906 |
| | Time | 0,049 | 0,005 | 6,590 *** | |
| Slovenia | Constant | 0,220 | 0,058 | 0,004 *** | 0,704 |
| | Time | 0,039 | 0,009 | 0,001 *** | |

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

The relationship between the synthetic indicator of the social development of manufacturing enterprises and the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022) was examined using Pearson's linear correlation analysis and Ordinary Least Squares Method.

The Pearson correlation coefficient between the synthetic indicator of social development of manufacturing enterprises and the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe in the period from 2012 to 2022 is statistically significant in all the analysed countries ($p < 0.05$). The highest level of correlation was in Czechia 0,911, while the lowest in Slovenia 0,673 (Figure 1).

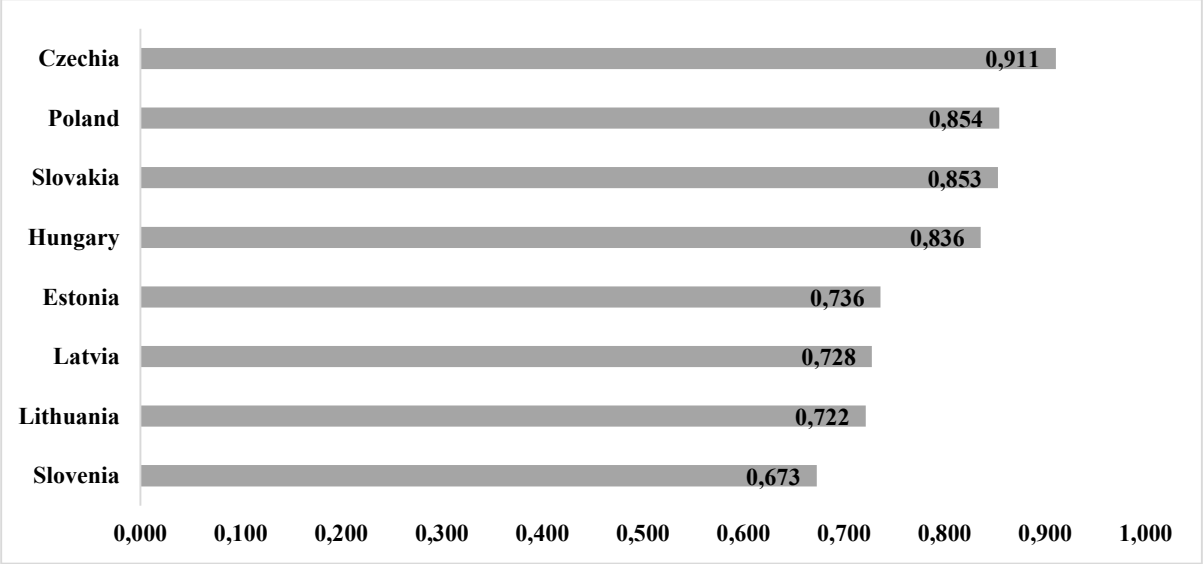


**Figure 1.** The Pearson's correlation coefficient (correlations between a synthetic indicator of social development of manufacturing enterprises and a synthetic macroeconomic indicator of selected countries of Central and Eastern Europe in the period from 2012 to 2022, p <, 05).

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

Estimation by the Ordinary Least Squares Method in the period from 2012 to 2022, where the explained variable is the synthetic indicator of the social development of manufacturing enterprises of selected countries of Central and Eastern Europe, the explanatory variable is the synthetic macroeconomic indicator of selected countries of Central and Eastern Europe, indicates that in all the countries survey there is a statistically significant, positive relationship between the examined variables. In all the analysed countries, the coefficients before the variable x are positive, which means that the increase in the level of the synthetic

macroeconomic indicator will increase the synthetic indicator of the social development of manufacturing enterprises. The highest level of impact of macroeconomic factors on the social development of manufacturing enterprises in the countries of Central and Eastern Europe is recorded in Estonia - when the synthetic macroeconomic indicator increases by 1, the synthetic indicator of the social development of manufacturing enterprises increases by 2,017, $R^2 = 0{,}542$ - the variability of the explained variable is explained in 54%. The lowest level of impact of macroeconomic factors on the social development of manufacturing enterprises in the countries of Central and Eastern Europe is recorded in Lithuania - when the synthetic macroeconomic indicator increases by 1, the synthetic indicator of the social development of manufacturing enterprises increases by 0,649, $R^2 = 0{,}521$ - the variability of the explained variable is explained in 52% (Table 6).

**Table 6.**
*Results of Ordinary Least Squares Method regressions in the period from 2012 to 2022 (explained variable: synthetic indicators of social development of manufacturing enterprises in selected countries of Central and Eastern Europe, explanatory variable: synthetic macroeconomic indicator of selected countries of Central and Eastern Europe)*

| Dependent variable (SI soc) | OLS | Coefficient | SD | P- value | $R^2$ |
|---|---|---|---|---|---|
| Czechia | Constant | 0,007 | 0,089 | 0,943 | 0,830 |
| | SI macro | 1,135 | 0,171 | 9,690 *** | |
| Estonia | Constant | 0,518 | 0,339 | 0,161 | 0,542 |
| | SI macro | 2,017 | 0,618 | 0,010 *** | |
| Hungary | Constant | 0,009 | 0,133 | 0,950 | 0,699 |
| | SI macro | 1,146 | 0,251 | 0,001 *** | |
| Latvia | Constant | 0,093 | 0,196 | 0,647 | 0,530 |
| | SI macro | 1,034 | 0,325 | 0,011 ** | |
| Lithuania | Constant | 0,211 | 0,117 | 0,106 | 0,521 |
| | SI macro | 0,649 | 0,208 | 0,012 ** | |
| Poland | Constant | 0,207 | 0,078 | 0,026 ** | 0,730 |
| | SI macro | 0,665 | 0,135 | 0,001 *** | |
| Slovakia | Constant | 0,113 | 0,093 | 0,253 | 0,728 |
| | SI macro | 0,876 | 0,178 | 0,001 *** | |
| Slovenia | Constant | 0,242 | 0,119 | 0,072 * | 0,453 |
| | SI macro | 0,676 | 0,248 | 0,023 ** | |

Source: retrieved from http://www.ec.europa.eu/eurostat, 12.01.2023.

The results of the Pearson's linear correlation and the Ordinary Least Squares Method allowed the adoption of the research hypothesis: macroeconomic factors has a statistically significant impact on the manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022.

## 5. Conclusions

Enterprise development is a complex and multi-dimensional category. Contemporary enterprises due to the increase of competitiveness and social and ecological awareness of citizens are obliged to implement the concept of sustainable development. One of the dimensions of sustainable development is social development. It can be understood as improving the conditions and quality of work as well as a positive impact on the local community. Social development depends on a number of internal and external factors.

The main aim of the study is to assess the impact of macroeconomic factors on the social development of manufacturing enterprises in selected countries of Central and Eastern Europe. For the purposes of the study, a synthetic indicator of the social development of manufacturing enterprises and a synthetic macroeconomic indicator of selected countries of Central and Eastern Europe (2012-2022) are developed. The influence of the time variable (t) on the examined variables and the relationship between synthetic indicators (using Pearson's linear correlation analysis and Ordinary Least Squares Method) are also analysed.

In the period from 2012 to 2022, the average value of the synthetic indicator of social development of manufacturing enterprises and the synthetic macroeconomic indicators of selected countries of Central and Eastern Europe are in the ranges 0,52-0,59 and 0,46-0,60, respectively. In the analysed period, in all selected countries of Central and Eastern Europe, the synthetic indicator of social development of manufacturing enterprises and the synthetic macroeconomic indicator are characterized by an upward trend. Pearson's linear correlation analysis and estimation using the Ordinary Least Squares Method indicate, that in all selected countries of Central and Eastern Europe, there is a statistically significant and positive relationship between the studied variables. It can be concluded, that macroeconomic factors has a statistically significant impact on the manufacturing enterprises in selected countries of Central and Eastern Europe in the period from 2012 to 2022. The highest level of impact of macroeconomic factors on the social development of manufacturing enterprises in the countries of Central and Eastern Europe is recorded in Estonia, while the lowest in Lithuania.

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# ARTIFICIAL INTELLIGENCE IN HIGHER EDUCATION INDUSTRY. JUST A BRIEF INTRODUCTION TO COMPLEXITY OF AN ISSUE OF FUTURE CHALLENGES

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> What is artificial intelligence?
> It is the science and engineering of making intelligent machines, especially intelligent computer programs. It is related to the similar task of using computers to understand human intelligence, but AI does not have to confine itself to methods that are biologically observable.
>
> *McCarthy, 2007*

**Purpose:** The article was written for review purposes in order to bring the definition of artificial intelligence closer and briefly present the possibilities of its use in management and economic sciences, as well as in higher education.
**Design/methodology/approach:** In order to obtain the desired information, the author conducted a research of the scientific papers on the relationship between higher education and artificial intelligence and extracted the most important conclusions and theories.
**Findings:** The review of the literature allowed the author to determine that there are many applications for artificial intelligence in higher education, but it should be noted that it should always be under human control and verification.
**Originality/value:** Apart from a brief attempt at the definition of AI and its use in higher education, the author also presents a critical perspective and possible threats, as well as proposes solutions that can regulate the ways of using artificial intelligence not only in higher education, but also in other areas of industry and social life.

**Keywords:** artificial intelligence, university, studying, science, future, ethics

## 1. Introduction

Artificial Intelligence (AI) represents a highly promising yet immensely challenging field, with vast implications for the future of society. As we move towards the Fourth Industrial Revolution, enterprises are poised for a significant transformation, utilizing integrated data to better serve customers and gain a competitive edge. Against this backdrop, AI has emerged as a critical topic of research, driving dynamic interest among scholars and practitioners alike (Chiu et al., 2023).

The revolutionary change that the ubiquity of artificial intelligence can bring about raises many hopes, but also concerns. For the first time in the history of human thought, the human mind may not be the only one possessing the ability to analyze and critically evaluate situations. This may lead to significant improvement in the quality of human life by avoiding human errors, but it also poses the risk of shifting the locus of decision-making from humans to machines.

On the other hand, vast collections of data enable the analysis of past experiences and anticipation of future needs, which could prove crucial for the survival and growth of an enterprise (Verma et al., 2021). Artificial intelligence presents a unique opportunity for a rapid acceleration of economic and social growth through the dynamism of innovation in all facets of human activity. By influencing educational processes, it can help expedite the attainment of desired outcomes and contribute to an individualized approach that considers the needs and capabilities of each participant in the learning process.

However, significant risks arising from the computational and analytical capabilities of artificial intelligence cannot be ignored. It is imperative to strive for appropriate legal and customary regulations to ensure that the primacy of decision-making always remains in human hands.

This paper was written to briefly characterize artificial intelligence and present its capabilities that may be used to optimize work in various fields, e.g. in management sciences, economics and higher education. Both the advantages and disadvantages of the use of artificial intelligence were presented, as well as ways to reduce the negative scenarios related to its development.

## 2. The essence of artificial intelligence

One of the seminal and oft-cited definitions of artificial intelligence was initially put forth by American scientist John McCarthy during the landmark Dartmouth Conference of 1956. In its original formulation the definition of artificial intelligence reads as follows:

'AI is the science and engineering of making intelligent machines' (McCarthy et al., 1955). This formulation not only recognizes the field as an interdisciplinary endeavor but also underscores the centrality of intelligence, both natural and artificial, to the development and implementation of AI technologies.

Artificial intelligence is an interdisciplinary field that encompasses a broad range of sciences, from mathematics to philosophy, as it involves complex cognitive tasks such as learning and problem-solving using novel technologies like neutral networks and machine learning (Zawacki-Richter et al., 2019). This highlights the interdisciplinary nature of artificial intelligence, as it draws from various fields to achieve its goals.

However, the first pioneering work on artificial intelligence was initiated by Alan Turing, as he announced during a lecture in 1947. In his paper 'Computing Machinery and Intelligence' in 1950, he deliberated on the question of whether machines can be intelligent, pointing out that there are grounds to claim that this is a true assertion (Turing, 1950; McCarthy, 2007).

The initial considerations of researchers also concerned the scope in which 'artificial intelligence' can operate. One of the important ones was '(…) the question of how man's own organization functions in adapting the message to the exigencies of the symbols and of the apparatus' (…) (Wiener, 1950). In his book, Norbert Wiener described the concept of artificial intelligence as a process of communication between humans and machines and discussed the concept of the "black box" as a mathematical model in which the machine is treated as a black box that receives input data and generates output data, but is unknown in itself (Wiener, 1950).

In his book "Artificial Intelligence", Kevin Knight and Elaine Rich. leading researchers in the field of AI, proposed an AI definition as "Artificial Intelligence is the study of how to make computers do things at which, at the moment, people are better" (Rich, Knight, 1991). This simplified but still profound definition touches the fundamentals of an AI, what is to strive to creation of the machines that can perform tasks that are currently possible for humans. That action is not possible without deep understanding of the human cognition that must be in some way replicated in machines.

Other authors, like Stuart Russell and Peter Norvig, define AI as "the study of agents that receive percepts from the environment and perform actions" (Russel, Norvig, 2010), what directly refers to the idea of an intelligent agent that interacts with its environment. Also, decision making processes can be assisted by AI (Rouhani et al., 2016).

A few years later, a much broader view of the issue was coined: "Computers which perform cognitive tasks, usually associated with human minds, particularly learning and problem-solving". In this view, the artificial intelligence is rather the environment than a technology and covers wide range of newest technologies that help to behave like a human being, or over much more that that (Baker, Smith, Anissa, 2019).

As the computing power of computers increased, massive datasets were generated and processed in the so-called cloud, while neural networks enabled the creation of what is known as artificial intelligence. The main goal was to create a machine that could not only mimic

human behavior but also perceive reality, analyze gathered data, predict future events, and autonomously react to and solve problems (Spector, Polson, Muraida, 1993; Kumar, Thakur, 2012).

The aim was for artificial intelligence to match or surpass human intelligence. It is estimated that in the near future machines will be guided by common sense, akin to that of humans. Other features of the human brain, such as self-learning, will also be within the reach of artificial intelligence (Kumar, Thakur, 2012).

In simpler terms, artificial intelligence can be seen as a complex system or technology that simulates the way humans perceive the world by analyzing stimuli and evaluating them in a manner that exhibits the characteristics of human intelligence (Akerkar, 2014).

It is important to note that artificial intelligence systems are created through the intellectual efforts of humans. Simply put, they learn from people. Therefore, technological solutions for the interface that connects humans and machines are also crucial. This is because the aim is to achieve the most complete and understandable communication between both parties in the process (Thomaz, Breazeal, 2008).

Artificial intelligence enables us to go beyond the limits of the physical capabilities of human intelligence through algorithmic machine learning and autonomous decision-making. Due to its versatility, artificial intelligence can be applied in practically every sector of the economy, as well as in the social sphere, creating a space for innovation and development everywhere (Dwivedi et al., 2021).

## 3. The Role of AI in Management Sciences and Economy

It is a trivial truth that artificial intelligence may and with almost certainty, will have a strong even revolutionary influence on not only every part of human's life, but also on all the sciences. The management sciences will not be an exception. The plethora of potential opportunities of change come by enabling better decision-making through the analysis of large amounts of data. Using predictive analytics with natural language processing makes the machine learning faster. But, to fully realize the potential of AI in management sciences, the further collaborative and interdisciplinary approach is needed (Gandomi, Haider, 2015).

Furthermore, artificial intelligence creates enormous possibilities for practical business applications. The creation of new tools or processes provides a chance to develop a completely new quality of network connections, thereby creating the foundation for the emerging digital environment (Sułkowski, Kaczorowska-Spychalska, 2021). Artificial intelligence can be extremely useful in creating marketing budgets, planning, or conducting environmental analysis. Efficient market analysis and customer-oriented targeting are elements that bring real change to the current business practices (Rai, 2020; Fayed, 2021).

Artificial intelligence, or machine learning, is becoming an increasingly important part of complex business processes. In essence, it changes the form and manner of human-machine communication, while simultaneously creating almost unlimited cognitive possibilities and generating a new space for competitive advantage (Lee, Shin, 2020).

It is worth mentioning the faster and more complete response to customer expectations and needs as one of the applications of artificial intelligence and its ability to collect and analyze real-time data (Wirth, 2018). Artificial intelligence enables efficient analysis and prediction of customer behaviors, decisions, and purchasing habits (Chatterjee et al., 2019). It can also be useful in influencing customer satisfaction levels, not only by attempting to predict their choices but also by suggesting them (Tjepkema, 2016).

Machines that autonomously analyze data allow for efficient building of strategies in the context of product or service positioning, as well as assessing the value of a given customer in terms of their importance to the company. Creating a personalized and relational path enables the creation of truly profitable relationships with customers (Huang, Rust, 2017).

Interestingly, this is not a common practice. There are managers who deliberately delay the implementation of artificial intelligence in their managed companies, mainly due to a lack of conviction about its ability to support the company's operations (McCarthy, Chui, Bughin, 2017).

As it turns out, artificial intelligence can suggest many solutions, but it required knowledge from the people who use it. This knowledge should not only include an understanding of how the machine analyzes data, but also knowledge and skills related to avoiding unnecessary expenses or applying an algorithm by the artificial intelligence that may not be suitable for the specific nature of the enterprise (Canhoto, Clear, 2020).

It is obvious that to effectively utilize technological advancements, including artificial intelligence, widespread knowledge is necessary. Correct implementation and understanding of how to use these advancements is essential for organizations to reap the benefits (Swanson, 1988). Perhaps a recommendation for management practitioners would be to expand their qualifications and knowledge of machine operations and, consequently, artificial intelligence (Solon, 2018). This simply shows that managers seek technological support in the areas of knowledge management and information processing and strive to utilize them in the practice of managing their organizations (Dereń, Skonieczny, Łukaszczykiewicz, 2022). Another issue is the number of possible solutions, which in the case of artificial intelligence can be almost infinite, and the difficulty may lie in making the right choice (Davenport, Beck, 2002).

However, attention must be paid to the issue of the interaction between human intelligence and artificial intelligence. It is necessary to take a broader look at the problem that just through data analysis and beyond data engineering. This will help in a better understanding of artificial intelligence by those managing the organization. It is also worthwhile to develop competencies for every employee and the entire organization, preparing for future collaboration with artificial intelligence and its method of data analysis and thus – understanding the world (Bérubé,

Giannelia, Vial, 2021). The issue of the interaction between artificial intelligence and humans is being scientifically explored under the concept of 'artificial intelligence human reasoning' and the impact on humans during interactions with such machines (Harika et al., 2022).

The development of artificial intelligence creates a foundation for a completely new stage in the process of knowledge transfer. Intelligent tools can provide excellent support for all participants in the educational environment. The ability of artificial intelligence to learn on its own creates an opportunity to expand cognitive horizons in the areas of different cultures or the further development of every individual. It is not surprising that this topic is becoming the subject of interest for an increasingly wider group of subject researchers (Hwang et al., 2020).

The possibilities of utilizing artificial intelligence are practically limitless. They provide a basis for significantly expanding human cognitive abilities. In the case of managing organizations, they will most likely soon become an integral tool for managing a company.

The impact of artificial intelligence on the way an organization functions can be overwhelming. It can be said that it fulfills the term "disruption" or "disruptive disorder" as understood by Clayton M. Christensen, about the possible threat to the organization from a completely unexpected side (Harvard Business Review, 2020). However, attempts can be made to efficiently use artificial intelligence or a potential threat as a huge opportunity (Gans, 2016).

Anyway, several decades ago, Stanisław Lem pointed out that "the point is not to construct a synthetic humanity (…). Technology will signify complete power of man over himself, over his own organism" (Lem, 2020).

## 4. Artificial Intelligence in Higher Education

The idea of using artificial intelligence in 2023 is no longer as innovative. Academic research on this matter has been ongoing for over 30 years. It has been viewed as a useful tool in traditional learning processes due to its interdisciplinary approach and adaptive learning environments (Luckin, Holmes, Griffiths, Mark, Forcier, 2016). The first publications related to the use of such new technologies in education appeared as early as 1983 (O'Shea, Self, 1983).

This idea was boldly developed, pointing to the possibilities offered by computer technology in supporting learning or assessing acquired knowledge. Despite the primacy of humans in education, significantly higher effectiveness and lower costs are indicated by the application of new technologies (Koedinger, Corbett, 2006).

The field of artificial intelligence began to be explored scientifically after the year 2004, with a handful of publications emerging annually since then. Various approaches and potential applications of artificial intelligence tools were analyzed for different forms of collaborative learning (Tan, Lee, Lee, 2022). As the topic of artificial intelligence has sparked the interest of

researchers, it has often been linked with areas such as digital transformation, industry 4.0, and the internet of things, thus indicating higher education's interest in various directions of possible transformation within the realm of new technologies (Yavuz, 2022).

When evaluating the decade 2010-2020, three areas of research can be identified (Zhai et al., 2021):

- classification, matching, recommendations, and deep learning,
- feedback analysis, adaptive learning, and reasoning, and
- application areas such as role playing, gamification, and deep learning.

The International Artificial Intelligence in Education Society (IAIED), with over 25 years of experience, consisting of more than 1000 researchers from over 40 countries in various scientific fields, provides evidence of the importance of artificial intelligence in the education process. Its mission is to promote and support the application of artificial intelligence in education on a global scale (The International Artificial Intelligence in Education Society, n.d.). Artificial intelligence can have various applications, such as stimulating imagination, utilizing emotions to expand knowledge, and interacting with human senses through text, films, images and sounds (Price, Flach, 2017).

Therefore, technology is a set of artifacts that enhance educational communication. It is a means of improving educational forms by actively developing individual learning paths (Della Ventura, 2017). At the same time, there is a noticeable synergy between the use of new technologies and student engagement, resulting in significantly better results for the latter (Chen, Lambert, Guidry, 2010).

The beginnings of the impact of technological changes on the education process were closely related to the popularization of computer techniques. The ability to collect and process data, as well as integrate many different devices, led to the creation of artificial intelligence. This, in turn, has applications in academic administration, as well as significant support for the educational process. In addition to platforms that support education, robots are also used to facilitate contact with interested parties by imitating human behavior. Furthermore, artificial intelligence enables the personalization of educational materials and the adjustment of the level of education to the abilities and perception of students (Chen et al., 2020).

It is evident that universities strive to provide their students with the latest scientific advancements with the support of the most up-to-date technologies. This applies to both the quality of the knowledge imparted and the use of tools that support the educational process. This is in line with changing expectations of students and the evolving role of academic teachers in the entire knowledge transmission process (Scott, 2000).

It is well-known that students have different ways of assimilating knowledge, and by using various technological aids, the knowledge transfer process can be improved and better understood whether they prefer active participation, passive learning, systematic work, sporadic work, or rely on their existing knowledge or intuition (García et al., 2007).

Additionally, it often happens that students are subject to different requirements if they started their studies on different semesters. They usually independently choose many different subjects (courses). This emphasizes the importance of an individual approach and the use of tools that artificial intelligence enables (Haderer, Ciolacu, 2022).

In general, it should be acknowledged that a crucial task of the higher education system is to educate students in the skills of efficient and effective use of artificial intelligence (Luckin et al., 2022). This requires not only knowledge but also communication skills. By incorporating the topic of artificial intelligence into individual subject programs, awareness, and knowledge of the possibilities of this tool can be increased (Su, Zhong, Ng, 2022).

One excellent example of using artificial intelligence is engaging over 6000 students from a university in active learning to familiarize them with various technological tools for future work. This serves as a background and is utilized in educational programs across different subjects, allowing users to become accustomed to the interdisciplinary nature of artificial intelligence and its specialized knowledge, as well as its specific forms of communication (Southworth et al., 2023).

It is not possible to narrow down the application of artificial intelligence in education solely to pure technology. Implementing such applications requires the efficient integration of many complex areas related to the process of knowledge transfer, such as the pedagogical and cultural aspects, as well as considering the economic and social context of the applied actions (Castañeda, Selwyn, 2018).

When it comes to the use of artificial intelligence in education, it is crucial not to overlook the significant ethical, social, cultural, and even pedagogical issues that arise. The importance of education must be emphasized, and the significance of this issue cannot be limited only to algorithms or even complex data processing (Selwyn, 2016). Furthermore, new technologies create a space for discussions in the field of the philosophical perspective of education, which also poses additional risks to the quality of education (Hwang et al., 2020).

Moreover, ethical threads seem to be particularly important in the education process at the higher education level. Artificial intelligence systems should support the creative abilities of students rather than serve excessive control. Developing intelligent support systems for students, considering the individual needs of each, may be a remedy for problems associated with massification of higher education institutions (Zawacki-Richter et al., 2019).

It is worth noting that more and more higher education institutions are recognizing the benefits of incorporating artificial intelligence into the education support process. It should be noted that its use increases student motivation and through interaction, feedback, and learning from mistakes, it contributes to the improvement of skills including computational ones (Bernius, Krusche, Bruegge, 2022; Martín-Núñez et al., 2023).

The advantages of artificial intelligence are enticing. It can enable completely new ways of conveying knowledge. It’s difficult to overlook the possible effects of using artificial intelligence in terms of equalizing educational opportunities and access to knowledge,

including that available in different languages. The perception of the teacher's work may also change, as well as the methods of assessing student work (Tuomi, 2018).

In the case of teachers as well, artificial intelligence can even replace their work by simulating or imitating their knowledge or experience. As a result, students can receive knowledge that is more tailored to their individual cognitive abilities (Pai et al., 2021; Xiao, Yi, 2021). This aspect proves to be extremely important because many researchers see the future of artificial intelligence solely in terms of concentrating on benefits for students through personalized knowledge gathered based on available data and considering the perspective of the knowledge recipient (Ouyang, Jiao, 2021).

However, there are concerns about the challenges posed to work in higher education. Predicting various possible scenarios of technological development in the field of artificial intelligence, some see a threat to the work of teachers, which can be replaced by more efficient machines (Lacity, 2017).

The Educause Horizon Report for 2021 has identified six pivotal technologies and practices that are poised to exert a significant impact on the landscape of higher education in the foreseeable future. There technologies and practices have been carefully selected based on rigorous research and analysis, and are expected to have a transformative effect on the way that higher education institutions operate and deliver education to their students (Pelletier et al., 2021):

1. Artificial Intelligence defined here as „computer systems that undertake tasks usually thought to require human cognitive processes and decision-making capabilities" (Allison-Hope, Park, Rohwer, 2018).
2. Blended and Hybrid Course Models – new, redesigned programs and courses to meet the students and society needs, with a spotlight on learner as well as faculty development. The online education should be "humanized" and oriented towards mental and social health of both, instructors, and students.
3. Learning Analytics – through analysis of the learning process supports the management of education, such as in creating or modifying teaching plans.
4. Microcredentialing – defined as the actions that helps to "verify, validate, and attest those specific skills and/or competencies have been achieved" (Micro-Credentials at SUNY, n.d.). More than 700 thousand various microcredentials are being offered currently worldwide.
5. Open Educational Resources – a multitude of educational content is freely available on the internet, which, thanks to its flexibility and accessibility from any device, becomes an alternative to traditional forms of learning.
6. Quality Online Learning – understood as a focus on providing high-quality online education by adopting appropriate strategies for creating programs, as well as motivating students to learn and preparing instructors to work in a changed, remote environment devoid of the individual, personal "student-master" relationship.

Therefore, it should be accepted that, in terms of its potential and the role it may play in the future, the thesis about the overwhelming influence of artificial intelligence on the processes of knowledge transmission and absorption is true (Loeckx, 2016; Seldon, Abidoye, 2018).

The use of artificial intelligence tools does not have to be limited solely to the educational process. Algorithms also allow for streamlining the processes of managing the university itself and, for example, predicting the percentage of potential student dropouts from their studies. Moreover, artificial intelligence also enables effective prevention of this unfavorable phenomenon (Kotsiantis, Pierrakeas, Pintelas, 2003).

Given the current state of technology development, it is difficult to make a definitive judgement about the impact of artificial intelligence on educational processes. Nevertheless, a positive aspect is the fact of acquainting students with the development of artificial intelligence. It can be assumed with a high degree of probability that their professional future will be based on these technologies to a significantly more advanced degree than at present (Laupichler et al., 2022).

## 5. Threats from artificial intelligence

Despite everything, the latest technologies in the field of artificial intelligence should be approached with caution. There are reasons to believe that it may be used not only for ethical purposes. Using photos or videos and processing them by giving them a changed context in terms of space, frequency, time, or place is known as "deep fake". At the same time, there are tools that allow effective recognition of such practices (Chamot, Geradts, Haasdijk, 2022; Liu, Wang, Wang, 2022).

The significance of the issue is evidenced by the European Commission's 'White Paper' on artificial intelligence. The potential benefits of its widespread use have also been recognized, particularly in three main dimensions (European Commission, 2020):

- for citizens – which means better public, transportation, or health services,
- for businesses – which means innovation in areas such as the electromechanical industry, agriculture, green economy, healthcare, tourism, and media,
- for the public interest – through more effective waste management, supporting sustainable development, transportation, and education.

However, there is a widely expressed concern about safety and individual rights in situations of informational asymmetry. Artificial intelligence can be useful for protecting them, but it can also pose a serious risk of misuse of that data. This creates the need for appropriate regulatory frameworks aimed at minimizing these threats. There are known examples of artificial intelligence algorithms that may exhibit a tendency to discriminate based on gender

or race, as well as preferences for people with lighter skin (Buolamwini, Gebru, 2018; Tolan et al., 2019). Adequate legal regulations are also necessary of a self-driving vehicle controlled by artificial intelligence.

The possibilities of artificial intelligence to generate ready-made texts (ChatGPT) also pose a threat to the ethics and transparency of research and scientific works. Not only in terms of possible plagiarism or problems with establishing authorship, as well as issues regarding scientific liability, but also in terms of the veracity of the presented facts. ChatGPT bases its knowledge on information published on the Internet and does not always process it correctly. It may happen that the created statements sound logical, but their content is not true. Mindless duplication, without proper verification, may therefore be a threat to the reliability of science. All the more that the sources of chatbot knowledge are not clear or known (Eke, 2023; Peres et al., 2023; Rahimi, Talebi Bezmin Abadi, 2023).

However, it is essential that regulatory frameworks do not in any way limit the dynamic development of technology, which can prove to be a significant impetus for development, while ensuring proper protection for those involved in the creation and use of technology – people.

## 6. Conclusion

When assessing the positive impact of artificial intelligence on higher education, on the support of the teaching and research process, one must keep in mind the priority of humans over machines, even those that emulate their personality. It should be remembered that artificial intelligence can never replace human creativity, ingenuity, and intuition. As in the statement: ‘first and foremost, require control by humans. Even the smartest AI systems can make very stupid mistakes. (…). AI systems are only as smart as the data used to train them’ (Kaplan, Haenlein, 2019).

It is assumed that the ability to navigate in the environment of artificial intelligence will soon become a skill that everyone should possess. Some authors even propose to expand education to include digital skills and proficient use of the benefits of artificial intelligence in personal and professional life (Ng et al., 2021).

Artificial intelligence creates almost limitless possibilities in higher education. It is expected to be intricately woven into the entire educational process at every stage. It will serve as an excellent tool to support the work of the teacher-lecturer, while also becoming a tutor that communicates with the students in a language that is accessible and understandable to their perception.

It should be emphasized that current attempts to anticipate the role of artificial intelligence in the higher education system and knowledge transmission processes are fraught with risk. The frameworks for human-machine interactions are still in the process of development, and it remains to be seen in which direction the future developments will take us. It is to be hoped that in the relationship between human and artificial intelligence, the former will maintain an unshakeable primacy, although even this is not entirely free of uncertainty.

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# THE RELEVANCE OF USING CASH FLOWS AND ECONOMIC PROFIT-BASED METHODS IN CAPITAL BUDGETING: A FOCUS ON TECHNIQUES – FCFF, FCFE AND EVA

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**Purpose:** The purpose of this paper is to examine consequences of choice: cash flow or economic value-added method on the net present value of investment project, further on company value.
**Design/methodology/approach**: The article introduces three main methods to measure the net present value of investment project: free cash flow to firm, free cash flow to equity, and economical value added. Paper examines the challenge of using these three-methods in determining what constitutes cash flow and what is the source of the investment value.
**Findings:** The cost of capital should be calculated in different ways to ensure the validity of the calculation. Estimation should be explored by other influencing factors, such as expected rate of return, market value of cost, rather than accounting/historical value. Implementing these factors is necessary to evaluate business value. According to the presented approach the use of the FCFF technique creates fewer risks of acting against the interests of the owners than the use of the FCFE or EVA techniques.
**Practical implications:** As one of the main implications in business, valuation is cost of capital. According to the financing priority theory, when a firm needs financing, the first consideration is internal financing, while equity financing is secondary. Both types of financing sources determine the financing structure and ultimately affect the value of the company.
**Originality/value:** The paper provided and insight in the different investment project valuation methods that are used in the nowadays practice. This was done in an attempt to answer the question: What method should not be used in the assessment of investment projects? The paper provides evidence that most appropriate method in estimating NPV value of investment project is FCFF.

**Keywords:** Cash flow, capital cost, financing structure, FCFF, FCFE, EVA.

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

## 1. Introduction

Globalization of capital markets leads to intensification of capital investment. Despite the practical cases and the extensive literature on capital budgeting, the authors believe that we still have some methodological problems with the commonly used approach for cash flow calculation.

For example, the debt tax shield affects only the equity holders, in that it creates an incentive to hold more debt in order to maximize the tax shield. To show and overcome these issues, the authors try to indicate the most necessary theoretical knowledge and apply it to mainstream cash flow approaches, Free Cash Flow to Firm (FCFF), Free Cash Flow to Equity (FCFE), and Economic Value Added (EVA). It should be noted that the criterion for choosing the particular method depends on the objectives of the company, the internal control environment, the external information process, and the level of risk of misinterpretation by different shareholders.

The relation between capital structure and firm performance has a long history. In the literature on the subject, capital structure can be defined as the composition of equity and debt (Algieri, Aquino, Succurro, 2018). L. Gitman and C. Zutter stated the definition of capital structure as the mix of long-term debt and equity retained by a firm (Gitman, Zutter, 2012).

F. Modigliani and M. Miller have developed a fundamental theory of capital structure. They theorize that the firm's value and its investment decisions are not influenced by a capital structure. Thus, its own assets determine the company value (Modigliani, Miller, 1958). Couple of years later, F. Modigliani and M. Miller adjusted their assumption of a tax-free world. In other words, when the tax deductibility of interest payments enters the model, the value of firm increases with leverage (Modigliani, Miller, 1963).

Consequently, imperfect markets lead to theories that have been proposed as alternatives to F. Modigliani and M. Miller, namely, respectively: trade of theory (TOT), the pecking order theory (POT), the agency theory, the signaling theory.

In corporate finance, the POT theory assumes that the cost of financing increases as the company information is not 'convenience' from a business point of view. The financing of an enterprise can come from three sources (Mielcarz, Mlinarič, 2014):

1. internal (financed by net working capital),
2. external (credit, loan, bond issue),
3. issuing its own shares.

It can be concluded that the source of financing for investment projects and the related costs depend on the capital needs and the rating of the company (Myers, Majluf, 1984).

In turn, the theory of the TOT assumes that companies choose partial debt and equity financing to offset the costs and benefits of this form of financing (Murray, Goyal, 2011).

The signaling theory has been developed by S. Ross, suggests that the choice between debt and equity will result in a signal to the market (Ross, 1977). Firms only issue additional equity if the stock price is higher than true value, which causes a negative signal to investors, which could reduce the shares price (Steinkopf, 2015).

The agency theory, developed by M. Jensen and W. Meckling (Jensen, Meckling, 1976), and O. Hart and J. Moore (Hart, Moore, 1994). Such a theory argues that the optimal capital structure to maximize firm value is the one which minimizes conflicts of interest among shareholders, managers, and debt holders.

An essential prerequisite for ensuring the firm's market positions and good direction of development is the ability to make investment decisions. One of the components of efficient financial management of a company is that management strives to achieve the optimum level of financing. As a result, the investment decisions could lead to (Sierpińska, Jachna, 2012):

- Accepting or rejecting a specific investment projects.
- The ability to classify the investment project data according to the expected rate of return.
- The precise development of the budget for approved investment projects.

In the subject literature, we can meet the four stages of investment project appraisal (Sierpińska, Jachna, 2012):

1. identification of the project,
2. research and development,
3. project selection,
4. control over the projects carried out.

The above-mentioned stages of the realization of investment can be analyzed by using the same procedures and methods for estimating cash flows. R. Burns and J. Walker indicate that the project selection area is the most neglected and undiscovered area of budgeting (Burns, Walker, 2009).

Determining the NPV of investment projects which directly influence the company's value is one of the most common and intensively process, but at the same time it is relatively complicated thus can be viewed from many perspectives. C.A Magni raises the valuation problem of company and investment projects from the perspective of scenarios that can be implemented by the investors and owners (Magni, 2020). The issue of valuation is viewed from an accounting point of view which based on financial statements. This valuation method is determined by the accounting principles that present the current image of the company's performance (Accounting Act). Nevertheless, from the point of view of potential investors, the present value of future cash flows - possible to be realized by a given company in the form of implementation of given investment projects - is particularly important, because it may have a higher information value from their perspective (Penman, Yehuda, 2019). One of the most effective methods is the discounted cash flow method, which includes models based on FCFF and FCFE. The values obtained in this way can be used to determine the competitiveness of the

assessed company or investment project. On the other hand, the advantage of the EVA model over the cash flow model is that the EVA is a useful measure for understanding the sources of value in each individual year of an investment.

The literature on the subject lists many techniques for cash flow and discount rate calculation, where applied correctly should lead to an identical Net Present Value (NPV) (Michelon, Lunkes, Bornia, 2020). According to the authors, most of the investor society believes that net profit is the best factor that represents the financial situation of the company. Therefore, for example, the widespread use of the P/E ratio in practice (Ghaeli, 2017). However, net profit does not reflect two underlying factors, such as the risk that has been associated with the company since its inception (which also affects the structure and cost of capital) and does not consider the value of money over time. Efficient alternative to net profit are methods which relay on cash flow estimation. Based on the authors' practical experience valuing dozens of investments projects and entities, we focused our research on the most comprehensible and informative NPV calculation: FCFF, FCFE, and EVA. These approaches should lead to the same result in NPV calculation. It should be noted that interchangeability of assumptions often causes wrong conclusions that can be used to estimate the impact of the analyzed project on the value of the whole company. C. Drury and M. Tyles pointed out frequent misapplications due to project risk with manufacturing technologies (Drury, Tyles, 1997). R. Burns and J. Walker have also revealed an investment problem. They identified misapplications due to treatment of inflation in project valuation (Burns, Walker, 2009). P. Fernandez and A. Bilan listed 110 errors in six categories concerning company valuation (Fernandez, Bilan, 2013). We are faced with contradictory decisions where correctly applied techniques give the same NPV, but still can lead to decreasing value investment decisions. Many corporates compare expected investment returns to a hurdle rate (minimum acceptable rate of return). Nevertheless, plenty of studies indicate that hurdle rates differ from the standard cost of capital due to adding a buffer to the capital cost. Practice intimate that setting higher hurdle rate helps entities to focus on the best projects (Decaire, 2021).

In Section 1, the authors present a review of the relevant literature on capital budgeting techniques used by practitioners. Section 2 presents the three most common valuation approaches and ground for future discussion has been prepared. In Section 3 the authors show short numerical examples to demonstrate the divergence between the mentioned above methods. It helps to harmonize the final result of the study. The section also elaborates on the risk found in the FCFE application and the risk using Weighted Average Cost of Capital (WACC) of a particular investment project instead of the WACC of the company WACC. Final section summary of our major findings.

All three methods always give the same value if the input data are consistent within the estimation of the profitability of investment project. The result is logical, since all of them analyse the same hypotheses, they differ only in amount of cash flows considered at the early stage of investment. Thus, the main aim of this paper is to find advantages and limitations of

these three methods. The substantive review of these methods leads the conclusion of the choice of adequate method to assess the value of project, further the value of whole company. Therefore, the study findings are expected to benefit both academicians and practitioners. Academicians could assist their future research or revising curriculum adopted by business school by using article results. Practitioners could also draw many benefits. This study shows analysis, which could improve investment decision by using the right capital budgeting technique.

## 2. Literature review

There is no doubt that one of the most important parts of company value creation is the analysis and evaluation of investment projects and the decision which among them should be undertaken. Complex decisions and accompanying uncertainty in connection with future cash flow, as well as relation in technological and economic impacts on the calculation increase their complexity (Egbide, Uwalomwa, Agbude, 2013). Empirical research provides inconclusive evidence on project investment valuations among practitioners. A sample of research showed that payback period (PB) as the most popular technique, other ones indicate cash flow as the most frequently used budgeting technique (Andrés, Fuente, San Martin, 2015).

According to L. Alles (Alles et al., 2020), the selection of the appropriate technique can be influenced by both financial and non-financial factors. Research conducted in Tanzania indicated the following business-related factors: industry of the business, sales growth, and number of employees, which play a vital role in selecting capital budgeting methods (Katabi, Dimoso, 2016).

S.-O. Daunfeldt and F. Hartiwg showed that the choice between cash flow technique estimation of entities listed on Stockholm Stock Exchange depended on leverage, growth opportunities, dividend payout ratio, industry, and CEO personal traits (Daunfeldt, Hartiwg, 2014).

G. Kester and G. Robbins performed analysis on the Irish Stock Exchange on capital budgeting techniques used by Irish listed companies. The discounted cash flow method (DCF) and NPV was the most popular measure for capital budgeting decisions. Respondents also indicate for a single discount rate based on WACC as the most widely accepted method used for calculating discount rate (Kaster, Robins, 2011).

The study of 200 non-financial firms listed on the Pakistan Stock Exchange with a response rate of 35% found NPV and internal rate of return (IRR) for capital budgeting (61.4% of the respondents always use NPV). WACC is estimated using target value weights and capital assets pricing model (CAPM) is used to estimate cost of equity (Mubashar, Tariq, 2019).

The study of 75 listed companies of Morocco revealed that 64% of the firms used IRR, 63% accounting discount rate (ARR), but NPV is the least popular method (Baker et al., 2017).

The study conducted by P. Alleyne suggested that analyzed firms in Barbados are not likely to use capital budgeting practices in project selection (Alleyne et al., 2018).

Phone survey of 400 CEOs of small, medium, and large companies in the countries of central and Easter Europe showed that the choice of capital budgeting techniques depends on the size of the firm, the culture, the code of ethics. Larger firms used mostly the DCF method - 56%, which is more than small and medium companies - 46% (Andor et al., 2015). Other surveys which refer to CFO's, suggest that cash flow expectations play a significant role for both, investment plans and their realization. Thus, downside and upside scenarios are developed in the base case investments scenario (Bordalo et.al., 2020).

K. Bennouna stated that Canadian companies preferred to use NPV. 17% of the companies did not use DCF. Of these, the majority firms used NPV and IRR. Only 8% preferred real options implementation in the process of project selection (Bennouna et al., 2010). Recently studies also showed that subjectivity of the corporate managers leads to miscalibration of the IRR's outcomes which impact on the given entity capital structure policy (Shleifer, 2019; Barrero, 2022).

On the other hand, complementarity theory perspective says, that NPV analysis should be expanded including additional factors. Research performed by S. Ioulianou et.al. indicates that the real option, which could help to choose strategy investments directions is a key factor which should be considered. Various of studies states, that real option valuation combined with finance performance analysis – for example expressed through free cash flow, allow to increase the value of investments (Jensen, Kristensen, 2022; Belderbos et. al., 2019).

Comprehensive research of CFO responses of manufacturing and trading companies listed on the Colombo Stock Exchange revealed that NPV was the most used capital budgeting method and the most preferred method to calculating cost of capital was WACC (Nurullah, Kengatharan, 2015).

P. De Suoza and R. Lunkes investigated capital budgeting techniques used by practitioners in large Brazilian public interesting entities. They concluded that widely used methods are: PB (71%), closely followed by NPV (65%) and IRR (61%). Research also revealed that the most frequent practice used in calculating the rate of return is WACC (63%) (De Suoza, Lunkes, 2016).

The evidence from 77 companies listed on Bombay Stock Exchange reveals that managers follow capital budgeting practices proposed by academic theory – NPV and IRR techniques are to most popular (Batra, Verma, 2017).

T. Wnuk-Pel stated that Polish companies employ the same methods of capital budgeting as companies in more developing countries. The most extensively used techniques by entities are IRR and NPV (Wunk-Pel, 2015).

W. Rogowski, in his research, focused on investment practice in Polish companies. Findings reveal that Polish companies employ discounted methods (32%) or discounted and simple appraisal methods (39%) (Rogowski, 2013).

Mukhlynina and Nyborg found that almost 84% professional's analysts always or almost always use NPV valuation techniques (Mukhlynina, Nyborg, 2020). Their conclude that gap between theory and practice is wide. In authors opinion such conclusion creates needs for additional analysis which might help close the theory and practice.

The popularity of NPV among the presented studies, rise several questions which should be explored. For instance, whether each time managers with appropriates power of authority conduct detailed and consistent cash flow discount rate estimations? And whether changing in environmental nature of corporation have been properly reflected in their cash flow?

Bearing in mind performed literature review, following conclusion could be drawn: NPV method is a critical one, for assessing the profitability of the project investments. Considering techniques implications and the knowledge gap between theory and practice, create a strong argument to accomplish theoretical research which allow to indicate potential opportunities and threats from using the NPV techniques.

## 3. Choosing the optimal NPV calculation technique: FCFF, FCFE, EVA?

The methods of calculating cash flows have a fundamental character for the appropriate assessment of investment projects, as they cause a change in the cash flows generated by the entity treated as a whole. Contrary to appearances, the use of an appropriate technique of its estimation is not an easy task.

The FCFF technique is one of the most applied techniques in economic practice (Fernandez, 2007). It reflects free cash flows owed to all parties involved in the financing of the investment project. In this method, interest on debt capital is not considered because the cost of such financing is included in a discount rate expressed as an average weighted cost of capital. Therefore, including interests in the cash flow calculation using the FCFF method would lead to decreasing costs of debt and would unduly decrease the net present value of the project and thus the value of the whole company (Rogowski, Michalczewski, 2005).

The value of free cash flows for all funding parties can be calculated using the following formula (Mielcarz, Paszczyk, 2013):

$$FCFF = NOPAT + A - CI,$$

$$NOPAT = EBIT * (1 - TC),$$

where:

*NOPAT (net operating profit after tax)* – operating profit after tax,

*EBIT (earnings before interest and tax)* – gross profit + interest (financial cost),

*A* (*depreciation)* – depreciation costs,
*CI* (*capital invested*) – additional capital expenditure excluding expenditure incurred during the zero period and investments in net working capital,
*TC* – tax rate.

In the last period, the free cash flow should be increased by the residual value.

The subject literature interprets EBIT as operating profit (Mielcarz, Paszczyk, 2013). According to the authors, this is just a social approach. EBIT should be calculated as gross income plus interest. At first glance, one can claim EBIT does not differ from operating profit. However, EBIT does not include only this operating category of profit. The U.S. Securities and Exchange Commission interprets EBIT as follows (https://www.sec.gov/rules/final/33-8176.htm, before the beginning of 17.08.2021):

$$EBIT = net\ profit + tax + interest.$$

An incorrect interpretation of EBIT could lead to an incorrect calculation formula, which could negatively affect the valuation of investment projects.

According to the authors, the following formula can be used to calculate FCFF for a specific investment:

$$EBIT\ (adjusted) = Project\ revenue - Variable\ costs - rising\ fixed\ costs\ without\ depreciation - (tax\ depreciation).$$

The argument for considering tax depreciation instead of the balance sheet is that the level of the tax shield is affected by tax-deductible expenses (the balance sheet depreciation reflects only the economic consumption of the assets).

The calculation of NPV using the FCFF technique, assuming unchanged discount rate (WACC), should be based on the following formula (Fernandez, 2007):

$$NPV = -CAPEX_0 + \sum_{t=0}^{n} \frac{FCFF_t}{(1+WACC)^t},$$

where: $CAPEX_0$ - capital investment expenditures incurred in period 0.

A common formula to calculate the Weighted Average Cost of Capital is (Fernandez, 2020):

$$WACC = EU * re + UD * rd * (1-TC),$$

where:
*EU* - the share of equity in the structure of funding,
*re* - the cost of equity,
*UD* - is the share of debt in the structure of funding,
*rd* - the cost of debt.

The methodology for calculating FCFF and FCFE is set out in Table 1.

When FCFE is used, the free cash flow generated by the project reflects the flows which are only due to the owners of the company. According to this method, the interest on the debt is taken into account in the calculation. The FCFE technique measures investment outlays

differently, considering only those incurred by the company's owners. The discount rate is also set differently. FCFE, unlike the FCFF method, is discounted at the rate of return required by the owners. FCFE can be calculated using the following formula (Cegłowski, Podgórski, 2012):

$$FCFE = EBIT(adjusted) - Int - Tax + a - CAPEX - DN - DR,$$

where:

*INT (interest)* - interest on external capital,

*Tax* - the value of income tax paid,

*A (depreciation)* - depreciation costs,

*CAPEX* (*capital expenditures*) – expenditure for investment,

*DN (new assets)* - external resources for each period,

*DR (debt redemption)* – repayment of external capital in subsequent periods.

**Table 1.**
*Methodology for estimating the NPV using the FCFF and FCFE technique.*

| **FCFF during the project period** | **FCFE during the project period** |
|---|---|
| Revenue from sales<br>- variable costs<br>- fixed costs without depreciation<br>depreciation costs (tax)<br>**= EBIT** | Revenue from sales<br>- variable costs<br>- fixed costs without depreciation<br>depreciation costs (tax)<br>**= EBIT** |
| **FCFF during the project period** | **FCFE during the project period** |
| - income tax<br>**=NOPAT**<br>+ depreciation (tax)<br>- investments for net working capital<br>– additional investment expenditure<br>+ residual value | - interest on debt capital<br>**=Gross profit**<br>- income tax<br>**=Net profit**<br>+ depreciation (tax)<br>- investments for net working capital<br>– additional investment expenditure |
| **= FCFF** | + drawing of new credits/loans and other related charges<br>- repayment of external debt<br>+ residual value (due to owners of the enterprise)<br>**= FCFE** |

Source: Own analysis.

An important element in distinguishing the FCFF method compared to FCFE is the residual value treatment (Copeland, Koller, Murrin, 2020). The FCFE technique considers only and exclusively the funds belonging to owners (Szczepanowski, 2004).

Economic added value has been developed by Stern Steward & Co. It is defined as NOPAT less the cost of capital invested (Behera, 2020):

$$Eva = NOPAT - WACC * CAPEX_{T-1},$$

where: *CAPEX* - additional capital expenditure, excluding those incurred during the period T= 0, and expenditure on working capital requirement.

This method, like FCFE, assumes the calculation of the residual value attributable only to the owners of the company. EVA represents in a way the difference between the market value of the assets sold or liquidated and the value of the capital involved in the investment project in the last analysis period. It should also be noted that investment expenditure is treated differently.

They are not shown with a '-' and therefore EVA is adjusted by the weighted average cost of capital and additional investment costs (Maćkowiak, 2009).

## 4. Reconciliation of the NPV calculation using different calculation techniques: FCFF, FCFE and EVA

The process of estimating the NPV using the methods described in this article is illustrated by the following example.

The weighted average cost of capital for the example is as follows:

$$WACC= 0.4 * 4\% * (1-0.19) + 0.6 * 9\% = 6.69\%.$$

Based on the presented in-put data, the FCFF, FCFE, EVA calculation algorithms, NPV, and IRR values were calculated.

**Table 2.**
*Basic forecast data, for example*

| Data | Period | | | |
|---|---|---|---|---|
| | **0** | **0-1** | **1-2** | **2-3** |
| EBIT | | 1.100 | 1.500 | 1.800 |
| Tax rate | 19% | | | |
| CAPEX | 2.700 | | | |
| A | | 900 | 900 | 900 |
| Investments for net working capital | | 40 | 50 | 60 |
| Residual value for all financing parties | | | | 500 |
| UD | | 0.4 | 0.4 | 0.4 |
| EU | | 0.6 | 0.6 | 0.6 |
| $r_d$ | | 4% | 4% | 4% |
| $r_e$ | | 9% | 9% | 9% |

Source: Own calculations.

**Table 3.**
*FCFF calculation*

| Data | Period | | | |
|---|---|---|---|---|
| | **0** | **0-1** | **1-2** | **2-3** |
| **EBIT** | | 1.100 | 1.500 | 1.800 |
| Tax | | 209 | 285 | 342 |
| **= NOPAT** | | 891 | 1.215 | 1,458 |
| + depreciation | | 900 | 900 | 900 |
| Investments for net working capital | | 40 | 50 | 60 |
| CAPEX | | | | 2.700 |
| + residual value for all financing parties | | | | 500 |
| **FCFF** | -2.700 | 1.751 | 2.065 | 2.798 |
| **Discounted FCFF** | -2.700 | 1.641 | 1.813 | 2.303 |
| **NPV** | 3.058 | | | |
| **IRR** | 46% | | | |

Source: Own calculations.

According to Modigliani-Miller theory, which forms the basis for science on the valuation of companies, the value of the weighted average cost of equity should be calculated based on the market values of equity and debt (Grzywacz, 2012). In the assumption that the sample figures reflect the market values of individual equity and if the project will not change and constant structure of the company, it is possible to calculate the implicit values of debt and equity for the periods. For moment 0, we can therefore calculate:

$$D0 = 5.759 * 0.4 = 2.303,$$

where: *D0* - Value of the debt in period 0.

The results of the calculation of the project value and the implied debt at the end of each period are shown in the table below.

**Table 4.**
*Calculation of the value of the project and the debt at the different stages of its duration*

| Data | Symbol | 0 | 1 | 2 | 3 |
|---|---|---|---|---|---|
| The value of the project at the end of the period | *V(FCFF)* | 5.759 | 4.129 | 2.622 | 500 |
| The value of the debt at the end of the period | *D* | 2.303 | 1.652 | 1.049 | 200 |

Source: Own calculations.

The financing costs of the project using the FCFE method are calculated as the result of the capital cost and the value of the debt at the beginning of the period.

**Table 5.**
*FCFE calculation*

| Data | Period | | | |
|---|---|---|---|---|
| | 0 | 0-1 | 1-2 | 2-3 |
| **EBIT** | | 1.100 | 1.500 | 1.800 |
| financing costs | | 92.14 | 70.29 | 41.96 |
| **= gross profit** | | 1.008 | 1.430 | 1.758 |
| Tax | | 191 | 272 | 334 |
| **= net profit** | | 816 | 1.158 | 1.424 |
| + depreciation | | 900 | 900 | 900 |
| Investments for net working capital | | 40 | 50 | 60 |
| CAPEX | | | | 2.700 |
| +/- borrowing/repayment of credits | 2.303 | -546 | -708 | -849 |
| + residual value for owners | | | | 300 |
| **FCFE** | -397 | 1.130 | 1.300 | 1.715 |
| **Discounted FCFE** | -397 | 1.037 | 1.094 | 1.324 |
| **NPV** | 3.058 | | | |
| **IRR** | 263% | | | |

Source: Own calculations.

Calculating NPV based on the EVA methodology requires an estimate of the capital invested at the beginning of the period. It reflects the value of fixed assets and investments in net working capital, less depreciation costs. The calculation for period 1 is as follows:

$$EVA_1 = 891 - 6.69\% * 2700 = 710.$$

**Table 6.**
*EVA calculation*

| Data | Period | | | |
|---|---|---|---|---|
| | **0** | **0-1** | **1-2** | **2-3** |
| Capital invested | 0 | 2.700 | 1.840 | 990 |
| Depreciation | | 900 | 900 | 900 |
| + capital expenditure | 2.700 | 0 | 0 | 0 |
| + expenditure on net working capital | | 40 | 50 | 60 |
| = capital invested at the end of the period | 2.700 | 1.840 | 990 | 150 |
| NOPAT | | 891 | 1.215 | 1,458 |
| Economic added values | | 710 | 1.092 | 1.392 |
| Residual value (EVA) | | | | 350 |
| Economic value added + residual value | | 710 | 1.092 | 1.742 |
| Discounted EVA | | 665 | 959 | 1.434 |
| **NPV** | 3.058 | | | |

Source: Own calculations.

The presented example shows that using the market values of the capital involved in the WACC calculation leads to identical NPV results using different calculation techniques. Such a concept can lead to the conclusion that, in principle, the choice of the technique is irrelevant. According to the authors, this line of reasoning is wrong.

In the first instance, the authors of the paper decided to answer the question: Why FCFE method should not be used in the assessment of investment projects?

The first assumption is the scale of the company's business activity – from this point of view, it can be said that the presented example of investment project is relatively small. Therefore, a possible increase in debt should not significantly cause an increase in expected rates of return required by investors. The investment was financed with external capital at effective rate of 4% per annum, repaid over the next 5 years. The tax rate is 19%, while the rate of return expected by the owner is 9%. Three options for financing the project were considered:

1. No external capital.
2. A loan financing 75% of the initial capital expenditure.
3. A loan financing 100% of the initial capital expenditure.

**Table 7.**
*Basic forecast for Example 1*

| **Period** | **0** | **1** | **2** | **3** | **4** | **5** |
|---|---|---|---|---|---|---|
| Investment expenditures | -2,700 | | | | | |
| **FCFF** | **-2,700** | **650** | **650** | **650** | **650** | **650** |

Source: Own calculations.

In the absence of external financing, the NPV is: – 171.73.

The calculation of NPV with 75% loan financing allowed to increase the NPV value of the project, without changing its real profitability. This phenomenon is a consequence of the use of cheaper external capital instead of more expensive capital of the owners and the assumed lack of reaction from investors to a small increase in debt.

**Table 8.**
*NPV calculation based on FCFE technique for Example 2*

| Data | Symbol | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Free cash flow for all business financing parties | FCFF | -2,700 | 650 | 650 | 650 | 650 | 650 |
| + drawing credits | $D_N$ | 2,025 | | | | | |
| - credit pay-offs | $D_R$ | | 405 | 405 | 405 | 405 | 405 |
| - interest after the tax shield | *Int**(1-t) | | 65.61 | 63.48 | 61.43 | 59.44 | 57.51 |
| = free cash flow to equity | FCFE | -675.00 | 179.39 | 181.52 | 183.57 | 185.56 | 187.49 |
| **Discounted FCFE** | | -675.00 | 164.58 | 152.78 | 141.75 | 131.46 | 121.85 |
| **NPV** | | **37.42** | | | | | |

Source: Own calculations.

Calculations of the NPV value in the case of financing the project with 100% debt allowed to almost triple the NPV value compared to the involvement of external capital at the level of 75%. Thanks to incurring debt, the initial capital involvement of the owners decreases. This results in lower capital expenditures in the NPV calculation conducted using the FCFE technique. The loan is repaid later, but its cost is lower than the cost of equity. Thus, distant debt repayment is discounted at the expected rate of return by the owners i.e., rate of return higher than the cost of debt. According to the principles of financial mathematics, increasing the discount rate reduces the impact of distant cash flows on the valuation result. As a result, the NPV increases, and this effect is greater, the greater the difference between the cost of debt and equity is.

**Table 9.**
*NPV calculation based on FCFE technique for Example 3*

| Data | Symbol | 0 | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|---|
| Free cash flow for all business financing parties | FCFF | -2,700.00 | 650.00 | 650.00 | 650.00 | 650.00 | 650.00 |
| + drawing credits | Dn | 2,700.00 | | | | | |
| - credit pay-offs | Dr | | 540.00 | 540.00 | 540.00 | 540.00 | 540.00 |
| - interest after the tax shield | Int*(1-t) | | 87.48 | 84.65 | 81.90 | 79.25 | 76.68 |
| = free cash flow to equity | FCFE | 0.00 | 22.52 | 25.35 | 28.10 | 30.75 | 33.32 |
| **Discounted FCFE** | | 0.00 | 20.66 | 21.34 | 21.70 | 21.78 | 21.65 |
| **NPV** | | **107.14** | | | | | |

Source: Own calculations.

Nevertheless, the authors of the paper would like to emphasize that debt financing of further investments is consistent with the concept of value-based management, if the company has not yet reached the optimal level of debt. However, this approach carries some risks. The use of the FCFE technique may lead to the effect of displacement of projects for the implementation of which it is difficult to take bank loans. Therefore, it should be concluded that the use of the FCFE technique in the assessment of standard projects is not an effective solution from the perspective of the company's value management objectives.

The issue of traps related to the improper use of FCFF and EVA techniques using WACC associated with the project is another scenario which negatively impact on the entity value in the long-time horizon. NPV value was estimated using:

1. WACC at the level of the cost of capital from the perspective of company.
2. WACC of the investment project, if the company finances the project with 100% debt from the issue of bonds. It was assumed that the issue would be rolled, until the end of the project period.

The WACC calculation from the perspective of company is 6.98%. The NPV value of an investment can be calculated by using perpetual pension method.

$$NPV = -2.700+650/0.0698 = 6.612.$$

The WACC associated with the project is 3.24%:

$$WACC = 0*9\%+1*4\%*(1-0.19) = 3.24\%.$$

The NPV value is:

$$NPV = -2700+650/0.0324 = 17.361.$$

The calculation of NPV based on the WACC associated with the investment project, as opposed to the calculations based on the company WACC, indicates that the project is much more profitable. The result obtained is the effect of applying a lower discount rate in the case of a WACC calculation based on the structure of the project's capital. Such a result may suggest that the use of WACC associated with the project in the analysis allows to increase the attractiveness of the investment. The argument for rejecting such a line of thinking is exactly the same as that presented when discussing the problem of the failure to adapt the FCFE technique to the assessment of investment projects. The use of WACC calculated based on the project financing structure encourages the increasing indebtedness of the company. As a consequence, there may be a situation in which further loans will lead to an increase in the risk of the functioning of the entire enterprise, and thus to an increase in the company's WACC and, as a result, to a decrease in its value.

The following are arguments that indicate the danger associated with the assumption of full interchangeability of individual techniques.

- The compatibility of NPV results does not apply to the IRR calculated on the basis on FCFE, which is expected to be a return rate only for owners. Therefore, to get a full picture of profitability, the authors recommend that NPV calculations be made using the FCFF technique where the resulting IRR reflects the calculated rate of return for all parties involved in the financing. It must be noted that IRR technique has internal features that limit the possibility of its use in the evaluation of investment projects in accordance with the concept of value management. The IRR assumes a reinvestment rate detached from market realities. The discount rate, and thus also the reinvestment, is not the rate of return that can be obtained under current conditions. This is the result of the mathematical exclusion of the discount rate equal to positive and negative cash flows.

- Whereas the EVA technique makes it impossible to calculate the IRR.
- The use of FCFE creates risks in making investment decisions that do not meet the expectations of the company owners. By applying an additional external debt, it decreases the capital exposure of the owners. The repayment of the debt is discounted at the rate of return requested by the owners (in principle higher than the cost of the debt). According to the principles of financial mathematics, an increase in the discount rate reduces the impact of distant cash flows. As a result, NPV increases. The greater the effect, the greater the difference between the cost of debt and equity are.
- Implementation in the NPV calculation process, WACC adequate just for the project, may suggest increasing the project's profitability. The mechanism when using the weighted average cost of capital budgeted based on the project financing structure carries similar risks as when using FCFE. In other words, the use of the WACC project in the cost-effectiveness analysis encourages the company to increase its debt. As a result, this can prove the risk of the whole business, increase the company's WACC, and decrease its company value.

It should be noted that, in a time of increasing globalization and changing environment, accurate investment decisions require flexibility. The answer to these requirements may be to expand the standard analyzes presented in this work by adding an analysis of the 'real options' (Gnap, 2017).

## 5. Conclusions and Discussions

In the study, the authors paid attention to the technical aspect of the calculation of free cash flows. Each technique has limitations, but the most important thing is the ability to identify these inaccuracies. Although the NPV estimation indicates the profitability of a specific investment project, this option may vary without the consequences of applying the initial assumptions. To present comprehensive profitability for different investors, one should calculate NPV and IRR based on FCFF technique. The EVA technique does not allow for calculating IRR, its algorithm is not commonly known.

When using WACC instead of marginal cost of the whole company leads to higher risk of over/underinvesting company. Furthermore, the discounted FCFF by the WACC company rather than the project should be pointed out as the appropriate solution.

Among the many methods, the FCFF technique appears to be the most 'secure' in terms of creating additional value for a company by carrying out the most profitable projects.

From the other hand, increase of WACC of the special purpose vehicle (SPV) does not rise WACC of the holding entity. In other words, the level of investment diversification by holding entity should allow using project WACC rather than superior entity WACC due to fact that potential operating losses could be amortized amongst other investments (high level of debt in SPV).

Choosing appropriate NPV technique is pivotal from the perspective of corporate sustainability. Presented results were derived from the qualitative analysis. Used methodology of computing free cash flow is align with studies referred to capital budgeting decision making. Presented by the authors methodological approach showed that there could be a good and productive partnership between the practitioners and academicians to develop capital budgeting knowledge. The following implications are noteworthy to report:

- Practitioners must develop their knowledge about the application of the appropriate technique to apprise the investment projects. Systematic training about valuation techniques is critical for a sustainable capital budget under uncertain economic environment.
- Complex and uncertain environment where entity operates should cause requirement of real option implementations into the profitability analysis.

Future scope of the research could be expended on: ESG concept (Environmental, Social and Corporate Governance) on modern projects investments, or post-covid-19 inflation impact on innovation projects which are facing with unstable macroeconomically factors.

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# APPLICATION OF INDUSTRIAL E-LEARNING IN THE PROCESS OF IMPLEMENTING THE STRATEGY OF GRUPA AZOTY S.A. – A CASE STUDY

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**Purpose:** The aim of the research described in this article is to specify the possibilities offered by e-learning, used in achieving the strategic goals of Grupa Azoty S.A. (within the scope appropriate for the research subject), as well as a process supporting strategy implementation.
**Design/methodology/approach:** Systematic literature review and content analysis (including internal documents). Interviews with selected managers of the studied company and specialists dealing with IT, general management, and staff development; self-observation; average rank method.
**Findings:** The specification of possibilities offered by e-learning in the process of strategy implementation has been determined, respondents' opinions have been collected, and ranks have been assigned to individual factors, indicated by respondents during the interviews.
**Research limitations/implications:** Research available in the literature refers exclusively to its training and educational functions (in the classic sense - acquiring knowledge). Industrial e-learning is a poorly recognizable construct and therefore arbitrarily interpreted, conceptually ungrounded, and subjectively defined. This is a significant limitation because, in the case of industrial e-learning, its repository function (knowledge available at your fingertips without the need to assimilate it) and monitoring, as in the described case, the implementation of strategic tasks are more important.
**Practical implications:** For the examined company, this means the necessity of building awareness of e-learning itself, its capabilities, and applications, not so much in training but as an essential repository of unique/unavailable online knowledge and as a supportive process throughout the entire stage of strategy implementation and execution.
**Originality/value:** The content of the article goes beyond the framework set in the literature, which deals with e-learning in a classical (educational and training) approach. There is a lack of research on e-learning treated as a process/tool (depending on the adopted semantic perspective) supporting the implementation of a company's strategy. There is also a lack of research on industrial e-learning. This article is an attempt to fill this gap.

**Keywords:** industrial e-learning, e-learning as a process, implementation/execution of the strategy, chemical industry.

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

## 1. Introduction

Currently, e-learning as an educational tool, used in both academic and corporate environments, is significantly gaining popularity. Undoubtedly, this is related to the development of information technologies and their accessibility to an increasingly wider audience. The dynamic development of online tools also stems from the fact that they have proven themselves in crisis situations, particularly during the SARS-CoV-2 pandemic.

In the vast majority of cases, e-learning is understood classically, i.e., as a platform/ repository/tool that enables the realization of educational tasks. Its effectiveness has been confirmed by the experience of isolation, where, without such tools and their basic educational functions, there would be a paralysis of the education system or higher education. Initially implemented as a tool supporting educational and training processes, facilitating access to educational offerings, and enhancing the form of delivery or attractiveness of content, e-learning has ultimately become an unexpected lifeline. It has prevented the paralysis of the education system. The forms and types of e-learning described in the literature mainly focus on its functionalities related to the dissemination and diffusion of knowledge. They are based on user opinions, beneficiaries, etc., to improve this tool as a useful, time-reducing training and educational platform. These are the main research trends illustrating the effectiveness of this tool as a praxeological category. Upon reviewing the literature, it can be concluded that there is a lack of research on e-learning as a process/tool (depending on the adopted semantic perspective) supporting the implementation of corporate strategy.

In the authors' opinion, e-learning has many possibilities, the functionality of which has not yet been identified, let alone studied. Assuming this premise and taking into account the fact of developing and approving a strategic plan for the period 2022-2030 in the economic entity under study, it seems reasonable to assess the usefulness of e-learning in implementing the newly adopted strategy.

The Grupa Azoty Capital Group's strategy is divided into two parts: corporate and segmental. By providing safe chemistry and implementing modern solutions that meet stakeholder expectations in harmony with the environment, the company indicates development directions up to 2030. The Group's strategy also includes looking forward to artificial intelligence (Kądzielawski, 2022). The actions contained in the strategy are subordinated to the basic pursuit of organizational excellence through continuous improvement of processes, systems, and the entire organization (Chojnacka, 2014). In this way, the company aims to increase value in the areas of environmental protection, energy transformation, and product development. It also aims at the development and professionalization of personnel, increasing motivation, especially focused on the goals arising from the "Green Deal" (Szeliga-Duchnowska, 2021). The realization of objectives focuses on the category of "Green Nitrogen", becoming the leitmotif that shapes the role and significance of the Group in implementing and

anticipating pro-ecological megatrends, as well as raising awareness of the fundamental values guiding the Group. These include preserving the natural environment, essential resources, concern for future generations, etc., constituting the axiological foundation of the Azoty Group's activities (Goranczewski, Kądzielawski, 2022). Therefore, taking into account mainly energy transformation, reducing harmful emissions to the environment, or introducing biodegradable products, the company identifies several key strategic areas, which are:

- Raw material diversification in the "green" direction.
- Implementation of the developed ESG strategy and its reporting to the market.
- Actions aimed at decarbonization and reducing environmentally harmful emissions.
- The "Green Hydrogen" project.
- The "Green Ammonia" project.

**The purpose of the research described in this article is to specify the possibilities offered by employing e-learning in the implementation and realization of the strategic objectives of Grupa Azoty S.A. (within the scope relevant for the research subject) and as a process supporting the implementation of the strategy. Based on the objective specified above, the following research questions were formulated:**

P.1 How can e-learning be incorporated into the realization of business objectives resulting from the overall "Green Nitrogen" strategy?

P.2 How can e-learning support the process of strategy implementation?

## 2. Research Method

To conduct research related to explaining the research problems formulated above, qualitative tools were used. The presented research problems have a utilitarian nature, applicable in the studied economic entity. They also have an explanatory character, explaining the specifics of industrial e-learning, different in its functionality from educational e-learning, but preserving the essence of e-learning as a source of knowledge in the organization (Łukaszczykiewicz, 2022). Such formulated research objectives and methods selected to explain them, in accordance with generally accepted principles, do not require the formulation of hypotheses (Kostera, 2003). The primary goal of the conducted research is to determine the possibilities of using e-learning as a process supporting the implementation of the Grupa Azoty S.A. strategy. Taking this into consideration, the authors applied the following research methods:

1. Systematic literature review and content analysis (including internal documents). Specification of keywords such as industrial e-learning, strategy, implementation, e-learning in the work environment, e-learning as a process was performed. Based on this, a query of articles containing the above keywords was conducted in scientific

databases such as: Academic Search Ultimate, including Business Source Ultimate, Education Resources Information Center, AGRICOLA, Open Dissertations, Green FILE, Newspaper Source, and Google Scholar. While educational e-learning is represented on a large scale in available literature, industrial e-learning or process-oriented (standardized) e-learning is represented in a small number of records. Hence, it may be considered a niche area. The same applies to e-learning as a process supporting strategy implementation. No such publications were found concerning the chemical sector. Next, the content of the available articles was reviewed, and the collected research material was organized (e.g., Łuczewski, Bednarz-Łuczewska, 2012; Easterby-Smith, Thorne, Jackson, 2015).

2. Interviews with selected managers of the studied company and specialists dealing with IT, general management, or personnel development. It was assumed that these people could have a general orientation in the issue of using e-learning in the work environment (Gudkova, 2012).
3. Self-observation (the authors are employees of the entity in which the research was conducted) (Ciesielska, Wolanik, Boström, Öhlander, 2012; Goranczewski, 2018).
4. To maintain the principle of triangulation, using interviews conducted with key individuals, the average rank method was introduced, treating respondents discussing the application of e-learning in the strategy implementation process as experts (Cabała, 2010). Each of them received a table with 9 factors, which they then ranked from 1-5, where 1 meant the smallest impact and 5 the greatest impact on strategy implementation.

The research was conducted in January and February 2023 at Zakłady Azotowe Kędzierzyn SA, a member of Grupa Azoty SA, engaged in the production of nitrogen fertilizers, chemicals, and OXO alcohols and plasticizers. The basis for the research was the general strategy guidelines of Grupa Azoty S.A. for 2021-2030, along with indications (operationalization) of these guidelines for the entity constituting the research area. Respondents were therefore tasked with defining the role of e-learning as a support process in strategy implementation at the level of the studied company and the tasks carried out in this area. The selection of the studied entity was purposive. The conducted research is related to a scientific conference co-organized by Grupa Azoty Zakłady Azotowe Kędzierzyn S.A. and the Jagiellonian University. Its participants , including PhD students working in the company and external guests, were tasked with evaluating the newly developed strategy from the perspective of their research interests. The selection of respondents with whom the research was conducted was similar. Considering the strategic document, the focus was on representatives of managerial staff, who have a key role/responsibility for effective strategy implementation. Due to the specificity of the research area, the set of respondents was supplemented with people dealing with IT in the organization.

## 3. Literature review

Currently, in the scientific literature, we can observe a renewed increase in interest in the topic of e-learning. As mentioned earlier, this interest was triggered by the pandemic, which forced entrepreneurs to entrust employees with remote work. It is also a result of the growing interest of new generations of employees, including Generation Y, Generation Z, or "Millennials," entering the labor market, further freedom and universalization of performed activities, and the possibility of working in a sufficiently flexible way (Kotnis, 2005). Work that allows for the completion of tasks from any chosen location. The constant growth of interest in e-learning is also a consequence of digitization moving towards the model situation of Industry 4.0, currently being modified towards 5.0 to not forget about people in digitalization processes (Grabowska, 2018). The conducted literature review indicates that publications on e-learning can be divided into those which:

- refer to e-learning as a training tool used in academic environments, as well as those which
- are used in corporate environments.

Among the numerous articles examining e-learning in corporate environments, we can notice publications regarding factors determining the effective implementation of e-learning platforms, the reception of implemented tools by users, e-learning as an integral part of HR policy (Żołędziewski, 2011), and the effectiveness of e-learning (Bizon, 2011). In the available literature, there are no studies on the impact of e-learning on strategy implementation. According to M.E. Porter (1980), a company's strategy is one of the most important documents determining the company's development directions, affecting its success or failure. The information contained therein directly translates into the organization's future, and as a result, the achievement of set goals. However, strategy implementation in literature is described by P. Wołczek (2012) as the weakest link in strategic management, resulting, among others, from a lack of proper communication, misunderstanding of strategy, or lack of knowledge about the role of employees in implementing strategic actions. In the current turbulent times, additional factors not previously present, such as crises or catastrophes, which we are currently experiencing, are added. As a result, the directions of raw material supplies change, planning processes become inefficient, logistics chains are broken, overloaded, etc. All this requires immediate corrections in the strategies implemented by economic entities (e.g., Stoner, Freeman, Gilbert, 1997). The literature review shows that merely establishing a strategy is only half the success. Without implementing tasks resulting from such a document, daily duties of the entire organization, there can be no talk of achieving strategic success (e.g., Obłój, 2014; Gierszewska, Romanowska, 2009; Chojnacka, 2021). It is also the complementarity and joint "effort" of all systems and tools in the organization, including the tool that is e-learning. From the conducted literature review and the trace results of the research

presented there, which could be attributed to the research objective indicated in the introduction, it follows that e-learning increases the competitive advantage in higher education (Gregorczyk, 2010), or the development of managerial competencies (Ratalewska, Szymańska, 2013). which have a real impact on the implementation of the strategy (Halina, 2002). Researchers such as Bai, Y., Li, H., Liu, Y. (2021) point out that, in the perspective of the last 10 years, we can observe the dynamic development of research on e-learning in various contexts and reference criteria. E-learning itself is no longer treated exclusively as a tool (e.g., Łukaszczykiewicz, 2022; Borowiec, 2019). From the available literature, it appears that the main research trend is currently determining/identifying the processes of effective implementation, design, and evaluation of e-learning (e.g., Fee, 2013; Lin, Chen, Nien, 2014; Graves, 2001). However, this does not change the fact that despite pointing to the diversity of research, their number is scant, and the understanding of the essence of e-learning remains unchanged. It is education and training that set the research trends represented in the literature. Hence, for example, there is a lack of research that would determine how/if e-learning affects the strategy implementation process? What factors determine the effectiveness of implementation, which experts involved in strategy implementation and/or employees assigned to perform such tasks would assess/categorize/rank from the point of view of their importance and validity, as key? It can be assumed that such factors are not only universal. They may also have a specific character resulting from conditions such as:

- the type and form of the entity implementing the strategy,
- the sector/industry in which the strategy is to be implemented,
- the level of detail/cascading of actions related to the implementation of the strategy (very well described and ordered by the BSC method (Kaplan, Norton, 2009), in which so-called CAMs (goal, activity, indicator) are formulated),
- the selection of priorities and focusing on them to improve the effectiveness of the entire strategy and concentrate on important matters.

In all these areas, the role and influence of e-learning as a utilitarian tool supporting implementation processes should be sought. Thus, we are dealing with semantic dualism:

- e-learning as a process (in a subjective approach) supporting the implementation of the strategy, both in its general dimension and in specific objectives,
- e-learning, in an attributive approach, as a tool supporting the implementation processes detailed in the organization's strategy document and the resulting operationalizing documents.

The above collection of research possibilities in the field of e-learning could undoubtedly be even longer. The literature does not mention this, which means that researchers do not undertake such research topics, remaining in the sphere of straightforward training or classical education. For example, Mastalerz (2010) mentions that in times of crisis, companies reducing costs related to education and employee development should treat e-learning as a tool enabling

cheaper education substitute. On the other hand, Kępińska-Jakubiec, Majewski (2009) indicate that the application of an appropriate training base, allowing for the effective use of e-learning, supports both the strategy and the company's goals.

## 4. Results of the conducted own research

Solving the problems presented in the introduction required determining the research questions to be directed to the respondents during the interviews. Anticipating difficulties with interpreting the category of industrial e-learning, in order to facilitate the respondents understanding of the essence of this conceptual category, the set of asked questions related predominantly to the possibility of using e-learning within the organizational areas the respondents are currently assigned to. Tables 1 and 2 present the results of the conducted interviews in relation to problems P1 and P2. To maintain the principle of confidentiality/ ensuring the sense of security of respondents, it was decided that job titles or organizational areas will not be provided, and gender and age will be coded in the following way:

- A - Top management (board, directors of units and departments).
- B - Middle management (office and department managers).
- C - Independent employees (coordinators, specialists).
- Age range of work experience (D - 1-10; E - 11-20; F - 21-35).

**Table 1.**
*Findings in relation to P1 (N = 15)*

| Question number | Content of the question | Sample/most common answers with respondent code |
|---|---|---|
| 1.1 | What knowledge/information is necessary to achieve the business objectives resulting from the Green Nitrogen Strategy? | *"... knowledge and resources accumulated in the Capital Group over the past years..." A*/E<br>*"... a description of the main strategic objectives and initiatives to achieve those objectives..."* C/E<br>*"... the status of creating new products, reporting energy consumption levels, the status of implementation of a given investment, monitoring the market situation (competition, prices of services, raw materials...) ...*" B/E<br>*"... general knowledge of development directions and trends, both national and European..."* B/E<br>*"... employees' knowledge of the strategy, their awareness and understanding of the purposefulness of the implemented changes..."* A/F<br>*"... financial, industry and green technology trends..."* A/F |

Cont. table 1.

| | | |
|---|---|---|
| 1.2 | Where should you look for sources of knowledge, access to this information? | *"... inside the organization, currently knowledge very often remains underused – inventoried... "*A/E<br>*"... in Grupa Azoty's strategy for 2021-2030..."* B/E<br>*"... in industry-related publications, conference materials and portfolios of other companies in the industry..."* C/D<br>*"... in market analyses provided by corporate offices..."* A/F<br>*"... Currently, this knowledge is dispersed and not developed within the organization..."* B/E<br>*"... on the company's intranet..."* C/E |
| 1.3 | What should the form of conveying this information look like: flowcharts, infographics, VR, text? | *"... the form should be tailored to the users, intuitive, fast, supported by artificial intelligence..."* A/E<br>*"... a combination of different forms, concise texts, animations and infographics..."* C/E<br>*".. infographics, short form of transmitted content, VR..."* B/E<br>*"... tailored to the content, not based only on one form, concise but not monotonous..."* B/E<br>*"... containing infographics and flowcharts as well as sample simulations and scenes..."* A/F<br>*"... tailored to the type of information transmitted... synthetic and kept to a minimum."* A/F<br>*"... flowcharts or texts in the form of abstracts with reference to source materials..."* C/A<br>*"... any form depending on specific areas of the company..."* B/E |
| 1.4 | How can e-learning fit into the succession strategy of key employees and/or managers necessary and important to achieve strategic goals? | *"... Industrial e-learning is absolutely part of the strategy of succession of key employees and/or managerial staff. Maintaining aggregated knowledge about business goals, based on collected and systematized data, enables effective management of the change process, reducing risks and increasing efficiency. ."* A/E<br>*"... the e-learning platform may be a base for training and didactic materials created with the participation of persons performing strategic functions in the Company. This would allow to supplement the necessary theoretical knowledge with information on specific experience gained in a given position + building a database of files made available by people in key positions (transfer of developed know-how)..." C*/E |
| 1.5 | How does e-learning affect employees' ability to accept changes related to the implementation of the strategy? | "*... Building awareness and adapting to employee changes takes a long time and without access to knowledge raises many barriers...*" B/E<br>"*... Well-prepared e-learning builds awareness in Just in Time...*" A/F |

Source: Own elaboration based on conducted interviews.

In relation to the first research problem, respondents indicate a whole spectrum of knowledge relevant from the point of view of strategy implementation, starting from historical knowledge, affecting, for example, the ability to reproduce assets, to the prospective scope in terms of trends and directions of development of industries and the sector in which the research subject operates. Respondents point to the importance of both the external sources of knowledge (market analyses, industry studies, prepared by specialized entities) and internal ones, such as corporate materials, developed by internal services. Everyone wants the form of conveying available information to be as simple as possible, i.e., concise, engaging, and not monotonous. From conversations with respondents, it appears that e-learning is primarily associated with training.

In the next table, selected statements of the respondents related to the second research problem are presented.

**Table 2.**
*Research results in relation to P2 (N = 15)*

| Question number | Content of the question | Sample / most common answers with respondent code |
|---|---|---|
| 2.1 | Does e-learning increase employee involvement in the implementation process, and if so, why? | *"... Yes, because it has a chance to engage more employees."* C/E<br>*"... Definitely... the use of such tools makes employees feel directly responsible..."* A/E<br>*"... Yes, the employee is more motivated to receive basic information and does not waste time looking for information..."* B/E<br>*"... Yes, making employees aware of goals and their role in achieving those goals makes them feel part of the organization..."* A/F<br>*"... so can contribute to the increase of employees' awareness..."* A/F<br>*"... yes, because it allows you to monitor the progress of work on an ongoing basis..."* B/E |
| 2.2 | How does e-learning affect the effectiveness of providing information about the strategy to employees? | *"... allows for quick transmission of complete information..."* B/E<br>*"... allows multiple playbacks, is available at any time..."* A/F<br>*"... through the speed and contextuality of information..."* A/F<br>*"... the ability to access information at any time"* C/D<br>*"... access to knowledge "Here and Now"..."* B/E |
| 2.3 | How e-learning affects the ability of employees to embrace changes related to the implementation of the strategy | *"... allows to remove barriers and improve internal communication..."* B/E<br>*"... makes it easy to access and review the proposed changes anytime, anywhere..."* C/D<br>*".. allows for faster decision-making, reduces reaction time..."* B/E<br>*"... allows for prior assimilation/acceptance of upcoming changes..."* B/E<br>*"... supports the management of the cycle of change, eliminating the negative approach resulting from fears, leaving the comfort zone and thought patterns..."* A/E<br>*"... building awareness and adapting to employee changes takes a long time and without access to knowledge raises many barriers..."* B/E |
| 2.4 | How e-learning can increase employee motivation to achieve business goals | *"... through the exchange of experience, monitoring the implementation of projects..." A* /E<br>*"... By making employees aware of goals and their role in achieving these goals, it makes them feel part of the organization... have a real impact on the implementation of the strategy..." A* /F<br>*"... involving employees in individual processes, assigning specific tasks..., showing the benefits..."* C/E |

Source: Own elaboration based on conducted interviews.

The majority of respondents indicate that e-learning will have a positive impact on engagement in the implementation of tasks resulting from the strategy, on time-saving, on increased awareness, and consequently on motivation and commitment. Respondents emphasize the speed of access to information as an essential attribute of effective task execution, treating these two categories equivalently. Change management is crucial in strategy implementation; therefore, the people with whom the research was conducted see a positive

influence of e-learning. Mainly by shortening the change cycle due to information availability, greater awareness, the opportunity to familiarize oneself with planned changes beforehand, and the ability to adapt to them.

Taking into account the material collected during the interviews, it was decided that it is worth getting acquainted with the respondents' opinions on the importance of factors determining the effectiveness of e-learning in the process of strategy implementation. After collecting and processing the factual material, respondents were asked to assign importance to individual factors, and then the method of average ranks was applied.

**Table 3.**
*Experts' perception of the importance of individual factors*

| Factors | Ranks averaged | Rank |
|---|---|---|
| K1-Building employee awareness - help in understanding the company's strategy | 2,23 | 1 |
| K2-Defining the role of employees in achieving strategic goals | 2,37 | 2 |
| K3-Possibility of continuous monitoring of the progress of strategic activities | 4,43 | 4 |
| K4-Real impact of employees on the implementation of strategic goals | 3,77 | 3 |
| K5-Easy access to the necessary strategic assumptions | 5,47 | 6 |
| K6-Access to strategy-related training and courses | 5,63 | 7 |
| K7-Possibility to broaden knowledge of strategy at a distance | 8,57 | 9 |
| K8-Motivating and encouraging employees to exchange knowledge on strategy | 7,87 | 8 |
| K9-Access to expertise (not widely available on the Internet) necessary to carry out tasks in real time. Easily digestible message that does not require industry education | 4,73 | 5 |

Source: Own elaboration based on conducted interviews.

In order to examine the consistency of the experts' opinions obtained, the Kendall's coefficient was calculated.

$$W = \frac{S}{S_{max} - mT} = \frac{\sum_{j}^{n}=1\left(R_j - \frac{m(n+1)}{2}\right)^2}{\frac{1}{12}m^2(n^2-n) - mT} = 0.687 \quad (1)$$

The value of the coefficient equal to 0.687 indicates moderate agreement between experts' opinions. Therefore, it can be considered that the opinions of experts were not random. Experts indicated that the most important factor is building employee awareness and helping them understand the company's strategy. This means that from the experts' point of view, understanding the strategy and building awareness is the most important factor supporting its implementation. The least important factor, on the other hand, is the possibility of expanding knowledge remotely, which paradoxically constitutes the essence of the main research trends in the literature on the subject.

## 5. Conclusions

The final ranking order is shown in Table 3, based on which, taking into account the respondents' perspective, the following conclusions can be drawn. Building employee awareness and thus helping them understand the company's strategy is the foremost attribute of e-learning. In terms of strategy implementation, this is of key importance, which is associated with the distribution of information that contains the message - the idea - the values carried by the strategy. This is the foundation for identifying with its guidelines. Next, the respondents point to other groups of factors:

- access to knowledge not easily accessible online (in real-time), necessary for task execution; shortening the time needed to search for information, including easily digestible messages that do not require industry-specific education, facilitating the ability to monitor progress,
- familiarity with roles in the implementation of individual tasks.

As mentioned in the previous subsection, paradoxically, the possibility of expanding knowledge and access to courses was placed at the bottom of the list despite its relation to building awareness seen as the basic attribute of e-learning's role in the strategy implementation process. This confirms the fact that respondents (consciously or not) seek e-learning more for its repository function, enabling free access to easily digestible specialist knowledge, or for its function of monitoring progress in work related to strategy implementation, than for becoming a source of training materials. On the other hand, the research results show that respondents who deal with this tool treat it by default as an instrument supporting the education process, mainly in supportive areas such as occupational health and safety, or, for example, a collection of instructions for using IT applications, etc. Thus, they see its functionalities primarily in the area of "pure" training. Industrial e-learning is a poorly recognizable and therefore arbitrarily interpreted construct, conceptually ungrounded, and subjectively defined. Since this applies to both the authors of publications, who, with their work, create the possibilities and functionalities of e-learning (see the publication trends in the "literature review" subsection), it cannot be different in the environment of practitioners who derive their knowledge from the researchers' environment. Hence, both in the literature and among respondents, the classical understanding dominates. Also understood as a process (e.g., according to the ISO nomenclature), e-learning is unrecognizable to respondents. Taking into account the utilitarian nature of the research problems (significant for the entity constituting the research area) but also their cognitive dimension, it can be considered that the research objective has been achieved. The specification of possibilities that e-learning brings in the strategy implementation process was determined, respondents' opinions were collected, and rankings were assigned to individual factors indicated by respondents during the interviews. As a general conclusion from the conducted research,

it is necessary to build awareness about e-learning itself, its possibilities, and applications, not so much in terms of training but as an essential repository of unique/unavailable online knowledge and as a supportive process throughout the entire stage of strategy implementation and realization.

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# ASSESSING RISKY BEHAVIOR BASED ON SURVEY RESEARCH AMONG MINE RESCUERS

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**Purpose:** The aim of the paper was to analyze risky behavior in the mining industry on the example of survey research among mine rescuers.
**Design/methodology/approach:** The analysis of risky behaviors concerned the mine rescue service crew in a selected hard coal mine. The author's method of synthetic assessment of risky behaviors was used for the research. The surveys was conducted during rescue training on a group of 30 mine rescuers, which accounted for 25% of the crew's record.
**Findings:** The article presents the results of a study of synthetic assessment of mine rescuers according to six problem areas (assessment parameters). The synthetic assessment of risky behavior is a method that allows individual assessment for each respondent in all areas. If one of the areas receives an abnormal rank, only one selected area can be re-evaluated after applying suggestions for improvement. Survey questionnaires consisting of closed-ended questions were used for each area. All respondents were given an option to give either affirmative or negative responses. Having obtained the sum of the assessment criterion ranks for each area, a synthetic assessment of risky behavior was interpreted for the surveyed mine rescuers. The summative assessment was then interpreted on a four-point scale: outstanding, satisfactory, normal, and abnormal. Out of the entire study group, only two subjects received an abnormal rating, each in one of the areas; the first respondent in the area of risky behavior, the second respondent in the area of risky behavior in situations of unbreathable air. For these two mine rescuers, detailed results for all areas were presented.
**Research limitations/implications**: The research was dedicated to working conditions underground, but they can be adapted to working conditions on the surface, as well as to the specificity of other rescue services (e.g. firefighters, rescuers).
**Practical implications:** The results of the research can be used as criteria for the selection of mine rescuers for the mine rescue service (rescue emergencies, rescue teams).
**Originality/value:** The publication contains original results of research on risky behavior of mine rescuers, and they are addressed to the management of mining plants.

**Keywords:** risky behavior, survey research, underground mining, mine rescue.

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

## 1. Introduction

Decisions about risky behavior are most often made at the time of danger (such as a fire, evacuation or accident), under time pressure (when a decision must be made immediately or quickly), under conditions of uncertainty or lack of complete information. Risky behavior is observed, for example, when self-rescuing or rescuing others, but such behavior is exhibited not only by those with a high propensity for risk.

In 2017, a monograph was published (Grodzicka), which presents a proposal for a synthetic assessment of the risky behavior of mine rescuers for six areas (assessment parameters). Another monograph (Grodzicka, Krause, Plewa) was published in 2021, proposing a methodology basis for analyzing risky behavior among mine rescuers. An example of the use of a synthetic assessment of the risky behavior of mine rescuers for the purpose of recruiting workers for the ventilation system has been shown in one publication (Grodzicka et al., 2022).

The provisions of the Geological and Mining Law (2011 as amended) and the Executive Order on Mine Rescue (2017 as amended) provide a legal basis for the organization of rescue drills in coal mines. In addition, in the regulation (2017 as amended) in § 60.6, the curricula of specialist courses include in particular issues related to e.g. natural and technical hazards (item 5), first aid to victims (item 7) and the psychology of behavior of mine rescuers and action leaders (item 8).

The leading entity professionally engaged in mine rescue in Poland is Centralna Stacja Ratownictwa Górniczego S.A (The Central Mine Rescue Station) in Bytom city, which conducts rescue operations in the mining industry; not only in mining plants. Due to its specialized staff and the necessary equipment at the plant, it can carry out operations according to the established rescue emergencies: mining and technical emergency, fire emergency, air inerting emergency, water emergency, measuring emergency, and emergency of mobile rescue lifts.

## 2. Outline of methodology for analyzing risky behavior

Based on the literature, studies of risky behavior mainly focus on occupational accident analysis, occupational risk assessment, management systems, and safety culture. In any workplace, occupational health and safety should be an important part of both company policy and management system. The current approach to consciously shaping human behavior in an organization is to raise the level of safety culture, which can be assessed by research and analysis on perceptions of safety issues and risks.

Risky behavior has been the subject or element of many publications, and the basic theoretical and methodological premises for analyzing risky behavior are discussed in the following compact publications (monographs and manuals), which deal with the following applications, among other issues (chronologically):

- general applications outside the mining industry, such as: Studenski (1996), Goszczyńska (1997), Studenski et al. (2004), Studenski (2004), Goszczyńska, Studenski et al. (2006), Odachowska et al. (2012), Farnicka, Izdebski, Wąż et al. (2014), Dubis et al. (2017), Kwiatkowska, Siudem et al. (2017),
- detailed applications inside the mining industry, such as: Grodzicka (2012), Szlazak, Grodzicka and Cichy-Szczepańska (2016), Grodzicka (2017), Krause, Grodzicka and Plewa (2021).

Basic assumptions regarding methodology analysis of risky behavior are as follows (Krause, Grodzicka, Plewa, 2021, p. 41):

- to raise problem questions that affect individuals and social groups,
- to adopt research assumptions, which include, for example, the object of study and period of analysis, and assessment of the level of safety,
- to select the type and scope of prospective or retrospective analysis as well as research methods according to the stage of behavior analysis.

The basic areas of analysis and corresponding problem questions for dealing with risky behavior are as follows (Krause, Grodzicka, Plewa, 2021, p. 41):

- person exposed (question: who is subject to the behavior?),
- effects of exposure (question: what is the effect of the behavior?),
- period of exposure (question: when does the behavior occur?),
- danger zone (question: where does the behavior occur?),
- causes of the threat (question: why does the behavior occur?),
- risk prevention (question: how to reduce the risk for the behavior?).

The basic research assumptions for analyzing risky behavior are as follows (Krause, Grodzicka, Plewa, 2021, p. 42):

- the object of study – most often it is an individual or a social group (population of exposed people), studied in terms of criteria such as gender, age, seniority, personality traits, temperament traits, attitudes towards risk, among other factors,
- period of analysis – most often it is the current state, such as the reporting year; it can be a longer or shorter period (if justified by regulations or needs),
- object of reference – most often it is a similar social group (similarity in terms of risk attitudes like risk aversion, risk indifference, risk propensity),
- reference period – most often it is a period of several years preceding an analysis; it can be longer or shorter (if justified by regulations or needs),

- collection of information – most often by means of document analysis, observation and survey methods (including interview and questionnaire techniques), other research methods can be used (as needed),
- hazard identification – most often using checklist methods, TOL (human-organization-technology) systematics and case studies; other research methods can be used (as needed),
- risk estimation – most often using psychological testing and the human reliability analysis (HRA) group of methods; other testing methods can be used (as needed).

Examples of research methods for analyzing risky behavior are as follows (Krause, Grodzicka, 2017, pp. 198-204):

- psychological tests – an indirect method of data collection, used to measure risk propensity and risky behavior; examples of tests include: test of attitudes towards risks, test of decision-making preferences, test of personal silhouettes, test of risky behavior, the multi-factor scale of risky behavior,
- survey – an indirect method of data collection, used to analyze risky attitudes and behaviors of employees; examples of survey methods and techniques include: questionnaire, interview, brainstorming, Delphi technique,
- observation – a direct method of data collection, used to analyze dangerous events and risky behavior; examples of research techniques include: direct and indirect, overt and covert, controlled and uncontrolled,
- case study – a method of detailed analysis of a single event or person, used to analyze dangerous events and risky behavior; sources of information include: document analysis, observation, survey,
- document analysis – an indirect or direct method of data collection, used to analyze dangerous events and risky behavior; examples of research techniques include qualitative, quantitative and formal analysis,
- checklists – a direct method of data collection, used to analyze the state of occupational health and safety, including the analysis of dangerous events and risky behavior, an example of inductive, qualitative and quantitative method; sources of information include observation, survey, document analysis,
- TOL systematics – a method of detailed classification of the causes of accident events, used for accident investigation and risk assessment (hazard identification), an example of a deductive, qualitative and quantitative method in terms of human error and risky behavior,
- HRA method – a method of detailed analysis of human reliability, used for risk assessment (risk estimation) and accident investigation, an example of inductive, qualitative and quantitative method in terms of human error and risky behavior; examples of research methods include: TESEO, THERP, HEART.

## 3. Material and methods

For the purpose of the article, the method of synthetic assessment of risky behavior was used according to the author's proposal published in one monograph (Grodzicka, 2017), where one should:

- conduct a survey of the prepared six questionnaires, with a total of 56 closed-ended questions,
- conduct an analysis of the results according to the procedure, taking into account the affirmative and negative answers,
- estimate the rank for each area,
- make interpretations according to the proposed evaluation criteria for the six preferred areas,
- make final conclusions.

The assessment of risky behaviors was verified on a group of mine rescuers, taking into account the following parameters – areas (Grodzicka, 2017, p. 163):

- knowledge acquired during rescue training,
- skills acquired during rescue drills,
- first aid skills,
- coping with occupational stress,
- risky behavior,
- risky behavior in situations of unbreathable air.

Basic assumptions for the survey – the survey was conducted during training for a group of 30 mine rescuers, which accounted for 25% of the register status and thus met the requirements of the survey sample. All respondents were informed how to complete the questionnaires. Once agreed, they proceeded to fill out 6 sheets according to the evaluation parameters for the following six areas.

Evaluation parameter *knowledge acquired during rescue training*. The survey was based on a survey questionnaire, prepared by the author, including 10 questions with Yes or No responses.

Criterion evaluation questions used (Grodzicka, 2017, pp. 124-130):

1. Do you happen to disobey health and safety regulations?
2. During your OSH training, did the instructor inform you of the occupational risks that occur in your job?
3. Did you notice your colleague's incompatible behavior with OHS regulations?
4. Do you use personal protective equipment?
5. Are you using the right equipment to perform the activities assigned to you?
6. Do you feel safe around your colleagues?
7. Do you happen to smoke cigarettes underground?

8. Do you pay attention to the expiration date of OSH equipment?
9. When you notice a significant violation of OSH regulations by your colleague, do you report it to your supervisor?
10. Do you happen to take shortcuts on your way back from work contrary to regulations?

Evaluation parameter *skills acquired during rescue drills*. The survey was based on a survey questionnaire, including 8 questions with Yes or No responses.

Criterion evaluation questions used (Grodzicka, 2017, pp. 134-138):

1. Do you think chamber training is frequent enough?
2. Do drills make you feel stress?
3. Do you feel more confident in action after drills?
4. Would you change anything in drills?
5. Do you feel that the training content presented by the trainer is clear and understandable to you?
6. Does it make it easier for you to understand the issues when the instructor combines theory and practice during the training sessions provided?
7. Do you yourself analyze the behavior of your colleagues who participated in the operations?
8. When performing a task, do you get disturbed knowing that the trainer, during chamber training, can make it difficult for you at any time through sound effects, temperature, etc.?

Evaluation parameter *first aid skills*. The survey was based on a survey questionnaire, including 10 questions with Yes or No responses.

Criterion evaluation questions used (Grodzicka, 2017, pp. 142-147):

1. Do you think you have a lot of knowledge in the field of premedical care?
2. Do you happen to provide first aid outside of work?
3. Do you analyze your behavior after the action?
4. Before making a decision to enter a danger zone, do you analyze it to see if it is correct?
5. Do you have a feeling of automatic performance during first aid?
6. Would you increase the number of training courses in pre-medical care?
7. When you hear from your colleagues "go get him", "he's injured", do you head toward the injured person without a second thought?
8. Knowing that you still have 100 m to the victim, conditions are getting worse and you have sagged, will you decide to return, saving your life?
9. Do you happen to think about your family when you take part in difficult operations?
10. Do you relieve your emotions on your loved ones after a rescue operation?

Evaluation parameter *coping with occupational stress*. The survey was based on a survey questionnaire, prepared by the author, including 9 questions with Yes or No responses.

Criterion evaluation questions used (Grodzicka, 2017, pp. 151-155):

1. Do you find working in mining stressful?
2. Do you find your job as a mine rescuer stressful?
3. Does your job affect your personal life?
4. Does the phone signal make you feel anxious?
5. Do you think about your family during the action?
6. Are you satisfied with your work?
7. Can you count on colleagues during a rescue operation?
8. Do you want to improve your skills?
9. Would you change your profession to a more secure one?

Evaluation parameter *risky behavior*. The survey was based on a survey questionnaire, prepared by the author, including 15 questions with Yes or No responses.

Criterion evaluation questions used (Grodzicka, 2017, pp. 55-62):

1. When you see a person who is unconscious, do you immediately begin administering premedical care?
2. Has frequent participation in training in first aid made you more confident in carrying it out?
3. Are you able to give first aid to even a very injured person without inhibition?
4. Do you fear for your life and health when administering first aid?
5. When taking part in a rescue operation, knowing that something could happen to you, do you think about your family?
6. Do you find any participation in rescue operations stressful?
7. Did you become a mine rescuer because you like risks?
8. Does risk give you an extra boost of excitement?
9. When participating in a rescue operation, do you feel safe knowing that your fellow rescue squad members are by your side?
10. Do you tend to analyze every time you make a decision to enter a danger zone to help other colleagues?
11. When you see an accident, will you make the decision to rescue the injured yourself?
12. Seeing the threat to the lives of others, will you wait for instructions from your superiors on what to do next?
13. Do you analyze the decisions you made after the rescue operation is over?
14. Do you need to de-stress after the operation is over?
15. Will you share your isolation apparatus with the person you are taking out of the danger zone?

Evaluation parameter *risky behavior in situations of unbreathable air*. The survey was based on a survey questionnaire, prepared by the author, with 5 parts of 5 questions each (25 in total), with Yes or No responses. The following are key questions for evaluating this

criterion – the need to ask key questions along with the description and situation sketch, which are included in Chapter 6 (Grodzicka, 2017, pp. 67-84):

1. For Part II – going to the passenger station you know that the passage of fire line I is longer, do you choose the passage of fire line II or III, knowing that there is a ban on the movement of the crew.
2. For Part III – knowing that there is an outflow of methane gas in the gallery and knowing that the dispatcher has ordered to wait for rescuers, you ask a colleague to reach the stranded miner together and lead him to clear air, using an escape apparatus.
3. For Part IV – after putting on the escape apparatus, you decide to retreat by a longer route, taking the electrician's escape apparatus with you to deliver it to him in case you meet him.
4. For Part V – you disobey the dispatcher's order and also remain in the alcove behind the wall, waiting with your colleague for rescuers, using the escape apparatus all the time.

Rank estimation based on (Grodzicka, 2017, pp. 165-170):

- Proposed criteria for evaluating the parameter "knowledge acquired during rescue training" – affirmative answers. Affirmative responses to survey questions 2-6, 8-9.
  Number of points obtained 7 Criterion rank 3 outstanding.
  Number of points obtained 5-6 Criterion rank 2 satisfactory.
  Number of points obtained 3-4 Criterion rank 1 normal.
  Number of points obtained 0-2 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "knowledge acquired during rescue training" – negative answers. Negative responses to survey questions 1, 7, 10.
  Number of points obtained 3 Criterion rank 3 outstanding.
  Number of points obtained 2 Criterion rank 2 satisfactory.
  Number of points obtained 1 Criterion rank 1 normal.
  Number of points obtained 0 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "skills acquired during rescue drills" – affirmative answers. Affirmative responses to survey questions 1, 3-7.
  Number of points obtained 6 Criterion rank 3 outstanding.
  Number of points obtained 5 Criterion rank 2 satisfactory.
  Number of points obtained 3-4 Criterion rank 1 normal.
  Number of points obtained 0-2 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "skills acquired during rescue drills" – negative answers. Negative responses to survey questions 2, 8.
  Number of points obtained 2 Criterion rank 2 satisfactory.
  Number of points obtained 1 Criterion rank 1 normal.
  Number of points obtained 0 Criterion rank 0 abnormal.

- Proposed criteria for evaluating the parameter "first aid skills" – affirmative answers. Affirmative responses to survey questions 1-4, 6-8.
  Number of points obtained 7 Criterion rank 3 outstanding.
  Number of points obtained 5-6 Criterion rank 2 satisfactory.
  Number of points obtained 3-4 Criterion rank 1 normal.
  Number of points obtained 0-2 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "first aid skills" – negative answers. Negative responses to survey questions 5, 9-10.
  Number of points obtained 3 Criterion rank 3 outstanding.
  Number of points obtained 2 Criterion rank 2 satisfactory.
  Number of points obtained 1 Criterion rank 1 normal.
  Number of points obtained 0 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "coping with occupational stress" – affirmative answers. Affirmative responses to survey questions 6-8.
  Number of points obtained 3 Criterion rank 3 outstanding.
  Number of points obtained 2 Criterion rank 2 satisfactory.
  Number of points obtained 1 Criterion rank 1 normal.
  Number of points obtained 0 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "coping with occupational stress" – negative answers. Negative responses to survey questions 1-5, 9.
  Number of points obtained 6 Criterion rank 3 outstanding.
  Number of points obtained 5 Criterion rank 2 satisfactory.
  Number of points obtained 3-4 Criterion rank 1 normal.
  Number of points obtained 0-2 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "risky behavior" – affirmative answers. Affirmative responses to survey questions 1-3, 9-14.
  Number of points obtained 8-9 Criterion rank 3 outstanding.
  Number of points obtained 6-7 Criterion rank 2 satisfactory.
  Number of points obtained 4-5 Criterion rank 1 normal.
  Number of points obtained 0-3 Criterion rank 0 abnormal.
- Proposed criteria for evaluating the parameter "risky behavior" – negative answers. Negative responses to survey questions 4-8, 15.
  Number of points obtained 6 Criterion rank 3 outstanding.
  Number of points obtained 4-5 Criterion rank 2 satisfactory.
  Number of points obtained 3-4 Criterion rank 1 normal.
  Number of points obtained 0-2 Criterion rank 0 abnormal.

- Proposed criteria for evaluating the parameter "risky behavior in situations of unbreathable air" – negative answers. Negative responses to key survey questions.
  Number of points obtained 4 Criterion rank 3 outstanding
  Number of points obtained 3 Criterion rank 2 satisfactory
  Number of points obtained 2 Criterion rank 1 normal
  Number of points obtained 1 Criterion rank 0 abnormal

Interpretation according to the proposal of the evaluation criteria for the six preferred areas based on the summative assessment obtained from the criterion rank sum survey.

**Table 1.**
*Proposed summative evaluation (including affirmative and negative answers) for 5 parameters characterizing the behavior of mine rescuers: "knowledge acquired during rescue training", "skills acquired during rescue drills", "first aid skills", "coping with occupational stress", "risky behavior"*

| Ordinal no. | Sum of evaluation criterion ranks for individual parameters | Interpretation of the summative assessment for individual parameters |
|---|---|---|
| 1. | 6 | outstanding |
| 2. | 4-5 | satisfactory |
| 3. | 2-3 | normal |
| 4. | 0-1 | abnormal |

Source: Grodzicka, 2017, p. 170.

**Table 2.**
*Proposals for the final evaluation for the ranking of the evaluation of risky behavior of mine rescuers based on the average rank of the evaluation criterion for all 6 parameters determining the behaviors of mine rescuers*

| Ordinal no. | The average rank of the evaluation criterion for all parameters | Interpretation of the final assessment for the risk behavior evaluation ranking |
|---|---|---|
| 1. | Over 60% | normal |
| 2. | Up to 60% | abnormal |

Source: Grodzicka, 2017, p. 172.

A respondent with an abnormal rating (up to 60% of the desired responses) is subject to a reassessment of risky behavior to identify areas of higher risk and take improvement activities.

Conclusions were drawn and it was determined whether the surveyed respondents received an "incorrect" interpretation, i.e., the assessment should be repeated, as these people tend to engage in risky behavior.

If the respondent gets an abnormal rating, a detailed analysis of individual parameters (areas) should be carried out, areas of increased risk should be identified, and appropriate improvement measures should be taken, which consist of raising the level of safety culture, such as through awareness, talks, instruction, training, and practical exercises.

## 4. An example of a survey research in the field of risky behavior

An analysis was made for each area after the survey. Each area involved the same 30 respondents, for which affirmative and negative responses, criterion rank and evaluation interpretation were correlated. Table 3 below shows the results of research on risky behavior.

**Table 3.**
*Summary of survey results for the area of risky behavior*

| No. of respondent | Responses | | Criterion rank | | Total | Interpretation of the assessment |
|---|---|---|---|---|---|---|
| | yes | no | yes | no | | |
| 1. | 8 | 5 | 3 | 2 | 5 | satisfactory |
| 2. | 6 | 3 | 2 | 1 | 3 | normal |
| 3. | 7 | 4 | 2 | 1 | 3 | outstanding |
| 4. | 8 | 6 | 3 | 3 | 6 | normal |
| 5. | 5 | 4 | 1 | 1 | 2 | normal |
| 6. | 4 | 4 | 1 | 1 | 2 | normal |
| 7. | 4 | 5 | 1 | 2 | 3 | normal |
| 8. | 7 | 4 | 2 | 1 | 3 | normal |
| 9. | 6 | 4 | 2 | 1 | 3 | normal |
| 10. | 8 | 4 | 3 | 1 | 4 | satisfactory |
| 11. | 6 | 5 | 2 | 2 | 4 | satisfactory |
| 12. | 7 | 3 | 2 | 1 | 3 | normal |
| 13. | 9 | 6 | 3 | 3 | 6 | outstanding |
| 14. | 4 | 4 | 1 | 1 | 2 | normal |
| 15. | 3 | 4 | 0 | 1 | 1 | abnormal |
| 16. | 5 | 3 | 1 | 1 | 2 | normal |
| 17. | 7 | 5 | 2 | 2 | 4 | satisfactory |
| 18. | 5 | 5 | 1 | 2 | 3 | normal |
| 19. | 8 | 6 | 3 | 3 | 6 | outstanding |
| 20. | 6 | 3 | 2 | 1 | 3 | normal |
| 21. | 5 | 4 | 1 | 1 | 2 | normal |
| 22. | 5 | 3 | 1 | 1 | 2 | normal |
| 23. | 8 | 6 | 3 | 3 | 6 | outstanding |
| 24. | 6 | 5 | 2 | 2 | 4 | satisfactory |
| 25. | 6 | 4 | 2 | 1 | 3 | normal |
| 26. | 4 | 5 | 1 | 2 | 3 | normal |
| 27. | 7 | 5 | 2 | 2 | 4 | satisfactory |
| 28. | 6 | 5 | 2 | 2 | 4 | satisfactory |
| 29. | 4 | 4 | 1 | 1 | 2 | normal |
| 30. | 6 | 5 | 2 | 2 | 4 | satisfactory |

Source: own work.

Table 4 includes a summary of survey results for all areas (parameters): knowledge acquired during rescue training, skills acquired during rescue drills, first aid skills, coping with occupational stress, risky behavior, risky behavior in situations of unbreathable air.

**Table 4.**
*Summary of test results for all areas (evaluation parameters)*

| Ordinal no. | Evaluation parameter | Outstanding | | Satisfactory | | Normal | | Abnormal | |
|---|---|---|---|---|---|---|---|---|---|
| 1. | Knowledge acquired during rescue training | 3 | 10% | 12 | 40% | 15 | 50% | 0 | 0 |
| 2. | Skills acquired during rescue drills | 0 | 0 | 8 | 27% | 22 | 73% | 0 | 0 |
| 3. | First aid skills | 4 | 13.3% | 10 | 33.3% | 16 | 53.4% | 0 | 0 |
| 4. | Coping with occupational stress | 3 | 10% | 13 | 43,4% | 14 | 46.6% | 0 | 0 |
| 5. | Risky behavior | 4 | 13.3% | 8 | 26.7% | 17 | 56.7% | 1 | 3.3% |
| 6. | Risky behavior in situations of unbreathable air | 1 | 3.3% | 14 | 46.7% | 14 | 46.7% | 1 | 3.3% |

Source: own work.

For the analyzed areas of "Risky Behavior" and "Risky Behavior in situations of unbreathable air", the following summary results were obtained: outstanding – 4 subjects and 1 subject, satisfactory – 8 subjects and 14 subjects, normal – 17 subjects and 14 subjects, abnormal – 1 subject and 1 subject.

Only two subjects received an abnormal rating in one of the areas, so a summary of the test results for all areas was made, as well as a summary of the assessment results for rescuers no. 15 (the "Risky Behavior" area) and no. 20 (the "Risky Behavior in situations of unbreathable air" area).

**Table 5.**
*Summary of evaluation results for rescuer no. 15*

| Ordinal no. | Evaluation parameter | Affirmative answers | | Negative answers | | Summative evaluation | | Interpretation of the assessment for the parameter |
|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | yes | no | |
| 1. | Knowledge acquired during rescue training | 5 | 71.43 | 0 | 0 | 2 | 0 | normal |
| 2. | Skills acquired during rescue drills | 3 | 50.00 | 1 | 50.00 | 1 | 1 | normal |
| 3. | First aid skills | 4 | 57.14 | 2 | 66.66 | 1 | 3 | normal |
| 4. | Coping with occupational stress | 1 | 33.33 | 3 | 50.00 | 1 | 1 | normal |
| 5. | Risky behavior | 3 | 33.33 | 4 | 66.66 | 0 | 1 | abnormal |
| 6. | Risky behavior in situations of unbreathable air | 0 | 0 | 3 | 75 | 0 | 0 | satisfactory |
| The average rank of the evaluation criterion for all parameters | | | | | 46.1% | | | |
| Interpretation of the final assessment for the risk behavior evaluation ranking | | | | | abnormal | | | |

Note. N – number of responses, % – percentage of responses, yes – affirmative responses, no – negative responses.

Source: own work.

**Table 6.**
*Summary of evaluation results for rescuer no. 20*

| Ordinal no. | Evaluation parameter | Affirmative answers | | Negative answers | | Summative evaluation | | Interpretation of the assessment for the parameter |
|---|---|---|---|---|---|---|---|---|
| | | N | % | N | % | yes | no | |
| 1. | Knowledge acquired during rescue training | 4 | 57.14 | 1 | 50.00 | 1 | 1 | normal |
| 2. | Skills acquired during rescue drills | 3 | 50.00 | 1 | 50.00 | 1 | 1 | normal |
| 3. | First aid skills | 6 | 85.71 | 2 | 66.66 | 2 | 2 | satisfactory |
| 4. | Coping with occupational stress | 1 | 33.33 | 5 | 83.33 | 1 | 2 | normal |
| 5. | Risky behavior | 6 | 66.66 | 3 | 50.00 | 2 | 1 | normal |
| 6. | Risky behavior in situations of unbreathable air | 0 | 0 | 1 | 25.00 | 0 | 0 | abnormal |
| The average rank of the evaluation criterion for all parameters | | | | | | 51.5% | | |
| Interpretation of the final assessment for the risk behavior evaluation ranking | | | | | | abnormal | | |

Note. N – number of responses, % – percentage of responses, yes – affirmative responses, no – negative responses.

Source: own work.

Summary of assessment results for six areas:

- For the area of "Knowledge acquired during rescue training," an outstanding rating was given to 10% of the respondents. This means that people have extensive professional knowledge, which they systematically increase and update during rescue training. 40.0% received a satisfactory rating – these respondents show an appropriate and reasonable approach to their job. 50.0% received a normal rating – these individuals are characterized by an ambitious and emotional approach to their job. There is no need for additional training in this area (no negative evaluation).
- For the area "Skills acquired during rescue drills," a 80% rating was given to 27.0% of the respondents, showing no increased confidence or doubt. 73.0% received a normal rating – these individuals are characterized by efficiency and effectiveness during rescue operations. There is no need for additional training in this area (no negative evaluation).
- For the area "First aid skills", 13.3% received an outstanding rating – the respondents have the skills to apply the knowledge acquired during the exercises to variable and difficult life-threatening conditions. 33.3% received a satisfactory rating – these people demonstrate a great deal of knowledge and skill combining theory and practice. 53.4% received a normal rating – these individuals are characterized by efficiency and effectiveness during rescue operations. There is no need for additional training in this area (no negative evaluation).
- For the area of "Coping with occupational stress," 10.0% received an outstanding rating – these respondents are characterized by their mastery of stress in variable and difficult rescue operations. 43.4% received a satisfactory rating – these people demonstrate a great deal of knowledge and skill combining theory and practice. 46.6% received a normal rating – these individuals are characterized by efficiency and effectiveness

during rescue operations. There is no need for additional training in this area (no negative evaluation).

- For the area of "Coping with occupational stress," 13.3% received an outstanding rating – these respondents are characterized by their mastery of stress in variable and difficult rescue operations. 26.7% received a satisfactory rating – these people demonstrate a great deal of knowledge and skill combining theory and practice. 56.7% received a normal rating – these individuals are characterized by efficiency and effectiveness during rescue operations. 3.3% received an abnormal rating, and additional training and reassessment of risky behavior was indicated.
- For the area of "Risky behavior in situations of unbreathable air," an outstanding rating was given to 3.3% of respondents who have extensive knowledge and regularly update their knowledge of risky behavior in non-breathable air situations. 46.7% received a satisfactory rating – these individuals take effective rescue and self-rescue actions. 46.7% received a normal rating – these individuals are characterized by efficiency and effectiveness during rescue operations. 3.3% received a normal rating – these individuals are characterized by efficiency and effectiveness during rescue operations.

## 5. Discussion of results

The issue of studying the level of safety culture in underground mining in terms of analyzing risky behavior was taken up, among others, by the following authors (chronologically):

- Grodzicka, Kulaga-Tetera and Musioł in their publication (2010), which discusses the results of a survey of miners employed in selected coal mine, used the standardized Test of Risky Behavior (TZR) by R. Studenski to assess miners' propensity to engage in risky behavior underground.
- Grodzicka in her publication (2011) presents the results of a study based on the survey method and interview technique among miners employed in a coal mine. She assessed the frequency of risky behavior among correspondent miners and their colleagues on the basis of the author's interview questionnaire.
- Martyka and Lebecki in their publication (2014) present the results of a survey of middle management and workers in manual positions at three coal mines. They pay particular attention to the conditions for improving safety culture and a program to modify risky behavior.
- Grodzicka in her publication (2015) presents the results of a study based on the survey method and questionnaire technique among mine rescuers employed in selected coal mine. She assessed the type and frequency of risky behavior among rescuers-miners on the basis of the author's survey questionnaire.

In this publication, based on the original proposal for a synthetic assessment of risky behaviors of mine rescuers (Grodzicka, 2017), an example of survey research in the field of risky behaviors has been developed.

Two areas received an abnormal rating for two subjects, so the article presents a summary of test results for all areas (Table 4) and for rescuers 15 and 20 (Tables 5-6).

Based on the sample analysis of risky behaviors of a mine rescuer, it can be concluded that: 2 areas ("risky behavior" for rescuer no. 15 and "risky behavior in situations of unbreathable air" for rescuer no. 20) urgently need to be corrected (abnormal evaluation). 3.3% received a normal rating – these individuals are characterized by efficiency and effectiveness during rescue operations.

Improvement activities are recommended (normal rating) for the 4 areas ("knowledge acquired during rescue training" for rescuers 15 and 20, "first aid skills" for rescuer 15, "coping with occupational stress" for rescuers 15 and 20, "risky behavior" for rescuer 20).

2 areas received a satisfactory rating ("skills acquired during rescue drills" for rescuer 20 and "risky behavior in situations of unbreathable air" for rescuer 15).

The results of the behavioral study will verify the areas that need improvement measures. The proposed method does not apply only to the individual, but also the results of the whole group can be presented. For management, an overall assessment of all employees presented collectively is by far the better solution, but the results of an individual employee and a selected area (parameter) can be presented at any time.

## 6. Final conclusions

The assessment of risky behavior was verified on a group of mine rescuers, taking into account the following parameters (areas):

- Knowledge acquired during rescue training – 10% of the outstanding rating, 40% of the satisfactory rating and 50% of the normal rating. No abnormal rating was received in this area.
- Skills acquired during rescue drills – 27% of the outstanding rating, 40% of the satisfactory rating and 73% of the normal rating. No abnormal rating was received in this area.
- First aid skills – 13.3% of the outstanding rating, 33.3% of the satisfactory rating and 53.4% of the normal rating. No abnormal rating was received in this area.
- Coping with professional stress – 10% of the outstanding rating, 43.4% of the satisfactory rating and 46.6% of the normal rating. No abnormal rating was received in this area.

- Risky behavior – 13.3% of the outstanding rating, 46.7% of the satisfactory rating, 46.7% of the normal rating, and 3.3% of the abnormal rating.
- Risky behavior is situation of unbreathable air – 3.3% of the outstanding rating, 46.7% of the satisfactory rating, 46.7% of the normal rating, and 3.3% of the abnormal rating.

Only two areas received an abnormal rating, i.e.: risky behavior and risky behavior in situations of unbreathable air. In both areas, an abnormal rating was obtained for only one rescuer, but not the same one.

A detailed summary for the two rescuers who received an abnormal rating in one of the two areas is shown below. The first rescuer received an abnormal rating in the "risky behavior" area and a satisfactory rating in the "risky behavior in situations of unbreathable air" area, and received a normal rating in the other areas. By contrast, the second rescuer received an abnormal rating in the area of "risky behaviors in situations of unbreathable air", a satisfactory rating in the area of "first aid skills," and received a normal rating in the other areas.

There was a preponderance of normal ratings for all areas and only the area of "skills acquired during rescue drills" received no outstanding rating.

In conclusion, it can be said that a synthetic assessment of risky behavior showed that the surveyed group is not risk-prone, and only for two subjects in two areas improvement measures can be applied, which involve raising the level of safety culture, such as through awareness-raising, talks, instruction, training, and practical exercises.

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# MANAGING AN AGILE ORGANIZATION – KEY DETERMINANTS OF ORGNIZATIONAL AGILITY

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**Purpose:** The subject of this study is to look at the management of an agile organization with the identification of key factors affecting its agility.
**Design/methodology/approach**: The method used in the study is based on the interpretation of the literature on the subject, the analysis of the author's own experience and the analysis of the results of secondary research.
**Findings:** There key factor of organizational agility is always a man with his competences - knowledge, skills and attitude towards changes - a man with his ability to be agile. Whether and how the organization will be ready to cope with the changes taking place around it, and thus what level of agility it will be able to demonstrate, depends on the openness to this human agility and agile competences possessed by people who create this organization. There will be as much agility in the organization as there will be openness to agility in the people who create it. This is a factor that, is crucial in defining the ability to agile transformation of an organization.
**Practical implications:** Based on the conclusions of the analysis, when implementing agile work systems, organizations should pay the greatest attention to people – not only technology, as is the case in many business organizations - and start agile transformations from people.
**Originality/value:** The article presents a detailed, multifaceted analysis of the factors determining organizational agility, which in the era of BANI world is crucial, for the survival and success of business organizations. The conclusions contained in the paper can be the base to prepare, implement and constantly increasing organizational agility.

**Keywords:** agile management, agile leadership, competence, organizational agility.

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

## 1. Introduction

Social, economic and political changes, globalization, the development of new technologies and generational changes pose new challenges to the organization of the 21st century. What we can define as the only constant element of modern reality is change.

The ability to quickly adapt to ubiquitous changes can be defined by the adaptability of the organization - organizational agility. The level of organizational agility is conditioned by many factors - both internal and external.

Undoubtedly, there can be said that the first half of the 21st century and the related challenges faced by organizations is the time of organizational agility testing, readiness to agilely respond to the challenges set by everyday reality.

Organizational courage, commitment, determination, proper preparation and openness to change, treating change as a constant factor accompanying us in today's world, but also a factor driving innovation and development, agility in adapting to change, will determine the success or failure of the organization.

The importance of agility for organizations is constantly growing, the reason for this is the influence of many factors such as continuous development, unflagging progress and technological changes, constantly increasing market expectations and social and economic changes. Organizations tend to come to the conclusion that the traditional organizational structure makes them too slow, and therefore inefficient and characterized by low effectiveness. This, in turn, results in the inability to quickly adapt to changing conditions.

The way organizations can operate effectively in a complex, unpredictable, ambiguous and constantly changing environment is referred to as "VUCA" (Bennett, Lemoine, 2014 p. 311-317), which has been a dominant topic in both the business and academic worlds. VUCA is a type of acronym that was first used in 1987. The United States Army military college implemented the VUCA concept to accurately describe the post-Cold War world: Volatility - volatility, Uncertainty - uncertainty, Complexity - complexity, Ambiguity - ambiguity. The concept of VUCA, especially after the attack on the World Trade Center, gained great popularity and functions both in the context of the military and strategic leadership in organizations. (EY Poland, 2023)

The high volatility, uncertainty and unpredictability of the situation that we could observe during the outbreak of the global COVID-19 pandemic was a kind of test for many organizations that had to adapt overnight to the new conditions in which they functioned. It was the level of agility of the organization that determined whether and how quickly they would be able to adapt to the new reality.

The speed of changes that takes place around us results in the feeling of permanent chaos, anxiety and a strong need to define ourselves and the world around us in a new reality.

In 2020, Jamais Cascio attempted to update the VUCA approach by creating a new model - the acronym BANI - whose task is to help understand the effects of the pandemic, the processes that are happening around us and which we are experiencing, and what we can expect in the future (Cascio, 2020). As in the previous model, also in the BANI model, each letter has its own meaning: Brittle - fragile, Anxious - restless, Non-linear - non-linear, Impereceptible - incomprehensible. As defined by Cascio (Cascio, 2020) “What used to be unstable is no longer reliable. People no longer feel insecure, they are restless. Things are no

longer complicated, instead they are subject to non-linear logic systems. What used to be ambiguous, today seems incomprehensible to us".

The answer to this is the concept of agile organization management, which is the next stage in the evolution of the implementation of new management models.

A big challenge when introducing changes towards agility is also preparing the organization - in terms of structure, technology, competencies, but also in terms of the way of thinking. Ability to quickly adapt to changing market conditions and expectations.

The subject of this study is to look at the management of an agile organization with the identification of key factors affecting its agility. The method used in the study is based on the interpretation of the literature on the subject, the analysis of the author's own experience and the analysis of the results of secondary research, illustrating the subject of organizational agility.

## 2. Literature review

The concept of agility has been used in literature and business for many years, and interest in the subject is growing day by day. The first mentions of agility can be found as early as the 1920s, and in particular in the 1960s, when management scientists undertook activities aimed at developing a concept illustrating how organizations deal with a constantly changing and unstable external environment. The concept and term "agility" was further explored in the 20th century by researchers at Lehigh University in Pennsylvania, who initially focused on agile manufacturing. Subsequently, the concept of agility was continued by researchers dealing with production and supply chain management, production economics, and information technology. However, the adoption of the concept of agility by production software and the IT industry, where this concept is most often used today, was of key importance for the development of the agility concept. Methods that operationalize agility, such as Design Thinking, Scrum, or Kanban, are widely known and relevant. It is also a fact that the topic of agility has become one of the main business concepts of the 21st century (Włodarkiewicz-Klimek, 2018, p. 148; Trzcieliński, 2011, p. 75).

### 2.1. What is organizational agility?

The literature on the subject points to various features that make up agility. In relation to the company, it is speed, i.e. the ability to quickly perceive market opportunities and threats that flow from the environment. Agility is also understood as the ability to use available resources, intelligence, i.e. the company's ability to understand the situation and react appropriately to it, and astuteness, i.e. the ability to use knowledge to deal with new, changing situations in practice (Włodarkiewicz-Klimek 2018, p. 148; Trzcieliński 2011, p. 75).

As the authors of Fast and flexible: Corporate communications in agile organizations (Zerfaß et al., 2018) point out, agility means that an organization by establishing new ways of organizing work and planning should become more flexible, definitely faster and take over the activity in responding to emerging internal and external challenges and needs. Agility requires a change in the organization of work, introducing more flexible and resistant teams, a flatter functional structure as well as openness to cooperation with a wide range of stakeholders.

Organizational agility is an intangible concept, the definition of which was consistently not uniform, and the researchers of the subject defined the concept of agility in various ways. The conducted research shows that agility itself is an abstract concept, affecting both the internal and external aspects of the organization's functioning.

Capturing the concept of agility as a concept that captures agility as a whole turns out to be a big challenge. The definitions of agility that are widely known come mainly from research on the manufacturing industry. Research on the concept of agility has led to an image of agility that is characterized by several similarities, some areas indicating contradictions and showing some gaps (Harraf, Wanasika, Tate, Talbott, 2015, pp. 675-686).

Conducted research in the area of organizational agility (Dyer, Shafer, 1998, p. 6) led to the conclusion that agility is not an individual achievable standard. There is no single formula for what agility looks like, so an organization may become more and more agile, but it will probably never be completely agile (Alzoubi, Al-otoum, Albatainh, 2011, pp. 503-515).

Sharifi and Zhang are among the most frequently cited authors when it comes to the description of agility, in particular in terms of attributes characterizing this agility (cf. Sharifi, Zhang, 1999, pp. 7-22).

They divide the organization's agile capabilities into four categories/criteria, namely:

- responsiveness, which is described by the authors as the ability to identify changes and react quickly to them,
- competencies that they perceive as a broad set of skills that ensure productivity, efficiency, and effectiveness of activities in relation to the challenges and goals of the company,
- flexibility/adaptability, i.e. the ability to process different products and achieve different goals with the same approach,
- speed, i.e. the ability to perform activities in the shortest possible time.

Organizational agility can be defined as the effective use of competitive factors such as speed, flexibility, quality and profitability, activities that strengthen innovation by integrating variable resources and best practices in a knowledge-rich environment, in order to provide products and services that will be tailored to the needs of customers in rapidly changing market environment (Yusuf et al., 1999, p. 37).

**Table 1.**
*Agility criteria by. Shari and Zhang*

| Agility criteria | Defined by: |
|---|---|
| RESPONSIVENESS | - Sensing, perceiving and anticipating change<br>- Immediate response to changes by entering them into the system<br>- Recovery after change |
| COMPETENCES | - Strategic vision<br>- Appropriate hard and soft technology or sufficient technological skill<br>- Quality of product services<br>- Cost effectiveness<br>- Speed of introducing new products<br>- Change management<br>- Competent people with knowledge and commitment<br>- Operational efficiency and effectiveness<br>- Internal and external cooperation<br>- integration |
| FLEXIBILITY | - Product volume flexibility<br>- Flexibility in product configuration and modelling<br>- Organisational flexibility and flexibility within an organisation<br>- People flexibility |
| SPEED | - Speed of introducing new products to the market<br>- Speed and timely delivery of products and services<br>- Speed of operations |

Source: Sharifi, Zhang, 1999.

In turn, Gunasekaran (Gunasekaran, 1999, pp. 87-105) defines agility as "the ability to survive and thrive in a competitive environment of constant and unpredictable change, by responding quickly and effectively to changing markets, driven by products and services designed by customers".

Worley and Lawler look at the issues of agility differently (Worley, Lawler, 2010, pp. 194-204), indicating the definitions of agility in the following way: “Agility is a dynamic design of the organization, it is the organization's capabilities that allow you to sense the need for changes

coming from both sources, both internal and external, and allowing the change to be carried out as a routine activity while maintaining above-average performance".

An interesting look at agility is presented by Lu and Ramamurthy (quoted by Lu, Ramamurthy, 2011, pp. 931-954), who define agility as "the company-wide ability to cope with changes that often occur unexpectedly in business environments, through quick and innovative reactions, taking advantage of changes as development opportunities. In turn, Dove, in his 2001 publication, Response Ability: The Language, Structure, and Culture of the Agile Enterprise, (quoted in Dove, 2001, pp. 1-36) sees organizational agility as "the company's ability to deal with rapid, inexorable and uncertain changes in an environment where changes occur continuously and unpredictably".

Another researcher who attempted to define organizational agility is Felipe (cited Felipe et al., 2016, pp. 4624-4631), he defines organizational agility as a key ability of organizational dynamics and defines it by referring to "the company's ability to sense changes in the environment and responding to them effectively".

The definition of agility given by Haq and Boddu (2015) indicates that agility covers many aspects of an organization. This pair of researchers have defined agility as "a business-wide opportunity and its organizational structures, information systems, and especially mindset".

The already quoted Dove R., continuing research on agility, in his webinar "Agile Systems and Processes (...) from 2018 (quote Dove 2018) defines agility as "an effective response to opportunities and problems within the organization". At the same time, he emphasizes the effectiveness of the reaction and additionally defines its characteristics. According to him, a reaction can be considered effective if it is:

- fast enough to deliver value,
- cost-optimal,
- predictable,
- comprehensive.

The concept of an agile organization is also described by Linda Holbeche (2018), who points out that "agility goes beyond being flexible" and that "a flexible business is able to make changes within the current organizational system when a predictable event occurs", while "agile organizations are able to change the whole system completely in response to an unpredictable external force".

Thus, organizational agility is the overall ability of an organization to react quickly and benefit from changes initiated by external and internal environmental factors. Agility includes the ability to identify significant changes that will have a key impact on organizations and to respond to them proactively, effectively and efficiently with the involvement of a team competently prepared to cope with these changes. Agility is based on flexible functional structures, not on hierarchical models of organizational structures. An important aspect of agility is the ability to quickly create flexible processes and organizational structures that

respond to the current, often changing needs of the organization and the right selection of people for changing tasks.

Extremely interesting research related to the agile transformation of organizations was conducted by McKinsey (cf. Salo, 2017). In the McKinsey Global Survey, "How to create an agile organization", organizational agility was defined as the ability to quickly reconfigure strategy, structure, processes, people and technology towards the possibility of creating new and protecting the existing value. The cited studies clearly show that companies that are undergoing a transformation in terms of increasing agility observe much greater efficiency and higher work results in units where agile methods have been fully adopted compared to other areas of the organization where agile transformation has not yet been completed. For many respondents to the McKinsey study, agility is a strategic priority. However, respondents indicate that few agile transformations across the organization have been completed so far, with only 4% of all respondents confirming that their companies have fully implemented agile solutions across all areas of their business.

The areas that the survey respondents indicate as those where agile transformation and agile work methods have been implemented to the greatest extent are those that are in contact with the client, in particular, they relate to innovation, sales, service and building positive customer experiences and product management. Nearly half of respondents say their companies are adopting agile ways of working in operations, strategy and technology processes, and roughly a third say they are also doing so in supply chain management and talent management. Over 70% of respondents to the survey confirm that organizational agility is one of the top priorities in the organization's development programs, and over 80% of respondents working in agile units confirm an increase in overall efficiency since the implementation of agile transformation.

According to Prats et al. organizational agility is characterized by three abilities: sensitivity, security and fluidity (Prats, Siota, Wyman, Gillespie, Singleton, 2018, p. 7).

- Sensitivity is defined as the organization's ability to recognize, identify and assess opportunities and challenges related to the changing external environment. It addresses the need for change at a particular point in time and the areas where switching, innovating and adapting is required. This function supports making well-thought-out and informed decisions.
- Security refers to the company's effectiveness in engaging the required resources from various areas - internal and external organizations - in order to properly use the potential of the opportunities identified by it.
- Fluidity indicates the organization's ability to transform internally as a response to the emerging demands of the external environment.

In this sense, agility means the ability to change not only the company's resources, but also the way it works. Organizations with such abilities are the most open to changes (Juchnowicz, Wolińska-Skuza, 2021, p. 29).

Organizational agility is therefore a broad concept and requires a multidimensional consideration, both taking into account the aspects of dealing with challenges coming from the outside as well as inside the organization. At the same time, the view on agility and the organization's ability to quickly adapt to change should be considered in the context of operational, organizational, technological and competence agility. Only such a view gives a full picture of agility.

### 2.2. External agility enablers of the organization

The focus of attention and strong emphasis on developing corporate agility has its sources both in the external environment and the changes taking place there, as well as in internal factors - both the organizations themselves and the people who create these organizations. These changes are undoubtedly a source of potential opportunities and opportunities for the organization, but they can also be a significant threat to it.

Both the literature on the subject as well as conducted research and observations lead to the identification of key factors having a significant impact on the growing agility in organizations. One such factor is the ubiquitous technological changes regarding, in particular, the digital transformation of work and life. Technological changes affect all parts of the value chain. Significant changes and acceleration are observed in the development cycles of new products and technologies, thanks to which organizations become much faster and more flexible in operation. High-speed internet is also an important driver of agility. mobile phones, artificial intelligence, big data analytics and the technological cloud.

Intelligent systems and machines take over boring and repetitive tasks. Automation of processes, robotization and increasing efficiency results in less demand for employees. New needs, growing demand for new products and services result in the emergence of new professions and new jobs. This situation, in turn, determines changes in the qualifications and development of employees and the creation of new, not yet functioning jobs.

Growing market requirements are also an important external factor driving the development of organizational agility. Rapidly changing markets, ever-increasing costs, inflation, increased competition on the international market, growing customer expectations for an individual approach and personalization of products, higher quality requirements and longer delivery times encourage organizations to adapt to market conditions. New competitors, start-ups are often smaller and faster, and thus more agile (cf. Zerfass et al., 2018, pp. 4-33).

Generational changes also have an impact on the increase in corporate flexibility and agility. As the authors of the study indicate (Zerfass et al., 2018, pp. 4-33), employees of generations Y and Z have different expectations related to their professional career than previous generations. They want to take responsibility for their own projects and definitely prefer teamwork. For many of Generation Y and Generation Z, leadership is no longer a top priority. A much more important aspect that fits their expectations is the flexible work structures that are characteristic of agile organizations.

An important catalyst for changes towards increasing organizational agility is also an unstable and complex political environment, regulatory changes that put enormous pressure on enterprises. The flexibility of the organization also determines the need to adapt the organization to changing legal regulations in various areas, in particular in the area of data protection, environmental protection, etc. The impact of changes introduced by companies and the ongoing digital transformation on regulatory changes is also significant, experts are considering changing the regulations to take into account the role of artificial intelligence (AI) in various areas of activity, in particular in consumer finance. As Zdrojewski points out (Zdrojewski, 2022), for example, in order to avoid gender inequality in credit decisions, it is important to take into account the role of artificial intelligence in consumer finance . It turns out, therefore, that the growing flexibility of the organization has a significant impact on the need for regulatory changes.

The conclusions defined in the Institute for the Future - Future work skills 2020 study remain valid, as indicated by Balog (Balog, 2020, pp. 14-27), we can distinguish six factors determining changes, and thus factors affecting increasing agility, they are:

- Increasing life expectancy, which significantly affects changes in career and learning - lifelong learning and changing careers several times in the course of life is becoming something natural.
- Partnership of machines and people - the use of synergy and the use of human competences for more complex tasks.
- Digital synergy - in a computerized world, all devices are interconnected, and interactions between them are recorded and transformed into data, which can build new connections and patterns that increase productivity.
- New media - communication tools, video production, digital animations, augmented reality and gamification give birth to a new, more advanced form of communication and transmission.
- Organizations with a "superstructure" - technology community - organizations known today, are considered products of the last century. New organizational and work skills will not come from traditional management theories, but from areas such as game theory, neuroscience and positive psychology.
- Global multicultural teams - outsourcing of experts scattered around the world requires different processes and methods of work.

All this raises the need for change in the construction and management of a modern organization, an organization that meets the expectations posed by the reality of the 21st century.

### 2.3. Internal factors affecting agile transformation

For agile transformation, both the above-mentioned external factors are important, which induce the need to introduce agile solutions, but equally important is what the situation inside the organization looks like and what elements must interact with each other for agile transformation to occur and be efficiently implemented.

One of the most important links in any organization are the people who create it - without people there was no company. It is the human aspect - the agility of a person and his openness or reluctance to change - that will determine whether the agile transformation into an organization will run smoothly and bring the expected results. The human factor is one of the first factors to be taken into account when planning an agile transformation.

An organizational culture that favors agility is a culture based on trust, openness, diversity, mutual acceptance, support and knowledge sharing. Organizations increase their agility precisely because of the actions of the people who create these organizations. Managers and employees need openness to work in interdisciplinary teams for which the foundations of an agile organizational culture become jointly cultivated values with which the entire organization identifies.

As the report The Future of Jobs Report, The World Economic (2018) indicates, one of the most important factors having a key impact on the course of agile transformation is the role of top management in the organization. It is the attitude of the company's management board, its openness to changes, unconventional, forward-looking thinking, its readiness to depart from the clichés to which the organization has become accustomed over the years and commitment to change - agile transformation - that will determine the success and effect of the implemented changes. The lack of support from the board and its lack of openness to change is one of the biggest obstacles on the way to agile organizational transformation.

An extremely important internal factor that is significant for the course of agile transformations in organizations, and as a result for the effectiveness and efficiency of an agile organization, is the area related to the competences of its leaders and employees. Importantly, unlike previous trends, as indicated by research and analysis of the literature on the subject, soft skills turn out to be the key. This has also been confirmed in numerous studies conducted in this area. The desired competencies of employees in agile organizations will be discussed in more detail later in this study.

Undoubtedly, an important factor affecting the agile capabilities of an organization is the concept of continuous development - the concept of lifelong learning. This concept radically changes the view on development, learning and changes in the scope of functions, positions and changes in professions in the course of a person's life. The changing environment and the requirements related to it are a kind of motivator to take adaptive actions to keep pace with the changing reality. It is the level of openness, on the one hand, on the part of employees, to learning new things, and, on the other hand, on the part of the organization, to diagnosing

future needs and enabling employees to develop, combining the needs of both, will determine the subsequent success and level of agility of the organization.

Another factor qualified as an internal factor is the size of the organization. Undoubtedly, it is much easier for smaller organizations, such as start-ups, to implement agile work models. The level of complexity of the processes here is much lower compared to the complex, multi-level structures of large corporations. Nevertheless, many large corporations, realizing the benefits of agile structures and a high level of organizational agility, have no doubts that implementing changes towards increasing flexibility and agility is something necessary and indispensable to be competitive on the market.

The authors of Fast and flexible: Corporate communications in agile organizations (cf. Zerfaß, 2018, pp. 6-8) express the view that not all companies are suitable for implementing agile working methods. Pointing to industries such as accounting, investor relations or legal services, they are of the opinion that agility is not a favorable model for these areas of activity, and rigidly defined chains of command and responsibility will work better. The author of the study does not share the above-mentioned view. Each industry, area of activity or process requires looking through the prism of agility. Looking through the prism of the definitions of agility quoted in the earlier parts of this study, as well as based on the author's long-term experience in improving and increasing the flexibility and agility of processes and organizations, it should be stated that in each of the areas of activity, you can find space for increasing agility. Of course, one should not forget about the key aspect underlying agile change - the aspect of purpose and efficiency resulting from increasing organizational agility. In some areas, agile transformation will be possible to a much wider extent, while in others, its dimension will be smaller. The ability to look at the organization not from the perspective of hierarchical dependencies, but from the point of view of the architecture of the processes that are implemented in it, is the key to flexibility and speed of operation, and this determines the agility of the organization. Bureaucratic, hierarchical organizational management structures can significantly slow down the implementation of tasks by e.g. extended decision-making process. Difficult flow of information and lack of transparency, which translates into low efficiency. Flat organizational structures, decentralization of power and the transfer of decision-making powers to properly empowered process owners and multifunctional teams translate into the speed of decision-making, and thus the effectiveness of processes implemented in individual areas. Operational agility is an important factor determining the agility of the entire organization.

Agile teams tend to be faster, smarter, more effective and more valuable compared to traditional hierarchies (Balog, 2020, pp. 14-27).

As pointed out by Zerfaß, A. et al. (2018) access to modern technologies and work tools is a prerequisite in today's world for organizations to function in an agile manner. We are talking here about extremely useful, agile methods and tools such as Scrum, Design Thinking or Kanban, which are a huge added value when creating and managing an agile organization.

At the same time, modern technologies cannot be omitted, including in particular tools supporting cooperation in virtual teams, often scattered around the world. Platforms for managing and sharing knowledge are also of great importance - by supporting quick access to aggregated data resources and knowledge needed to make decisions, they also serve the aforementioned development of the organization's employees.

### 2.4. Internal factors affecting agile transformation

As mentioned earlier in this study, the competencies of its leaders and employees are of great importance for the agility, and thus the effectiveness and efficiency of the organization. While in the past, "hard" knowledge was of key importance, now soft skills play and will play the most important role in the future. This has also been confirmed in numerous studies conducted in this area.

The topic related to the competencies that support the agility of organizations, which are in demand on the market, was raised, among others, by in The World Economic Forum's 2018 Report, which identifies as key skills for agility such as flexibility, emotional intelligence, analytical thinking, innovative approach, proactivity, learning and complex problem solving skills, digital and technological agility, attention to detail , resilience, creativity, originality, initiative, critical thinking, influence and negotiation skills.

Similar conclusions are also drawn by the Ministry of Education Singapore (Ministry of Education Singapore, 18.10.2021), in the article "21st Century Competencies", which was published on October 18, 2021 on the ministry's website, indicating the key competences of the future, the development of which should be ensured by implementing appropriate changes to the education system. The authors of the article focus on the competences that are components of emotional intelligence. As the most important competences, they indicate in particular: self-awareness, social awareness, self-management, responsible decision-making, relationship management skills. They also point out that the essence of shaping the leader of the 21st century is taking care of shaping one's own identity, recognizing and managing emotions, a sense of responsibility, caring for oneself and others, building and developing relationships with other people, facing challenges, and the ability to make responsible decisions.

Minouche Shafik, Director of The London School of Economics and Political Science, also points out the importance of soft skills and the need to develop them at the stage of university education. In an interview with Alain Elkann on April 1, 2018 (Elkann, Shafik, 2018), Shafik points out that in order to educate people who will meet the challenges of the future, emphasis should be placed on key competences already during the university education process. The key competencies include: synthesizing and analyzing information, and the ability to critically look at it. As she says: "In the past, work was about muscles, now it's about the mind, in the future it's about the heart".

Shafik also shares the conclusions drawn by the Singapore Ministry, noting the important role of emotional intelligence - skills that robots cannot do will be in demand in the future. It also emphasizes the ability to work in multicultural, multidisciplinary teams as important. Shafik does not forget about digital competences, rightly stating that in the era of ubiquitous automation, they are desirable competences in agile organizations of the 21st century (Elkann, Shafik, 2018).

The author of this study attempted to define the model of competencies of leaders of the future, leaders of agile organizations in the article "The key competencies of leaders in organizations of the 21st century" (Grześ, 2022, pp. 164-169), indicating four areas of leadership and distinguishing key competencies for each of these areas. In the model, the author took into account the needs and roles that a leader assumes in his work, separating four key, mutually complementary areas of a leader's competences, which simultaneously define four aspects of his activity. They are:

- Human side of leadership - including such competences as emotional intelligence, responsibility, respect, trust.
- Strategic side of leadership - including such competencies as strategy, partnership, global view and decision making.
- Technological side of leadership - including new media, innovation management, data management and security.
- Operational side of leadership - which includes planning and organization, achieving goals, managing change and managing knowledge.

The areas shown in the model, which are the centers of the leader's competence, are shown in Figure 1.


**Figure 1.** Model – Key Areas of Competence of the XXI century Leader.

Source: Grześ, 2022, pp. 164-169.

The competences of the future affecting the agility of the organization have also been identified by researchers in the report The Future of Skills: Employment in 2030 (Bakhshi et al., 2017, pp. 7-120), in which they indicate the key skills conducive to meeting the needs of employees the requirements of the future – the requirements of agile organizations. Researchers have identified the competencies of agile employees of the future, which include the following skills:

- Sense-making – identifying this competence as an individual's ability to make sense of tasks and perceive important aspects on many social levels.
- Social intelligence - widely understood social intelligence, ensuring efficient and understandable communication as well as the ability to express empathy and understand the perspective of another person.
- Cross-cultural competency - the ability to cooperate in a multicultural environment.
- Virtual collaboration - the ability to effectively collaborate in a virtual team.
- Knowledge of new media (ang. New-media literacy) - an individual's ability to efficiently use new media that are offered by the market.
- Novel and adaptive thinking - it is the ability to go beyond the usual patterns and think "out of the box", but also the speed of adapting to a turbulent environment and quickly exploring knowledge about missing information.
- Information management (cognitive load management) - the ability to prioritize information in terms of its relevance.
- Design mindset - the ability to model effective thought processes leading to the achievement of intended goals.
- Transdisciplinarity - a skill understood as global thinking, a broad view of reality, thinking going beyond the area of a given field.
- Computational thinking - is the ability to properly use the available data, combine them together and use them to make the right decisions.

## 3. Discussion and Conclusions

On the one hand, the world of VUCA, which all the time seems to be present, characterized by constant volatility, uncertainty, complexity of situations and their ambiguity, and at the same time emerging fragility, restlessness, non-linearity and incomprehensibility defined by the BANI model, provide strong grounds for saying that openness to agility and the ability to follow it in today's world is a key attribute for the survival and development of an organization. As it has been described in this study, we must look at the agility of an organization from many aspects. Both external and internal factors – individual for each organization – should be taken

into account. The key external factors affecting agile transformation are dominated by technological changes, in particular the digital revolution and work transformation, automation, robotization, the use of artificial intelligence and growing market requirements. The transformation of life and generational changes, as well as employees' expectations regarding the development of their career paths are also significant, which also have a significant impact and accelerate processes aimed at increasing the agility of the organization. People and soft skills are of key importance in accelerating or slowing down the agile transformation, which, as indicated by the research cited in this study, turn out to be one of the most important in the 21st century. An important issue is the answer to the question whether investments in the development of people and soft skills are actually recognized as an important point in the development plans of the organization? How organizations prepare employee for agile transformation and whether it is one of the priorities in their plans? The answer can show the real preparation of business to inevitable changes.

## 4. Summary

Organizational agility is therefore a broad concept and requires a multidimensional consideration, both in terms of the organization's ability to deal with external and internal challenges. At the same time, the view on agility and the organization's ability to quickly adapt to changes should be considered in the context of operational, organizational, technological and competence agility. Only such a view gives a full picture of agility.

In the center, however, there is always a man with his competences - knowledge, skills and attitude towards changes - a man with his ability to be agile. Whether and how the organization will be ready to cope with the changes taking place around it, and thus what level of agility it will be able to demonstrate, depends on the openness to this human agility and agile competences possessed by people who create this organization. There will be as much agility in the organization as there will be openness to agility in the people who create it. This is a factor that, in the opinion of the author of this study, is crucial in defining the ability to agile transformation of an organization.

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# DEFECT ANALYSIS OF EN AC-435000 ALLOY DIE CASTINGS USING THE PARETO-LORENTZ DIAGRAM

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**Purpose:** The purpose of this research is to describe the most important defects in die castings made of EN AC-435000 alloy and to present preventive measures and to rank these defects using Pareto-Lorenz analysis.
**Design/methodology/approach**: The paper provides a comprehensive look at the causes of defects in finished products. During the analysis, Ishikawa and Pareto-Loretnz diagrams were used to get information on what are the main defects in finished products and what steps should be taken to optimize the production process.
**Findings:** An research was used a typical material applied in the aerospace and automotive industries. The article shows that even small deviations from the accepted technological assumptions, in this case temperature, leading to products that deviate from the accepted quality assumptions.
**Practical implications:** The article is intended not only for the scientific community, including students, but also for technologists working in industry. It shows the process of identifying the locations and types of damage to finished products and what steps should be taken to avoid them in the future.
**Originality/value:** Demonstration, difficulties in optimizing the die casting process for EN AC-435000 alloy.

**Keywords:** Pareto-Lorentz diagram, EN AC-435000 alloy, defect analysis.

**Category of the paper:** Technical Paper.

## 1. Introduction

In recent years, research carried out in the automotive and aviation fields has made significant progress. These advances are mainly related to the need to reduce the harmful effects of vehicles on the environment, including by reducing the weight of vehicles or reducing

emissions of toxic exhaust components (Satyarth, Rohan, Vibhuti, Sangwan, Mahanta, Feroskhan, 2022, pp. 1554-1560). A lot of possible solutions have been developed in this element, including the production of hybrid or electric cars (Asus, Madon, Che Daud, Said, Aglzim, Talib, Ahmad, 2022, p. 032012), downsizing technology in engine construction. Despite this, the abandonment of the use of internal combustion engines, takes time, and that is why manufacturers are focusing on reducing fuel consumption, and thus reducing the weight of vehicles and lower emissions of $CO_2$, among other things (Alemayeehu, Firew, Nallamothu, Wako, Gopal, 2022, p. e09679). Looking from this side, aluminum alloys are proving to be one of the best solutions to meet both structural and environmental requirements. Modern aluminum alloys, thanks to appropriate modifications, have significant specific mechanical properties and significant corrosion resistance. These unique properties make it possible to use these alloys in many parts of vehicles, from automobile chassis, aircraft structures to components of piston and turbine engines. Aluminum-silicon alloys are widely used in the automotive and aerospace sectors, for example, for the manufacture of pistons (Vamsikrishna, Shruti, Divya Sharma, 2021, pp. 589-597). The primary method of manufacturing automotive pistons from aluminum-silicon alloys is die-casting. This is due to the cost and speed of manufacturing. However, numerous manufacturing defects are revealed during production.

The number and type of defects in die-casting processes are influenced by technological parameters and physicochemical phenomena, which mainly include:

- the molding of the casting, especially compliance with the principles of die casting,
- the profile of the mold, i.e., its shape, position and dimension of the gating system, overflows and vents,
- optimization of process parameters.

In order to get them right, any errors should be detected and corrected during inter-operational inspection. This inspection influences the reduction of the proportion of defects, but does not eliminate them completely. Final testing of castings usually involves checking the castings for correct weight, chemical composition, dimensions, structure and strength properties. When the test results differ from the initial assumptions, it can be claimed that the castings are defective (Saxena, Godara, Chouhan, Saxena, 2021, pp. 1622-1634). The type of casting defects is defined by the Polish standard PN-85/H83105.

In die casting processes, the most characteristic casting defects are porosity, cracks, underfilling, subsurface blistering and adhesion to the mold (Gupta, Kumar, Chandna, Bhushan, 2020, pp. 2429-2443). These defects can be divided into two basic types: raw surface defects, visible to the naked eye, and internal defects (Dhisale, Vasavada, Tewari, 2022, pp. 3189-3196).

## 2. Aim and scope of the study

The purpose of the research is to describe the most important defects in die castings made of EN AC-435000 alloy and to present preventive measures and to rank these defects using Pareto-Lorenz analysis.

In order to realize the adopted goal, the scope of the study included:

- characterization of typical defects in EN AC-435000 alloy die castings and preventive measures,
- classification of casting defects using the Ishikawa diagram,
- analysis of casting defects using the Pareto-Lorenz method,
- summary and final conclusions.

EN AC-435000 alloy is a popular silumin used for die-casting of engine parts and so-called structural details that form the exterior structure of automobiles. Due to the complexity of the castings, often thin-walled castings, it is an alloy designed for high-pressure casting.

All materials presented in the paper are the property of Magna Casting Poland.

## 3. Typical defects in die castings with special emphasis on EN AC-435000 alloy

The main defects arising in die castings we can include:

1. Cold flows (underfills; non-fills; ripples).
2. Sticking.
3. Cracks in castings (hot and mechanical).
4. Mechanical defects (creases, pulls, cracks).
5. Subsurface blisters.
6. Fills.
7. Discoloration.
8. Porosity (gas and shrinkage).
9. Non-metallic inclusions.

The various defects that arise in die castings are presented in Figure 1.

If any of the defects shown occur, the product is marked as defective and requires disposal or additional treatment. Depending on the number of individual defects, appropriate corrective and preventive measures are introduced and must be implemented in the corresponding production or post-production process. As an example, a situation can be given where an increased number of defects in the form of cold flows (underflows, non-welds, folds) has been determined in the production process and the reasons for this can be various, i.e., incorrect

(too low or too high) casting temperature or too low casting pressure. In such a case, it will be necessary to verify the temperature measurement system, among other things, by checking whether maintenance (replacement / cleaning) was carried out as planned. Another example is mechanical defects (nicks, cracks, creases), which can arise either in the production process (mold damage) or post-production arising on the casting surface during the trimming process.

It should be remembered that some defects require correction (immediate action) at the appropriate production stage, e.g. underfills, and others require preventive action, e.g. discoloration, where the genesis of the cause is not easy to identify. In the latter case, in the analyzed company, the diagnosis of the origin of the cause is determined by the production manager together with the personnel responsible for the technical condition of the production line.

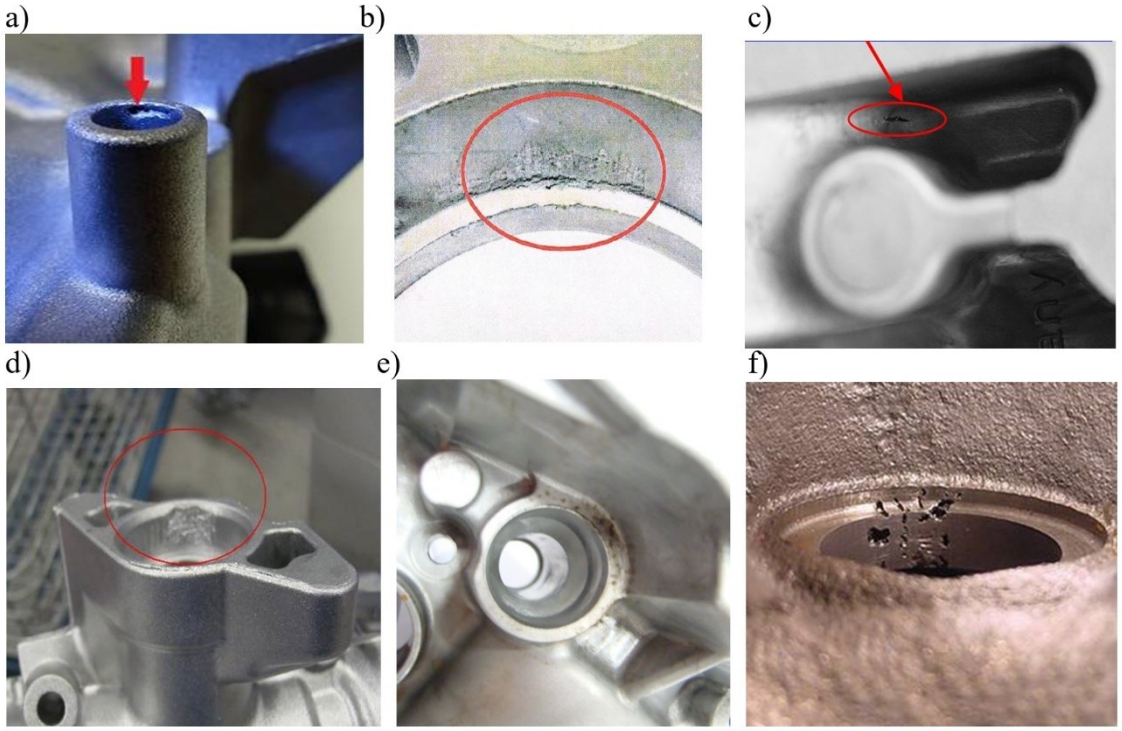


**Figure 1.** Defects in the workpieces revealed in the production process: a) underfilling, b) sticking, c) cracks, d) breakouts, e) discoloration, f) macroporosity.

## 4. Classification of casting defects using the Ishikawa diagram

In order to fully illustrate the casting defects that arise in the production process of die castings, an Ishikawa diagram was used. In creating it, due to the specifics of the analyzed process, the typically used groups of causes in the 5M (6M) form were omitted, while the main causes were divided into four basic groups:

a) defects in shape,
b) internal defects,
c) raw surface defects,
d) continuity breaks.

These groups were selected based on a review of the literature in this area and past experience from operating the manufacturing process. Then, to each of the main groups of causes, detailed casting defects were assigned based on past experience and ongoing internal analysis.

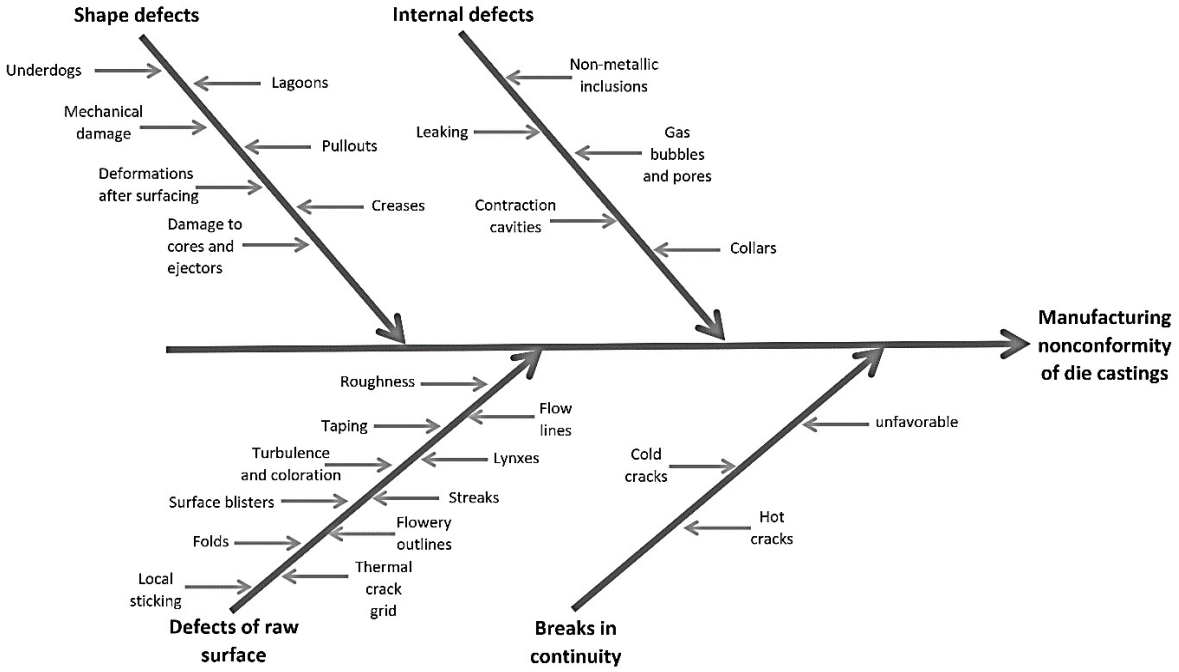


**Figure 2.** Ishikawa diagram for die casting defects.

Figure 2 shows an Ishikawa diagram depicting the problem of production irregularity associated with manufacturing nonconformity of die castings. In this type of diagram, it is not possible to assess the importance of individual causes, but it is possible, for example, to identify which group the most causes have been classified into. When analyzing the diagram related to the manufacturing process of die castings, it can be seen that the most causes of nonconformity are concentrated in the category of: shape defects and raw surface defects. However, as is known from a review of the technical literature, the vast majority of raw surface defects are a consequence of internal defects, primarily gas porosity. Therefore, a cautious conclusion can be drawn that further analysis should first be applied to these types of defects. However, this type of analysis on the basis of the Ishikawa diagram alone should be approached with great caution, as it is often easy to attribute a significant number of detailed causes, for example, in the process under study due to the appearance of defects in the finished products (thus easily identifiable) and, for example, internal defects, the disclosure of which requires additional research described in smaller numbers, and in fact account for the vast majority of all defects. Therefore, in the next step, casting defects were analyzed using a Pareto-Lorentz diagram.

## 5. Analysis of casting defects using the Pareto-Lorenz diagram

To make a detailed analysis of defects arising in the die casting process, a periodic quality report of manufactured die castings was analyzed. Based on it, a set of basic casting defects influencing the necessity of rejecting parts due to quality deficiencies was distinguished.

Those defects were singled out, which in the vast majority of cases directly contributed to the scrapping of rejected details. In some cases of revealed defects, due to the slight reduction in quality as well as the possibility of appropriate correction/repair/additional processing, such as puttying of surfaces where pores of less than 3 mm in size occurred after basic processing, it was possible to restore the final selection to the assumed quality level.

The occurrence of the main casting defects depending on the temperature value of the EN AC-435000 liquid alloy is shown in Figure 3. The main element influencing the number of defects in a given production cycle was the temperature of the liquid alloy. The highest number of casting defects, occurred at a temperature of 735ºC and amounted to as much as 49% of all manufactured products. The lowest percentage of defective products was obtained in the production cycle at 760ºC and was 19%. At a temperature of 775ºC, the percentage of defective castings was 39%.

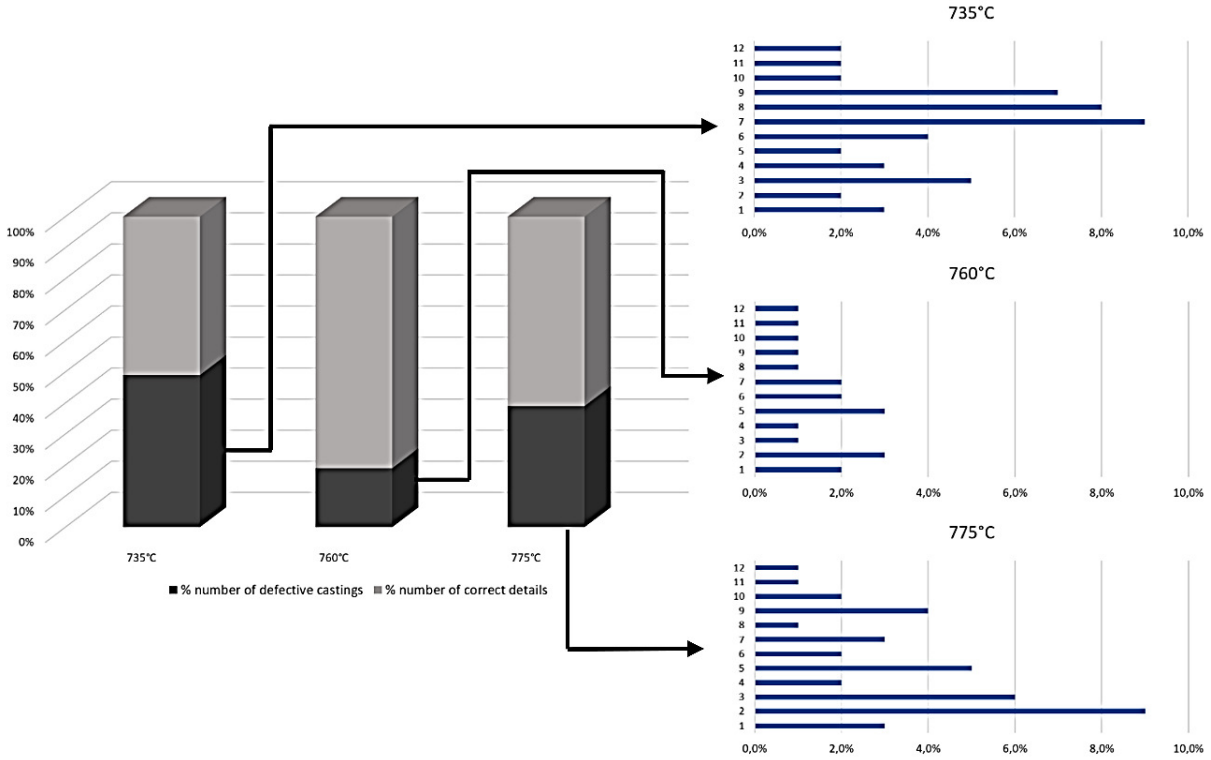


**Figure 3.** Occurrence of major casting defects depending on the temperature value of the EN AC-435000 liquid alloy, where 1. Gas blisters, 2. Dressings and shrinkage cavities, 3. Breakouts, 4. Mechanical damage, 5. Sealings, 6. Non-metallic inclusions, 7. Cracks, 8. Underfills, 9. Leakage, 10. Flat surface folds, 11. Seam welds, 12. Other.

With the use of computer analysis in conjunction with finished product inspection, it was possible to determine the exact type of individual defects that contributed to the need to reject the workpiece. Table 2 shows, ranked from most to least common defects in the case under review.

**Table 1.**
*Ranking of the most common casting defects in the case study*

| No. of casting defect | Type of casting defect | Percentage of defect | Cumulative share |
|---|---|---|---|
| 2 | Dressings and shrinkage cavities | 25% | 25% |
| 5 | Sealings | 20% | 45% |
| 7 | Cracks | 10% | 55% |
| 1 | Gas blisters | 9% | 64% |
| 6 | Non-metallic inclusions | 8% | 72% |
| 12 | Other | 6% | 78% |
| 8 | Underfills | 4% | 82% |
| 11 | Seam welds | 4% | 86% |
| 4 | Mechanical damage | 4% | 90% |
| 9 | Leakage | 3% | 94% |
| 10 | Flat surface folds | 3% | 97% |
| 3 | Breakouts | 3% | 100% |

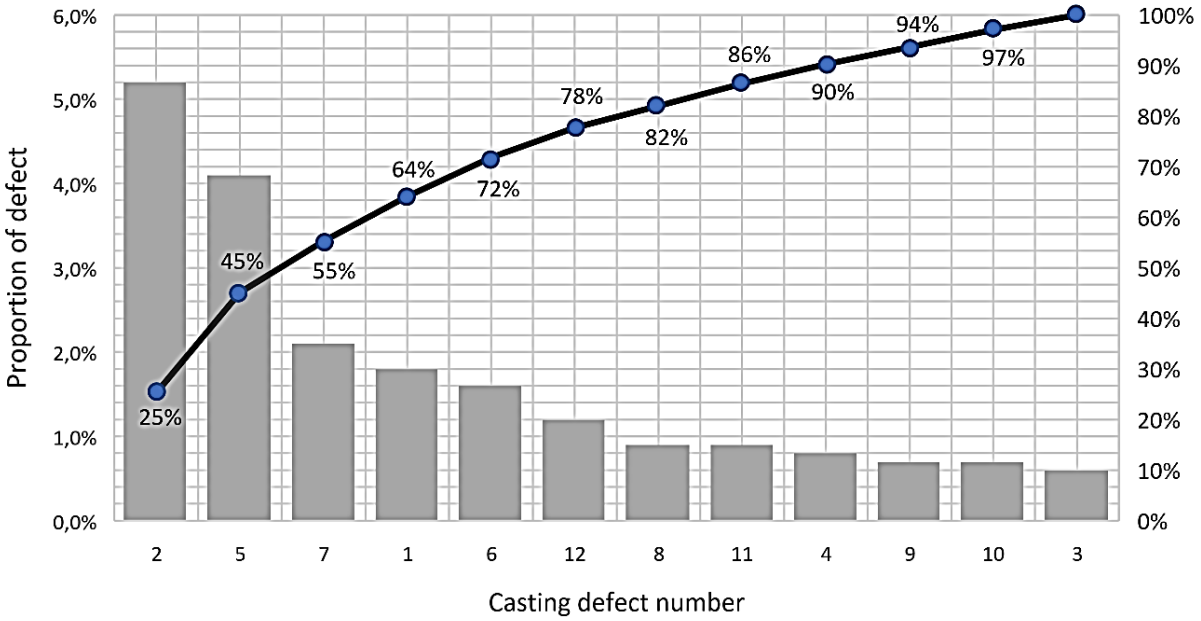


**Figure 4.** Pareto - Lorentz chart of casting defects (defect numbers according to Table 2).

Based on the data in Table 1, a Pareto-Lorenz chart was drawn up (Figure 4), for the determination of courses of action leading to a reduction in the production rate of defective details.

Analysis of the data allows us to note an even distribution of the causes of defective details. The first six of the listed defects, account for 78% of the total defects and the remaining six defects of the details, account for only 22%. This means that, according to the assumptions of Pareto analysis, in order to obtain a clear rationalization effect, it is necessary to evaluate the causes of the defects and their removal for the following defects: Dressings and shrinkage

cavities (25%), Sealings (20%), Cracks (10%), Gas blisters (9%), Non-metallic inclusions (8%) and other (6%).

## 6. Summary and conclusions

In accordance with the stated goal, the use of the Ishikawa diagram made it possible to classify casting defects for the general categories adopted. Then, based on materials from computer analysis of workpieces as well as inspection of finished products, a Pareto-Lorenz analysis was carried out, thanks to which the defects occurring in castings were ordered according to their degree of importance. The first four defects listed turned out to account for 78% of all defects occurring in the production process. The result of this analysis was to take the necessary measures to minimize the most significant casting quality problems:

- systematic verification of the chemical composition of the EN AC-435000 alloy, and in the event of non-compliance, supplementation of missing batch components,
- control of the range of crystallization, i.e. the temperature of liquidus, solidus and eutectic crystallization, with particular attention to the minima and maxima of these parameters, especially the superheating temperature of the liquid alloy, due to the possibility of causing an increase in the degree of gasification of the alloy, and thus an increase in the porosity of the finished casting,
- more frequent verification of the system for temperature measurement, throughout the production process,
- additional control of the cooling rate, as well as heat dissipation,
- minimization of turbulence during casting from the melting furnace and during mold filling,
- increased attention to the cleanliness of the metal bath,
- increased care during transport and supervision of the correct operation of the system for knocking the casting out of the mold.

Based on the study, the following conclusions were made:

1. The most significant defects contributing to casting rejection are defects related to gas porosity of the alloy. These defects are most often due to poor chemical composition of the casting alloy, inadequate solidification temperature range, volume change during solidification, inadequate cooling rate and heat dissipation, and the presence of non-metallic inclusions.
2. Metal quality control should begin with the melting of the batch components. Eliminating irregularities at this stage of production will contribute to a significant reduction in casting defects.

3. Pareto-Lorenz analysis illustrates the unevenness of the distribution of causes in relation to the number of defects present in the workpiece. The principle that 80% of the effects derive from 20% of the causes should not be taken literally, however, in the studied alloy, 6 defects, accounted for 78% of the total.
4. In order to minimize the occurrence of casting defects, it is necessary to introduce: inter-operational quality control, supervise the technological parameters of the die casting process (temperature, time, pressure), increase the supervision of supervisory personnel, influence the self-awareness of employees through a series of courses and training.

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# ODT PRODUCT QUALITY MANAGEMENT ON THE EXAMPLE OF AUTOMATIC CONTROL OF TABLET WEIGHT UNIFORMITY

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**Purpose:** The aim of the work was to present the automation of the mass measurement process as a factor that can significantly affect the quality and speed of analyzes in pharmaceutical industry.
**Design/methodology/approach**: In this study, two methods were presented for testing the mass uniformity of tablets whose weight ranged from 13 mg to 2580 mg. The first method involved determining the weight of 20 randomly selected tablets of pharmaceutical preparations by statically measuring the weight of these tablets. In the second method, an automatic tablet feeder type PA-04/H was used, in which, as a result of vibration, successive tablets were automatically moved via a special chute onto the weighing pan.
**Findings:** No significant differences were found in the weight measurements performed by the manual and automatic methods. The largest differences were noted at the 0.5% level. All tablets tested met the United States Pharmacopeia requirements for their mass uniformity. For orally disintegrating tablets, the largest percentage deviations in weight from the mean value were - 4.47% for tablet F6, - 4.26%, for tablet F1 and 3.31% for tablet F2. The differences in accuracy and precision between the automatic and manual methods were insignificant.
**Research limitations/implications**: Mass measurement by the manual method is one of the most frequently performed measurements in the laboratory. The final result from this measurement method may be subject to error caused, for example, by human error, i.e. reading, writing or calculation error. For this reason, process automation is increasingly being used, which eliminates the possibility of error to a large extent.
**Practical implications:** The automation of weight measurement reduces the effort required for product inspection. Thus, it can be an important factor in the process of optimization and product quality management.
**Originality/value:** The description of the research method and its results can be a valuable guideline for people who deal with product quality control in the pharmaceutical industry. It has been shown that automation to be effective does not have to be complicated but well designed.

**Keywords:** mass, measurement, mass uniformity, tablets, accuracy, weighing, time management.

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

## 1. Introduction

The production of tablets is a rather complex process with quite a high level of risk (EMA/CHMP/ICH/24235/2006) in which quality must be maintained at a constantly high level, hence the aim to have quality built into the product - Quality by Design (Schmitt, 2018; Snee, 2016; Anushka et al., 20121; Kishor et al., 2022; Pritam, Shubham, 2022). The compressing technologies in use today (Van der Haven et al., 2022; Abouzeid at al., 2014; Baroutaji et al., 2017) ensure maximum line efficiency while maintaining the relevant properties of the medical formulation. The key to achieving and maintaining both is to optimize the compressing process (Ganesh et al., 2012; Mohit et al., 2021; Antonyuk et al., 2010) taking into account the specific characteristics of the tablet (its size, composition, drug release rate) and the capabilities and limitations of the compressing system. One of the important parameters of each tablet is its mass, which is de facto the sum of all the components that make up its matrix.

One of the popular types of tablets today are polymeric matrix tablets with a controlled release rate of the drug substance, which ensures a constant concentration in the patient's blood (Sangmun et al., 2011; Raghuram et al., 2003; Katzhendler et al., 2000; Levina, Rajabi-Siahboomi, 2004; Viridén et al., 2010). In this solution, the rate of drug release can be modified by additives such as hypromellose - a semi-synthetic cellulose derivative (HPMC) that can account for approximately 20-40% of the tablet weight (The Down Chemical Company, 2000). Another novel tablet form is tablet that disintegrate in the mouth referred to as Oro-Dispersible Tablets (ODTs) (Teaima et al., 2022; Sipos et al., 2107; Etman et al., 2014; Mohammadali et al., 2021). The small size of ODTs and the rapid disintegration of the drug in the patient's mouth of about 30 seconds (Guidance for Industry-Orally Disintegrating Tablets, 2008) or a few minutes (European Pharmacopoeia, 2019) is an excellent example of personalisation in medicine dedicated to paediatric and geriatric patients and in cases of dysphagia. It should be noted that the rapid disintegration of ODTs (Mohammadali et al., 2021) in contact with the patient's saliva allows the appropriate dose of the drug to be applied also on the move without having to sip the drug with water, which is undoubtedly their advantage. Thanks to its small size, ODTs are a discreet and effective form of medication for patients with chronic diseases who need to take their medication frequently and systematically. From a medical point of view, the speed of action of ODTs is important, which is desirable in cases of migraine, severe pain or diarrhoea. Regardless of the type of tablet, the weight of each tablet must be within certain limits (US Pharmacopeia, 2011; European Pharmacopoeia…, 2019). On the one hand,

the uniformity of tablet mass over the production cycle is a normative requirement that must be met so that a production batch can be considered compliant. On the other hand, the tablet mass drifts observed in a production run are an indicator for process control (VanDrie, 2007), where uniformity of filling of the tablet die cavity is important. This is a complex process, the efficiency of which depends on the flowability, cohesion and particle size of the powder mixture. The parameters of the process equipment are also important in this regard. The aim of the study was to see if the introduction of automation in mass measurement has a significant effect on the accuracy of determining the uniformity of tablet mass. In the study, the authors also wanted to indicate that the search for alterative, simple methods can be one of the factors that fits into the model of proper time management not only of personnel, but also of performing a specific analysis.

## 2. Material and methods

The material in the study consisted of 10 selected pharmaceutical preparations including six ODT-type preparations two lozenges and two swallowable preparations. Twenty tablets of each pharmaceutical preparation were used for the study by conducting tests for each tablet separately. The characteristics of the formulations are shown in Table 1. From a metrological point of view, the size of the tested products and thus their weight was important. As the weight increases, significant differences can be expected between the manual and automatic measurements, mainly due to the impact that occurs when a tablet is dropped from a certain height onto the weighing pan, as was the case when measuring the weight of tablets using Method II.

**Table 1.**
*Characteristics of tablets tested for mass uniformity*

| Sample | Active substance | Type | Indication for use | Manufacturer |
|---|---|---|---|---|
| F1 | desloratadinum | ODT | allergies | Adamed Pharma, Poland |
| F2 | desloratadinum | | | US Pharmacia, Poland |
| F3 | meloxicamum | | pain, inflammation | Hasco-Lek S.A., Poland |
| F4 | 2 mg Loperamidi hydrochloridium | | diarrhoea | McNeil Healthcare, Ireland |
| F5 | Melatonin | | sleep problems | Olimp Laboratories, Poland |
| F6 | Folate Quatrefolic | | support of the immune system | Medimes, Poland |
| F7* | chlorquinaldolum 2 mg | lozenges | bacterial infections of the throat, mouth | Bausch Health Ireland Limited, Ireland |
| F8* | alcohol 1.2 mg, 2.4-dichlorobenzylicus, 0.6 mg amylometacresolum | | | Reckitt Benckiser S.A., Poland |

Cont. table 1.

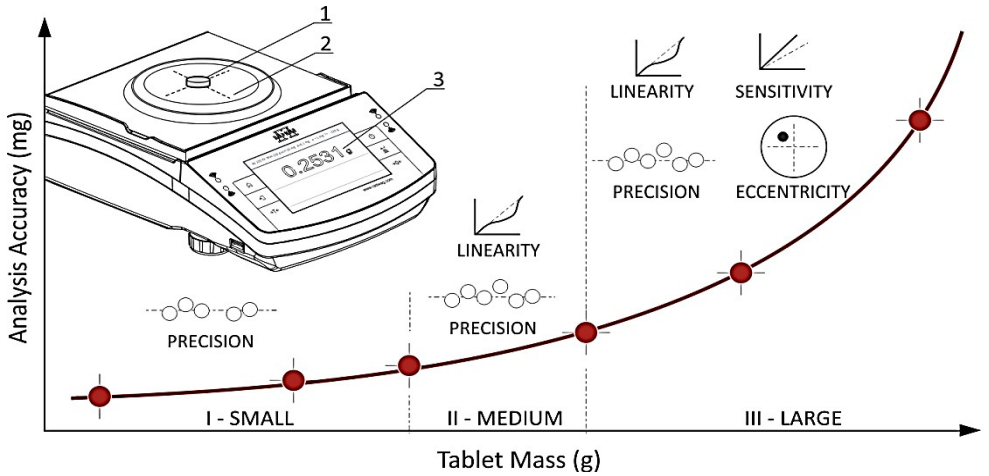
| | | | | |
|---|---|---|---|---|
| F9* | lutein 24 mg | oral tablets | improving vision | Aflofarm Polska Sp. z o.o., Poland |
| F10* | choline, L-aspartate, L-ornithine, extracts of artichoke, holly, chicory, holly | | improve liver function and maintain normal fat and homocysteine metabolism | Teva, Poland |

Legend: F1-F10 means symbols of tested pharmaceutical preparations; * dietary supplements.

## 2.1. Methods I – manual

The weight of each of the 20 tablets was determined by manual weighing by gently placing it with a pencil on the balance pan. An analytical balance AS 220.X2 manufactured by Radwag Wagi Elektroniczne, Radom, Poland, was used for the weight measurements; the elementary scale division for the weight measurement was 0.1 mg. The repeatability of the readings for tablet mass measurements was 0.06 mg, which was in accordance with the data provided by the balance manufacturer regarding the repeatability of readings when the sample mass is no more than 5 % of the balance maximum load.

The metrological relationships associated with manual mass measurement affecting the accuracy of tablet mass determination are shown in Figure 1.




Legend: 1 – weighted tablet, 2 – weighing pan, 3 – weighing result.

**Figure 1.** Manual weighing process - weighing accuracy depending on the size of the tablet weight.

In the first weighing range when the weight of the tablet was less than 5% of the maximum load of the balance, the accuracy of the weight measurement depended only on the precision of the measurement. For stable operating conditions in the temperature range, the measurement precision was very good (had a low value) because there were no impacts during weighing when the tablet was placed on the weighing pan. In the second and third weighing ranges, the accuracy of the weight measurement is further influenced by other metrological factors such as sensitivity, linearity and centricity of the balance. The sensitivity of the balance before the test was adjusted by internal adjustment of the balance. Performing the adjustment meant that the linearity characteristics of the balance were correct. Centricity deviations can be significant for the measurements carried out when the object to be weighed is placed off-centre on the pan.

The tablets were placed in the centre of the pan. The weight of the tablets tested ranged from 13 mg to 2580 mg. It was therefore assumed that the error in determining their weight was only affected by the precision of the measurements as stated by the manufacturer. The effects of sensitivity, linearity and centricity of the balance were considered negligible.

From the results obtained, the mean tablet weight was calculated and the percentage of tablet weight variation relative to the mean value was checked. The acceptable limits of variation in tablet weight (US Pharmacopeia, 2011; European Pharmacopoeia…, 2019) depending on the mean value are shown in Table 2.

**Table 2.**
*Tablet weight uniformity - allowable percentage deviations in tablet weight according to the United States Pharmacopeia*

| Average tablet weights | Percentage deviation | Number of tablets |
|---|---|---|
| m ≤ 80 mg | ± 10.0<br>± 20.0 | Minimum 18 units.<br>Max. 2 pcs. |
| 80 mg < m ≤ 250 mg | ± 7.5<br>± 15.0 | Minimum 18 units.<br>Max. 2 pcs. |
| m > 250 mg | ± 5.0<br>± 10.0 | Minimum 18 units.<br>Max. 2 pcs. |

The percentage deviation of each tablet was calculated according to the formula below:

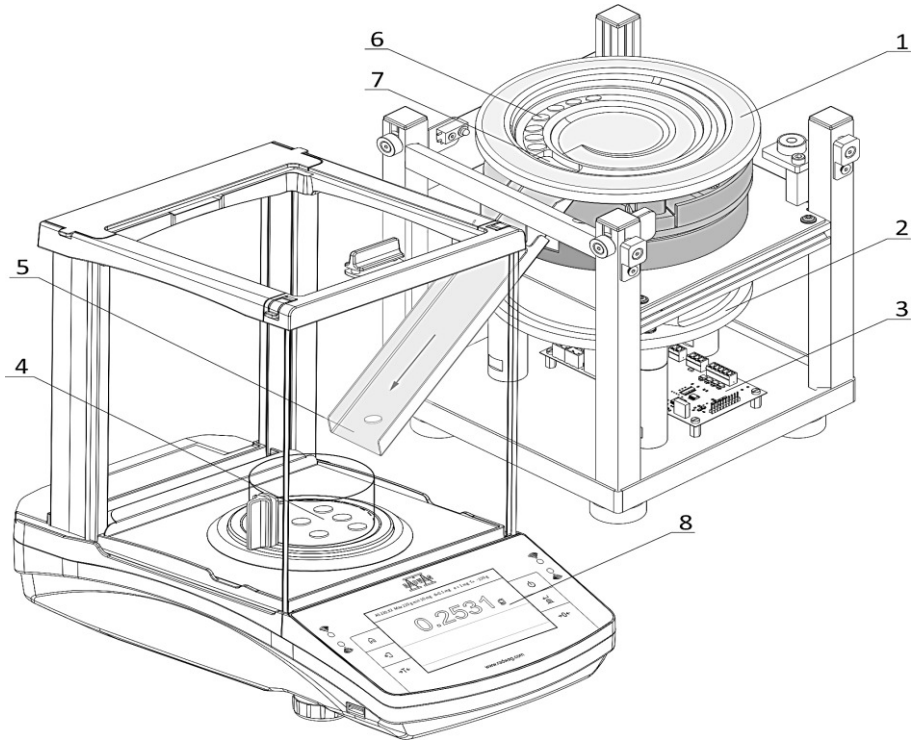
$$Deviation\ (\%) = \frac{|\ (\bar{m} - m_i)|}{\bar{m}} * 100\ \% \quad (1)$$

where:
$\bar{m}$ - average tablet weight,
mi - weight of the next tablet.

## 2.2. Method II - automatic

In the automatic method, a PA-04/H automatic feeder produced by Radwag Wagi Elektroniczne, Radom, Poland and an AS 220.X2 analytical balance were used (Figure 2). The tablets subjected to the weight test (6) were placed in the vibrating feeder (1). The spiral plane of the feeder was slightly inclined towards the drop hole (7), so that when the vibration of the feeder (1) was activated, an orderly array of tablets (6) was obtained, which automatically shuffled into the drop hole (7). The presence of a tablet in the drop hole was registered by a detector, which temporarily switched off the vibration of the device. The tablet was then transported via the discharge chute (5) to the weighing vessel (4). The AS 220.X2 balance recorded the weight of the tablet (8) and then zeroed the display so that the next measurement was taken from the exact zero state. Once the weight of the tablet had been recorded by the scale, the feeder received a signal back that it was ready for the next weighing and restarted the vibration of the tablet feeder (1). Such a measurement cycle was cycled for a series of 20 measurements of each tablet. At the end of the series of measurements, the balance display

showed the result of the test, i.e. the average value of the tablet weight and the deviation of the weight of each tablet from the average value.




Legend: 1 – vibrating feeder, 2 – base of vibrating feeder, 3 – control system of device operation, 4 – weighing pan with tablet container, 5 – drain chute, 6 – tablets, 7 – drop opening with tablet detector, 8 – weighing result.

**Figure 2.** Automatic feeder PA-04/H with scale AS 220.X2.

The PA-04/H vibration feeder allowed the vibration intensity to be adjusted from a low value to a high value, which was used when testing ODT tablets, mainly due to their small size. The accuracy of the automatic method used to test the mass uniformity of the tablets was determined by comparing the mass measurements obtained using this method with the results that were obtained using the manual method.

## 3. Results for precision and accuracy of tablet weight measurements

The hygroscopicity of ODT tablets is a desirable feature due to their rapid disintegration in the patient's mouth, but on the other hand, it is a factor that can affect the accuracy of mass measurement (ISO 5725-6, 2002). For this reason, the weight of each tablet was determined immediately after removal from the pack using both manual and automated methods. The average weight of each tablet, the precision of the tablet device defined by the standard deviation and the accuracy of the automatic method weight measurements are shown in Table 3.

**Table 3.**
*Mass of tablets (accuracy and precision of the automatic method)*

| Sample | M1 - method manual AS 220.X2 | M2 - method automatic PA-04/H + AS 220.X2 | Difference \|M2-M1\| |
|---|---|---|---|
| | $\underline{x}(mg) \pm S(mg)$ | | % |
| F1 | 171.69 ± 2.73 | 171.57 ± 2.73 | 0.07 |
| F2 | 85.32 ± 0.93 | 84.77 ± 0.90 | 0.53 |
| F3 | 253.98 ± 2.25 | 253.47 ± 2.22 | 0.20 |
| F4 | 13.30 ± 0.13 | 13.37± 0.15 | 0.49 |
| F5 | 176.22 ± 1.62 | 176.37 ± 1.55 | 0.09 |
| F6 | 407.76 ± 8.23 | 408.20 ± 8.20 | 0.11 |
| F7* | 400.14 ± 4.88 | 400.45 ± 4.94 | 0.08 |
| F8* | 2580.01 ± 31.55 | 2579.71 ± 27.52 | 0.01 |
| F9* | 918.14 ± 11.47 | 919.13 ± 8.34 | 0.11 |
| F10* | 494.69 ± 7.27 | 493.86 ± 7.50 | 0.17 |

Legend: F1-F10 means symbols of tested pharmaceutical preparations; * dietary supplements.

There were no significant differences in the accuracy of tablet weight measurements between the manual and automatic methods. The greatest discrepancy of approximately 0.50% between the measurements obtained by the manual and automatic methods was recorded for tablets F2 and F4 (ODT preparations), where the weight of these tablets was determined as 85 mg and 13 mg, respectively. It should be noted that the accuracy of the determination of the average tablet mass value is significantly affected by the precision of the measurements. In this case, the precision of the tablet weight measurements was not a measure of the repeatability of the balance readings, i.e. the ability to indicate the same measurements for the same object, but was a measure of the repeatability of the tablet machine used in the production cycle. It was found that as the average tablet weight increased, the discrepancy in tablet weight within a batch increased significantly, which may indicate a feature of the processes used during compressing (Partheniadis et al., 2022; Peciar et al., 2016). The relationship of tablet weight disparity to average tablet weight is shown in Figure 3.

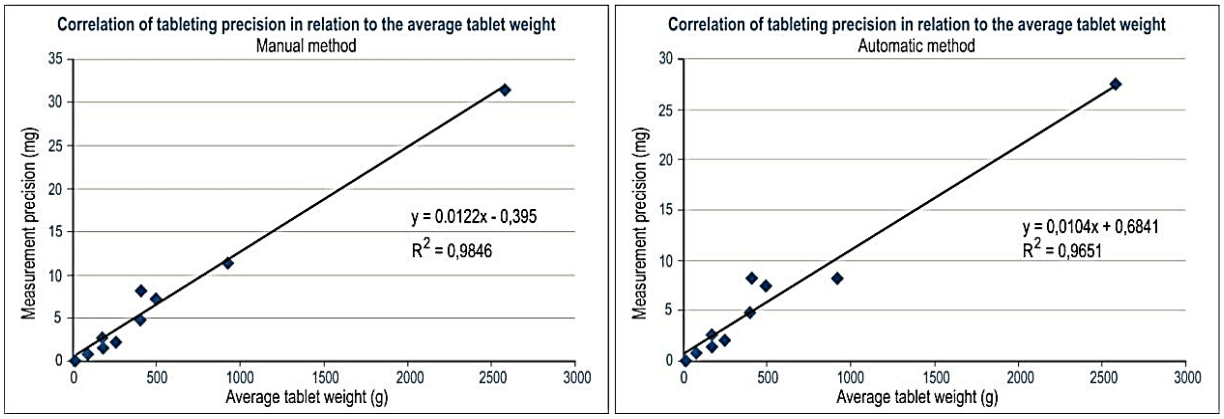


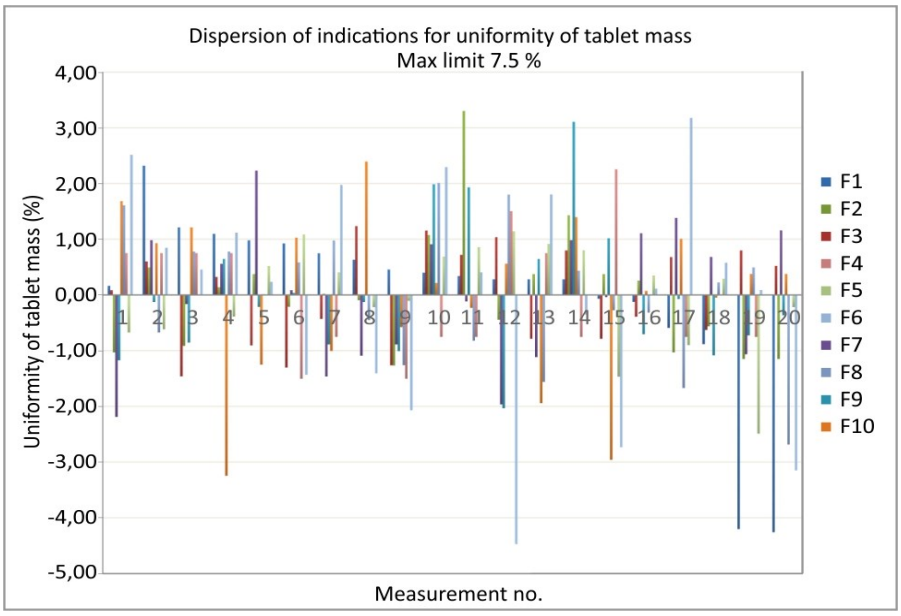

**Figure 3.** Mass uniformity in the compressing process - mass measurement precision.

The values of the r-Pearson correlation coefficients, i.e. the linear relationship between the mean tablet weight and tablet precision, were 0.99 and 0.98, indicating a significantly strong linear relationship between the value of the mean tablet weight and the discrepancy between their weights in the series. It was found that the use of an automated method during tablet

weighing did not introduce significant distortions - the coefficient of determination $R^2$, a measure of the fit of the linear regression model, was 0.98 and 0.96 for the methods used, respectively.

### 3.1. Test results for assessing the uniformity of tablet mass

Based on the percentage deviation of the weight of each tablet relative to its average weight, it was concluded that the weight uniformity requirement shown in Table 2 was met. A graphical interpretation of these relationships for the manual weighing method in which the AS 220.X2 balance was used is presented in Figure 4.




Legend: F1-F10 means symbols of tested pharmaceutical preparations.

**Figure 4.** Scatter of readings for tablet mass uniformity.

The largest weight percentage deviations from the mean values were noted for tablets F6 (- 4.47%) and F1 (- 4.26%). It should be noted that the maximum allowable limit for percentage deviations in mass was 10% for tablet F6 and 7.5 % for tablet F1. The observed percentage mass deviations were therefore considered to be insignificant. For most tablets, the mass uniformity was in the range of 1-2%, which was an acceptable result within the required limits (US Pharmacopeia, 2011; European Pharmacopoeia…, 2019). Table 4 shows the mean value of the percentage deviations from a series of 20 weighings of each tablet type and the precision of the determination of this value, which was a measure of the scatter that characterised the series of measurements. The scatter of the series of measurements was defined by the value of the standard deviation, and its value was used to estimate whether the tablet under test met the weight uniformity requirements (Table 2). On the other hand, these values were used to compare the accuracy and precision of the measurements of the automatic and manual methods. No significant differences were found in the accuracy as well as the precision of the analysis carried out, regardless of which method was used.

**Table 4.**
*Mass uniformity of tablets - manual and automatic method*

| Sample | Average mass | Precision and max. deviation masses of tablets | | Max. normative limit for mass uniformity |
|---|---|---|---|---|
| | | manual method | automatic method | |
| | $\bar{x}\ (mg)$ | $\overline{\Delta m}\ (\%) \pm S\ (\%)$ | | m (%) |
| F1 | 171.69 | 1.01 ± 1.60 | 1.00 ± 1.59 | 7.5 |
| F2 | 85.32 | 0.79 ± 1.09 | 0.78 ± 1.05 | 7.5 |
| F3 | 253.98 | 0.80 ± 0.89 | 0.74 ± 0.87 | 10 |
| F4 | 13.30 | 0.76 ± 0.98 | 0.81 ± 1.12 | 20 |
| F5 | 176.22 | 0.71 ± 0.92 | 0.67 ± 0.88 | 7.5 |
| F6 | 407.76 | 1.56 ± 2.02 | 1.56 ± 2.01 | 10 |
| F7* | 400.14 | 1.01 ± 1.22 | 1.02 ± 1.23 | 10 |
| F8* | 2580.01 | 0.97 ± 1.22 | 0.87 ± 1.07 | 10 |
| F9* | 918.14 | 0.94 ± 1.25 | 0.70 ± 0.91 | 10 |
| F10* | 494.69 | 1.13 ± 1.48 | 1.20 ± 1.52 | 10 |

Legend: F1-F10 means symbols of tested pharmaceutical preparations, * dietary supplements.

## 4. Conclusions

The difference in tablet masses in a production run is the result of inaccuracies in the technological methods and equipment used. From a technological point of view, it can be stated that factors such as powder flow, speed of the compressing machine, pressure applied during pressing and the type of machines used for compressing are important. The size and distribution of particles in the compression process are also important. Determining the mass uniformity and, in fact, the mass discrepancy of tablets in a production run by gravimetric mass measurement is the fastest, simplest and cheapest method. It is adaptable to any laboratory with minimal operator input and qualification. Manual mass measurement performed using analytical (0.1 mg) and semi-microanalytical (0.01 mg) balances requires stable operating conditions and tablet mass information is usually recorded manually. This mode of operation is prone to errors due to the so-called human factor and the method of data digitisation. The introduction of automation in the tablet mass uniformity testing method saves time and makes the process much more ergonomic. The study concluded that manual and automatic methods can be used interchangeably without losing the accuracy of the analysis. Today, the aim is to automate many processes in pharmacy, and observing and controlling the process remotely significantly increases safety and supervision of the control and production process. The PA-04/H automatic feeder fits into this trend as a small component of any pharmaceutical company's GLP/GMP system.

In summary, the introduction of the automatic mass measurement method using the PA-04/H vibrating feeder reduces analysis time while maintaining parameters such as precision and measurement accuracy. Its implementation in the pharmaceutical industry, in the authors' opinion, is a valid, convenient alternative to this type of measurement.

Thus, this method is part of effective time management which, to a large extent, allows you to optimally use the potential of the company in a consistent pursuit of the desired goal.

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# ACTIVITIES OF THE MUNICIPALITY IN MUNICIPAL RESOURCE MANAGEMENT ASSESSED BY RESIDENTS ON THE EXAMPLE OF THE CITY OF CZĘSTOCHOWA

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**Purpose:** The objective of the article is to identify activities of the municipality in the field of cooperation with the environment to develop appropriate pro-social activities in the management of municipal resources on the example of the Municipality of the City of Częstochowa.
**Design/methodology/approach**: The research tool was a structured survey questionnaire prepared by the authors of the article. The survey was conducted in June 2022 among residents of municipal resources in the city of Częstochowa, the Silesian Voivodeship, Poland.
**Findings:** The research indicated that housing resource management processes should assume cooperation with the economic and scientific environment and the implementation of scientific research results in shaping models for municipal housing resource management to meet social needs, strengthen social ties and create new models in the field of municipal resource management.
**Research limitations/implications**: In addition to scientific values, the study also has a practical aspect that can be used by municipalities and managers of municipal housing resources as support in conscious and effective planning and implementation of pro-social activities in resource management to improve the living conditions of residents.
**Practical implications:** In the future it is reasonable to conduct further research on pro-social activities in municipalities. Specific examples of pro-social activities in municipal resources of various municipalities should be indicated and their perception by residents should be analyzed.
**Social implications:** Due to the changes taking place in the resource, the development of techniques and information technologies, as well as in connection with demographic changes, growing expectations, needs and requirements of residents, it seems important to systematically carry out analyzes in this regard as well as to assess the impact of implemented solutions on the living conditions of the residents of the resource.
**Originality/value:** The conducted research included in the article potentially extends the literature on the subject, presenting pro-social activities in municipal resources on a specific example.

**Keywords:** management, gmina (municipality), municipal resources, inhabitants.

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

## Introduction

Municipal housing resources consist of real estate owned by the municipality, which has not been handed over in perpetual usufruct (Journal of Laws 2023.344). The basis for the creation of municipal housing resources is the studies of the conditions and directions of spatial development of municipalities, adopted on the basis of the provisions on spatial planning and development (Journal of Laws 2023.344). The creation and use of municipal housing resources is one of the main tasks of municipalities to create conditions to meet the housing needs of the self-government community - as stipulated in Art. 4 Sec. 1 of the Act on the protection of tenants' rights, housing resources of the municipality and on the amendment of the Civil Code (https://www.prawo.pl). Residential premises constituting housing resources of the municipality, except for social housing and premises intended for rent for the duration of the employment relationship, may be rented only for an indefinite period. To perform its tasks, the municipality may also rent premises from other owners and sublet them to persons whose households have a low income (Kabus, Dziadkiewicz, 2022, pp. 3-4).

The conditions and development of the knowledge-based economy bring about that nowadays municipalities must face many new challenges related to the need to adapt to changes and transformations taking place in the environment (Dziadkiewicz, 2014, pp. 27-28). Pro-social activities, including the search for knowledge necessary to manage the resources of the municipality, become the basis for modern entrepreneurship. The effective introduction of new ideas requires the acquisition or supplementation of knowledge in terms of the implementation of this process, considering the specificity of the changes made (Gill, Maung, Chowdhury, 2016, p. 566). Therefore, it becomes necessary for the environment of the city authorities to cooperate with the scientific field. This will allow for accelerating the implementation of the assumed development objectives.

The space for pro-social activities is inscribed in the skillful management of business and science relations, bringing not only mutual benefits, but it also significantly affects the development of the local economy (Witek, 2012, pp. 382-383).

In view of the above, municipalities should strive to ensure proper housing management, and thus effective and efficient management of housing resources created and owned by them, i.e., municipal housing resources (Nalepka, 2018, p. 67). In turn, the applied management methods, along with consultation with scientists should translate into an improvement in the quality of life of residents, in particular safety and satisfaction (Talib, Rahman, Qureshi, 2010, pp. 115-116).

The Municipality of the City of Częstochowa manages the municipal resources, thus it is inscribed in the mission and vision of the Strategy of Częstochowa, which is to meet the housing needs of residents and ensure sustainable social and spatial development of the city. Therefore, it can be concluded that actions aimed at restructuring tenants' debt, counteracting social exclusion of debtors and building social bonds in terms of tenants' participation in resource management are dictated not only by pure economic calculus, but also by the municipality's

obligation to ensure social and economic development for all residents of the city (Cichobłaziński 2013, pp.64-65, Czarnecka, Albrychiewicz-Słocińska, Dunay, Ensari 2017, p. 76).

The objective of the article is to identify the activities of the municipality in terms of cooperation with the environment to develop appropriate pro-social activities in the management of municipal resources on the example of the Municipality of the City of Częstochowa. The research tool was a questionnaire. The survey was conducted in June 2022 among residents of municipal resources in the city of Częstochowa, the Silesian Voivodeship, Poland. The conducted research included in the article potentially extends the literature on the subject, presenting pro-social activities in municipal resources on a specific example. In addition to scientific values, the study also has a practical aspect that can be used by municipalities and managers of municipal housing resources as support in conscious and effective planning and implementation of pro-social activities in resource management to improve the living conditions of residents.

## Methods

The main objective of the study was to diagnose the activities of the municipality in the field of cooperation with the environment to develop appropriate pro-social activities in the management of municipal resources on the example of the Municipality of the City of Częstochowa. The adoption of the objective of the study influenced the formulation of the research hypothesis.

RH: Undertaking the cooperation of municipalities with the scientific and economic environment to develop innovative pro-social solutions in the management of municipal resources is important for residents.

The research tool was a structured survey questionnaire prepared by the authors of the article. Following the principle of respondent data disclosure, the questionnaire was filled in anonymously. Simple one-dimensional balanced scales were used to represent the measured values, which reflected the values assigned by the respondents to the evaluated features.

Depending on the question, a forced scale was used, in which the respondent indicated a strictly defined category on the scale, and an unforced one, when they were unable to express their opinion. The respondents' task was to respond to the provided answer options, according to a certain degree to which they agreed with it. The intensity of the respondent's attitude was measured using a bipolar, five-point ordinal scale, described verbally and numerically. The answers were given numerical values (e.g., from 1 to 5), keeping the principle that the assigned values should increase in accordance with the nature and direction of the defined feature.

A Likert Scale was used, where 5 amounts to definitely significant; 4 - significant; 3 - insignificant; 2 - definitely insignificant and 1 - no opinion. The answers of 362 respondents were analyzed. The participants of the study were residents of municipal resources in Częstochowa. 400 completed questionnaires were received, 90.5% of which, i.e., 362 (N = 362) questionnaires were correctly completed. The questionnaire contained the main part and demographics. The study considered such variables as: the respondents' gender, age, education, and source of income (Table 1).

**Table1.**
*Characteristics of the respondents in terms of the variables*

| | | | |
|---|---|---|---|
| **gender** | female | 173 | 47.8% |
| | male | 189 | 52.2% |
| **age** | under 18 | 4 | 1.1% |
| | 18-25 | 19 | 5.3% |
| | 26-35 | 52 | 14.4% |
| | 36-45 | 100 | 27.7% |
| | 46-55 | 98 | 27.1% |
| | 56-65 | 66 | 18.3% |
| | over 65 | 22 | 6.1% |
| | *ND* | *1* | |
| **education** | primary | 21 | 5.8% |
| | vocational | 51 | 14.2% |
| | secondary | 136 | 37.8% |
| | higher | 152 | 42.2% |
| | *ND* | *2* | |
| **source of income** | full-time or part-time job | 201 | 55.5% |
| | earning a living from farming | 3 | 0.8% |
| | student/pupil | 12 | 3.3% |
| | own business | 48 | 13.3% |
| | contract work | 30 | 8.3% |
| | pensioner/annuitant | 33 | 9.1% |
| | odd job | 17 | 4.7% |
| | unemployed | 9 | 2.5% |
| | Other | 9 | 2.5% |
| **Total** | | **362** | **100.0%** |

N = 362, ND – no data, F – female, M – male.

The respondents in the study were 173 women and 189 men. The largest group was people aged 36-45 (27.7%), as well as people aged 46-55 (27.1%). Among the respondents, there were only 4 people under the age of 18 (1.1%) and 19 people (5.3%) aged 18-25. The largest number of respondents was people with higher education - 152 (42.2%). Primary education was indicated by only 21 respondents (5.8%), and two did not answer this question. The most frequently indicated primary source of income was full-time employment, accounting for 55.5% of all the responses. 13.3% of the respondents run their own company, 8.3% work on a contract basis. 33 respondents (9.1%) live on an annuity or pension, and 17 (4.7%) on casual work. The study involved 12 students (3.3%) and 3 respondents earning their living from farming (0.8%). 9 were unemployed, which amounted to 2.5% of the respondents.

## Result

In the Development Strategy for the City of Częstochowa 2030+, which was adopted by Resolution No. 435.XXXII.2016 of the Częstochowa City Council of December 1, 2016, in the chapter *Mission, vision and strategic goals*, there is, among other things, an obligation to make Częstochowa, in the perspective of 2030, a city friendly to residents, offering a high quality of life, understood not only as material living conditions, health, education, economic and cultural activity, free time and social relations, personal security, quality of infrastructure, natural environment, but also subjective well-being, understood as the satisfaction that people derive from various aspects of life as a whole, mental well-being and felt emotional states, a city efficiently managed in an effective, efficient way and through partnership, by means of increasingly integrated activities covering entire urban functional areas and active cooperation with residents (Strategy of the City of Częstochowa).

Therefore, in this paper, the issues related to pro-social activities of the municipality in the field of the management of municipal resources and the level of the respondents' acceptance of these activities have been interpreted. The survey included, among others, such activities as: strengthening the cooperation between the scientific community and the economic environment, implementing the results of scientific research and development works in practical activities of the municipality to improve the quality of life, analyzing the social needs of tenants, participating in the scientific life of the university, observing achievements of other municipalities from the point of view of commercialization opportunities or indicating areas for the application of social innovation. The answers obtained in the survey and the applied statistical methods made it possible to examine the extent to which the municipality implements pro-social initiatives and whether these activities are accepted by the tenants of municipal resources. The respondents were asked whether, in their opinion, the specified pro-social activities undertaken by the municipality are important to them (Table 2).

**Table 2.**
*Assessment of the significance of activities of the municipality*

| **Type of operation** | | | | **F** | **M** | **K-%** | **M-%** |
|---|---|---|---|---|---|---|---|
| strengthening the cooperation between the scientific community and the economic environment | I have no opinion | 51 | 14.1% | 19 | 32 | 11.0% | 16.9% |
| | definitely insignificant | 5 | 1.4% | 2 | 3 | 1.2% | 1.6% |
| | insignificant | 68 | 18.8% | 36 | 32 | 20.8% | 16.9% |
| | significant | **176** | 48.6% | 82 | 94 | 47.4% | 49.7% |
| | definitely significant | **62** | 17.1% | 34 | 28 | 19.7% | 14.8% |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| implementing the results of scientific research and development works in practical activities of the municipality | I have no opinion | 48 | 13.3% | 18 | 30 | 10.4% | 15.9% |
| | definitely insignificant | 7 | 1.9% | 2 | 5 | 1.2% | 2.6% |
| | insignificant | 57 | 15.7% | 29 | 28 | 16.8% | 14.8% |
| | significant | **179** | 49.4% | 85 | 94 | 49.1% | 49.7% |
| | definitely significant | **71** | 19.6% | 39 | 32 | 22.5% | 16.9% |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |

Cont. table 2.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| promoting technological offer through participation in exhibitions, conferences, and fairs | I have no opinion | 49 | 13.6% | 18 | 31 | 10.4% | 16.5% |
| | definitely insignificant | 7 | 1.9% | 3 | 4 | 1.7% | 2.1% |
| | insignificant | 60 | 16.6% | 32 | 28 | 18.5% | 14.9% |
| | significant | **176** | 48.8% | 82 | 94 | 47.4% | 50.0% |
| | definitely significant | **69** | 19.1% | 38 | 31 | 22.0% | 16.5% |
| | *ND* | *1* | | *0* | *1* | | |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| analyzing the social needs of tenants | I have no opinion | 42 | 11.6% | 14 | 28 | 8.1% | 14.8% |
| | definitely insignificant | 10 | 2.8% | 3 | 7 | 1.7% | 3.7% |
| | insignificant | 45 | 12.4% | 22 | 23 | 12.7% | 12.2% |
| | significant | **169** | 46.7% | 74 | 95 | 42.8% | 50.3% |
| | definitely significant | **96** | 26.5% | 60 | 36 | 34.7% | 19.0% |
| | | 362 | 100,0% | 173 | 189 | 100.0% | 100.0% |
| controlling the results of scientific research in terms of its practical usefulness | I have no opinion | 52 | 14.4% | 21 | 31 | 12.1% | 16.4% |
| | definitely insignificant | 10 | 2.8% | 5 | 5 | 2.9% | 2.6% |
| | insignificant | 61 | 16.9% | 28 | 33 | 16.2% | 17.5% |
| | significant | **167** | 46.1% | 74 | 93 | 42.8% | 49.2% |
| | definitely significant | **72** | 19.9% | 45 | 27 | 26.0% | 14.3% |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |

N = 362, ND – no data, F – female, M – male.

Subsequently, to explore the issues related to activities of the municipality, the respondents were asked which of the listed detailed tasks in terms of municipal resource management were rated the highest. The analysis showed that the most frequently mentioned aspect was the implementation of selected social innovation (121 women and 120 men indicated the relevance of this action) and the indication of interesting areas for the application of social innovation from the perspective of a practitioner. 49.9% of the respondents considered this activity as important and 13.3% as very important. Participation in the scientific life of the university and observation of the achievements of colleagues from the point of view of commercialization opportunities were the least frequently indicated by the respondents. The percentage distribution of responses is presented in Table 3.

**Table 3.**
*Type of operations of the municipality*

| **Type of operation** | | | | **F** | **M** | **F-%** | **M-%** |
|---|---|---|---|---|---|---|---|
| accepting the ideas of innovation | I have no opinion | 47 | 13.0% | 18 | 29 | 10.4% | 15.3% |
| | definitely insignificant | 6 | 1.7% | 2 | 4 | 1.2% | 2.1% |
| | insignificant | 47 | 13.0% | 21 | 26 | 12.1% | 13.8% |
| | significant | **186** | 51.4% | 90 | 96 | 52.0% | 50.8% |
| | definitely significant | **76** | 21.0% | 42 | 34 | 24.3% | 18.0% |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| active search for possible contractors for models and prototypes | I have no opinion | 57 | 15.7% | 25 | 32 | 14.5% | 16.9% |
| | definitely insignificant | 9 | 2.5% | 5 | 4 | 2.9% | 2.1% |
| | insignificant | 59 | 16.3% | 23 | 36 | 13.3% | 19.0% |
| | significant | **183** | 50.6% | 92 | 91 | 53.2% | 48.1% |
| | definitely significant | **54** | 14.9% | 28 | 26 | 16.2% | 13.8% |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |

Cont. table 3.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| participating in the scientific life of the university, observing the achievements of colleagues from the point of view of commercialization opportunities | I have no opinion | 68 | 18.8% | 32 | 36 | 18.6% | 19.0% |
| | definitely insignificant | 10 | 2.8% | 4 | 6 | 2.3% | 3.2% |
| | insignificant | 63 | 17.5% | 27 | 36 | 15.7% | 19.0% |
| | significant | **164** | 45.4% | 80 | 84 | 46.5% | 44.4% |
| | definitely significant | **56** | 15.5% | 29 | 27 | 16.9% | 14.3% |
| | *ND* | *1* | | *1* | *0* | | |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| indicating interesting areas for the application of social innovation from the perspective of a practitioner | I have no opinion | 65 | 18.0% | 30 | 35 | 17.4% | 18.5% |
| | definitely insignificant | 8 | 2.2% | 2 | 6 | 1.2% | 3.2% |
| | insignificant | 60 | 16.6% | 26 | 34 | 15.1% | 18.0% |
| | significant | **180** | 49.9% | 88 | 92 | 51.2% | 48.7% |
| | definitely significant | **48** | 13.3% | 26 | 22 | 15.1% | 11.6% |
| | *ND* | *1* | | *1* | *0* | | |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| implementation of selected social innovation | I have no opinion | 57 | 15.8% | 25 | 32 | 14.5% | 17.0% |
| | definitely insignificant | 9 | 2.5% | 3 | 6 | 1.7% | 3.2% |
| | insignificant | 53 | 14.7% | 23 | 30 | 13.4% | 16.0% |
| | significant | **181** | 50.3% | 88 | 93 | 51.2% | 49.5% |
| | definitely significant | **60** | 16.7% | 33 | 27 | 19.2% | 14.4% |
| | *ND* | *2* | | *1* | *1* | | |
| | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |

N = 362, ND – no data, F – female, M – male.

At the next stage, the respondents were asked which of the expected effects of the introduced social solutions in their environment they would consider significant. The percentage distribution of responses is presented in Table 4.

**Table 4.**
*Expected effects of the implemented social innovation*

| **Type of expected effects** | | | | **F** | **M** | **F-%** | **M-%** |
|---|---|---|---|---|---|---|---|
| financial benefits visible in the accounts | I have no opinion | 17 | 4.7% | 4 | 13 | 2.3% | 6.9% |
| | definitely insignificant | 1 | 0.3% | 1 | 0 | 0.6% | 0.0% |
| | Insignificant | 12 | 3.3% | 7 | 5 | 4.0% | 2.6% |
| | Significant | **178** | 49.2% | 72 | 106 | 41.6% | 56.1% |
| | definitely significant | **154** | 42.5% | 89 | 65 | 51.4% | 34.4% |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| improving the aesthetics of the environment | I have no opinion | 12 | 3.3% | 3 | 9 | 1.7% | 4.8% |
| | definitely insignificant | 2 | 0.6% | 1 | 1 | 0.6% | 0.5% |
| | Insignificant | 21 | 5.8% | 11 | 10 | 6.4% | 5.3% |
| | Significant | **195** | 53.9% | 83 | 112 | 48.0% | 59.3% |
| | definitely significant | **132** | 36.5% | 75 | 57 | 43.4% | 30.2% |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| better access to services in the area of the housing estate | I have no opinion | 18 | 5.0% | 7 | 11 | 4.0% | 5.8% |
| | definitely insignificant | 2 | 0.6% | 2 | 0 | 1.2% | 0.0% |
| | Insignificant | 34 | 9.4% | 17 | 17 | 9.8% | 9.0% |
| | Significant | **199** | 55.0% | 87 | 112 | 50.3% | 59.3% |
| | definitely significant | **109** | 30.1% | 60 | 49 | 34.7% | 25.9% |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| use of environmentally friendly technologies | I have no opinion | 19 | 5.2% | 6 | 13 | 3.5% | 6.9% |
| | definitely insignificant | 2 | 0.6% | 2 | 0 | 1.2% | 0.0% |
| | Insignificant | 32 | 8.8% | 16 | 16 | 9.2% | 8.5% |
| | Significant | **185** | 51.1% | 82 | 103 | 47.4% | 54.5% |
| | definitely significant | **124** | 34.3% | 67 | 57 | 38.7% | 30.2% |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |

Cont. table 4.

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| environmental effects, e.g., in terms of green areas | I have no opinion | 23 | 6.4% | 11 | 12 | 6.4% | 6.3% |
| | definitely insignificant | 2 | 0.6% | 2 | 0 | 1.2% | 0.0% |
| | Insignificant | 32 | 8.9% | 14 | 18 | 8.1% | 9.5% |
| | Significant | **190** | 52.6% | 88 | 102 | 51.2% | 54.0% |
| | definitely significant | **114** | 31.6% | 57 | 57 | 33.1% | 30.2% |
| | *ND* | *1* | | *1* | *0* | | |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| support for the elderly or people with disabilities | I have no opinion | 21 | 5.8% | 6 | 15 | 3.5% | 7.9% |
| | definitely insignificant | 2 | 0.6% | 2 | 0 | 1.2% | 0.0% |
| | Insignificant | 25 | 6.9% | 9 | 16 | 5.2% | 8.5% |
| | Significant | **184** | 50.8% | 88 | 96 | 50.9% | 50.8% |
| | definitely significant | **130** | 35.9% | 68 | 62 | 39.3% | 32.8% |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |
| Improving the safety of residents | I have no opinion | 17 | 4.7% | 6 | 11 | 3.5% | 5.8% |
| | definitely insignificant | 4 | 1.1% | 3 | 1 | 1.7% | 0.5% |
| | Insignificant | 25 | 6.9% | 12 | 13 | 6.9% | 6.9% |
| | Significant | **170** | 47.0% | 75 | 95 | 43.4% | 50.3% |
| | definitely significant | **146** | 40.3% | 77 | 69 | 44.5% | 36.5% |
| Total | | 362 | 100.0% | 173 | 189 | 100.0% | 100.0% |

N = 362, ND – no data, F – female, M – male.

The residents of municipal resources of the Municipality of the City of Częstochowa expect measurable effects from the conducted activities of the municipality. First, they expect that the implemented solutions and cooperation with the environment will translate into a reduction in charges (91% of the respondents claim that this effect is significant and definitely significant; only 3.6% of the respondents indicated the insignificance of the effect of actions). Subsequently, the respondents acknowledged that the improvement in the aesthetics of the environment is the expected result of projects undertaken by the municipality (53% of the respondents considered the effect significant, 36.5% as definitely significant; only 23 out of 362 respondents considered the improvement in the aesthetics of the environment as an insignificant effect). Support for the elderly or people with disabilities is important for residents. Improving the safety of residents is also an expected result of the effective management of municipal resources.

To sum up the conducted analyses, it can be observed that the cooperation of the municipality with the scientific and economic environment is accepted by inhabitants and, in their opinion, contributes to the implementation of solutions that improve the quality of life.

## Discussion

The subject matter referred to in the presented study is the result of the analysis of the data collected using the survey. It focuses on pro-social aspects of activities in terms of municipal resource management in the Municipality of the City of Częstochowa. The authors made an attempt to show the areas of cooperation of the municipality and the environment to develop

effective solutions in the management of municipal resources, which translate into an improvement in the quality of life of residents. The research results presented in the article allowed the following conclusions to be drawn:

- the respondents see the legitimacy of the cooperation of the municipality with the scientific and economic environment to develop activities supporting pro-social solutions,
- the research showed that the implementation of the results of scientific research and development works in practical activities of the municipality is significant or definitely significant for the inhabitants of resources,
- promoting technological offer through participation in exhibitions, conferences, and fairs is statistically significant,
- the results of the survey confirmed that the analysis of the social needs of tenants by the municipality is important and very important for the respondents,
- the respondents recognized that controlling the results of scientific research in terms of their practical usefulness is important in terms of municipal resource management.

The residents of resources also expect the effects of actions that translate into measurable benefits. The most frequently indicated type of expected effect was financial benefits visible in charges and improvement in the aesthetics of the environment. The respondents showed that support for the elderly or people with disabilities and improving the safety of residents is definitely significant in the actions taken by the municipality.

The empirical research conducted in this study confirmed the hypothesis. With regard to the hypothesis put forward, it should be stated that housing resource management processes should assume cooperation with the economic and scientific environment and the implementation of scientific research results in shaping models for the management of municipal housing resources to meet social needs, strengthen social ties and create new cooperation models in terms of the management of municipal resources based on sustainable development and knowledge management.

## Summary

Based on the presented considerations, it is possible to indicate areas in the process of the management of municipal resources which are important for residents and have an impact on the effective management of pro-social activities. The results of the conducted research, as well as the findings made in the presented study, may be of practical importance. They can be used by municipalities and managers of municipal housing resources to verify the legitimacy of the implementation of various types of solutions in the resource management process by them. However, the presented issue cannot be considered exhaustive since the subject matter covered

is a multifaceted and interdisciplinary research area. It should be emphasized that in the future it is reasonable to conduct further research on pro-social activities in municipalities. Specific examples of pro-social activities in municipal resources of various municipalities should be indicated and their perception by residents should be analyzed. Due to the changes taking place in the resource, the development of techniques and information technologies, as well as in connection with demographic changes, growing expectations, needs and requirements of residents, it seems important to systematically carry out analyzes in this regard as well as to assess the impact of implemented solutions on the living conditions of the residents of the resource.

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# DIGITAL TRANSFORMATION AS NEW CHALLENGE FOR ORGANISATION AND ITS ENVIRONMENT

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**Purpose:** Technological changes are nowadays some of the key points of reference for enterprises which take innovative steps with an intention of improving the efficiency of their operation on the market. For the reason the authors of the paper focus on the problems of digital transformation in organisations and their implications for the development of inter-organisational collaboration among various entities. The primary purpose of the paper is to define digital technologies that are essential in the process of establishing and reinforcing inter-organisational cooperation.
**Design/methodology/approach**: The study used an integrated research approach that included both direct interpretations and positivist research procedures. This required qualitative and quantitative research among 350 companies.
**Findings:** As a conclusion for the results of the study, it should be stated that it was possible to generate three factors referring to the knowledge on digital technologies (1: Monitoring and process automation; 2: Data integration and big data analytics, 3: Protection and cyber-security), as well as two factors which clearly correspond to the 'Establishment of bonds' and 'Bond reinforcement' components, used to measure the force of impact of knowledge about digital technologies on the process of forming long-term relations among enterprises and selected universities at individual stages of such process. The factors above have a stimulating impact on the company's willingness to establish and reinforce inter-organisational cooperation.
**Originality/value:** The presented factors: 1: Monitoring and process automation; 2: Data integration and big data analytics, 3: Protection and cyber-security, as well as two factors which clearly correspond to the 'Establishment of bonds' and 'Bond reinforcement' components, stimulate the company's willingness to establish and strengthen inter-organizational cooperation, which is the added value of this article.

**Keywords:** digital transformation, digitisation, inter-organisational relations.

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

## 1. Introduction

One of the modern world's challenges is dynamic development of technology, which is a catalyst of changes and growth of innovation in enterprises, determining the rate of their development (Ginevičius, Nazarko et al., 2021). Technologies offer new opportunities for operation and diverse conditions for competing at the market, and thus they are perceived subjectively: in the categories of opportunities or threats (Rajiani, Bačík et al., 2018). Diversity of technologies that surround an enterprise often intensifies the confusion as to which of them should be implemented and how to make it the most beneficial for the enterprise. Determining the directions of technological development is of primary importance for the formation of a development strategy of an enterprise, but it also requires careful observation of the enterprise's environment and trends changing within it (Wolniak, Saniuk et al., 2020; Michałek, Pachucki, 2020). Nowadays, one of the leading technological trends is digitisation; combined with the growing role of data flow processes in inter-organisational relations, it creates new determinants for the development of economy.

Digital maturity based on properly developed inter-organisational relations offers access to knowledge necessary in the innovation creation process, designated by highly advanced technologies. That is why the knowledge about digital technologies and their application is currently one of the most desired resources and unique competence conditioning survival of an organisation in a world that changes faster and faster (Lis, 2021). Multi-dimensional digital transformation is the most characteristic modern socio-economic process that is an expression of inevitable and permanent technological changes affecting states, societies and enterprises. This process has been additionally accelerated by the COVID-19 pandemic, which started in 2020 and became a catalyst for a digital transformation in enterprises and at universities. Changes in the life cycle of business models based on digitisation trigger a demand for new technologies, which also means the enterprises' greater willingness to search for specialist knowledge about this issue outside their own organisations. Similar processes also refer to universities that introduce digitisation to the sphere for education, science and research and to the organisational and administrative realm. Even though the rate of digital transformation of universities is diverse, without doubt the COVID-19 pandemic became a factor accelerating this process and highlighting multi-dimensional benefits that the academic sector can accomplish thanks to it. Universities develop educational, research, scientific and implementation services related to digital technologies, along with modern systems for administration management and communication with the environment. Given the fact that the competitive pressure related to technological development forces the companies to intensify the digitisation processes in cooperation with the organisations that offer valuable knowledge, a question arises whether and to which degree universities may become partners for the business sector with respect to the formation of inter-organisational ties.

The range of issues discussed in this way leads to the definition of the research problem, which refers to the identification of digital technologies that are significant in the process of establishing and reinforcing inter-organisational cooperation. The primary purpose of the paper is to define these digital technologies that are essential in the process of establishing and reinforcing inter-organisational cooperation. In reference to the central goal, the main research hypothesis was adopted, which is as follows: knowledge about digital technologies has stimulating (positive) impact on the enterprises' readiness to establish and reinforce inter-organisational cooperation, including ties between enterprises and universities.

## 2. Digital Transformation as Space to Establish and Reinforce Inter-Organisational Relations

Civilisation changes, in particular networking and digitisation, relying on faster than ever technical progress, nowadays apply to almost all areas, aspects and manifestations of the socio-economic life, including organisations operating in such environment and their stakeholders (Szczepańska-Woszczyna, Muras et al., 2021; Szczepańska-Woszczyna, Dacko-Pikiewicz et al., 2015). Apart from the phenomena associated with networking such as, among others, chaos, unpredictability, lack of borders, promotion of intangible resources and cooperation processes among organisations (Skrzypek, 2017), it is also possible to note very rapid absorption of technologies, in particular digital technologies by all entities (Pieriegud, 2016). The key factors driving the development of digital economy include:

- Internet of Things and Internet of Everything,
- hyper-connectivity,
- cloud computing,
- Big Data Analytics (BDA) and Big Data as a Service (BDaaS),
- automation and robotisation
- multi-channel and omni-channel models of product and service distribution (Pieriegud, 2016).

Use of these factors in the socio-economic system leads to, among others, development of the NBIC (nano-, bio-, info- and cogno-) (Stępień, 2015) technologies, which form a collection of components of practical and theoretical knowledge, *know-how* and methods, procedures and physical devices that use knowledge (Dosi, 1982) about digitisation. Such technologies may also be called systematised application of scientific rules and practical knowledge in the area of digitisation (Lowe, 1995) with respect to physical facts and systems. Developing digital technologies are used in organisations as the *know-how*, tools, methods or techniques, but also as a resource determining, among others, operation of machines and devices comprising production systems. For some organisations, the technologies are the product (value) offered to

clients (recipients), while for others they are the process supporting their operation (Bielińska-Dusza, 2020).

The growing dominance of information and the increasing role of data flow processes in inter-organisational relations foster conditions for their most effective processing and, at the same time, offer a basis for the new economy, based on digitisation processes (Zawiła-Niedźwiecki, 2018). One of cognition theories – dataism – stipulates that modern civilisation relies on data which, after uploading to management algorithms, acquire the form of information (Harrari, 2017). The reality creates data generated by machines, devices and artificial intelligence systems. Data processing with the use of algorithms leads to cognition and procurement of information as a result of which, thanks to mental processes, new knowledge is created. This process of cognition is repetitive (Sułkowski, 2005). Data and algorithms which are processed as part of flows guarantee generation of values that are expected by the recipients. This mode of operation characterises a digital organisation, i.e. an organisation efficiently managing data with the use of IT modes, mechanisms and tools defined by it. From the point of view of the recipients of products and services of such organisation, delivery of data generating value for it is of vital importance. In turn, mere sourcing and processing of data does not generate value. Only delivery of knowledge to the client who will be satisfied with it is a value generating action (Cieśliński, 2020).

The term ‘digitisation’ was used for the first time in 1971 in the context of analysis of the process of society digitisation (Brennen, Kreiss, 2016). Generally speaking, digitisation is a process of instrumental use of the ICT tools to efficiently distribute knowledge among decision-makers of the organisational space (Cieśliński, 2020), and thus unite multiple diverse domains of social and economic life around electronic communication and digital media. Use of technical hardware and software allows for rapid sharing of digital content pertaining to text and image; such content can easily be duplicated and teams can work on it in an inter-active mode; it becomes available on devices forming a repository of specific data, information and codified knowledge.

Digitisation, relying on hardware and software, is a sequence of mutually dependent technological solutions, which are manifested by new technical and organisational solutions. When a specific organisational, legal and competence environment has been created, digital technologies can support human creativity and innovation. Actions performed on the digital form of information not only stimulate access to knowledge and allow for generation of new knowledge, but also have a specific cost effect (cost close to zero) and thanks to this, new conditions for innovation are created. Hence, digitisation and digital transformation become a factor of innovation (Kowalczyk, 2017).

Digitisation has a strong value-driving context, as it does not consist in improving what already is at the disposal of an organisation, but in driving new values with efficient use of the ICT technologies. Technology is one of several factors shaping the structural solutions (Klincewicz, 2016), and that is why in the case of implementation of advanced digital

technologies, the organisational structure often needs to transform and become adjusted to the type and terms of using a given technology. Some researchers perceive technology as a component of an organisation, i.e. as the applied mode of production or knowledge about the premises of efficient operation. The representatives of this current tend to treat technology as an element of a technological sub-system of an organisation, which may be deemed strategic in reference to the progressing digitisation (Leonardi, Barley, 2008).

As noted by G. Mazurek, digitisation contributes to improved efficiency within an organisation in the area of quality, consistency, precision and accuracy of implemented processes. Thanks to this – irrespective of the type of organisation – better control is possible over its operational activities and results of its operation, available in real time, thanks to the integration of structured and non-structured data and a better insight into the organisational data, as well as integration of data from various sources. Better access to information had beneficial impact on decision-making and translated to an increase in productivity. Thanks to digitisation, benefits related to interactions between an organisation and its stakeholders, such as, e.g., shorter response time, reduced cost of relationship formation, better availability, etc., are also clearly noticeable (Mazurek, 2019). Digitisation has also changed the perspective of the recipients of products, services and knowledge who – thanks to ICT technologies – nowadays have the possibility of choosing among so many options that they are often unable to consciously analyse them (Feldman, 2002).

The organisations see the inevitability of the breakthrough change which the development of digitisation has brought for their operation. Wishing to meet it half-way or at least intending to adjust to the new conditions of operation, they undergo transformation, i.e. a significant, multidimensional change of organisational and process-related nature, caused by the impact of digital technologies. Digital transformation in an organisation may focus on cost reduction (Collin, Hiekkanen et al., 2015), improvement of performance and efficiency (Westerman, Calméjane, 2011), extension of communication with stakeholders and even procuring a new group, i.e. digital consumers (Berman, 2012), as well as may – in a holistic mode – simultaneously account for all four perspectives: technology, values, structure and finances (Matt, Hess et al., 2014).

In a broader dimension, digital transformation is related to an opportunity for economic development, improved quality of life, realisation of democratic ideals (Śledziewska, Włoch, 2020), but it also exerts a significant impact on the functioning of an organisation. For the majority of organisations, this phenomenon is often a challenge, but at the same time one of the foundations for retaining their position in the environment and further expansion (Adamczewski, 2017). This follows from the concurrent and multidimensional impact of the digital transformation on the society and people that make it up, assuming various roles, among others recipients of diverse products, services and other intangible values (e.g. knowledge) or their producers representing organisations of various types (e.g. public institutions, enterprises or non-governmental organisations).

From the perspective of man as an individual in the socio-economic system, digital transformation heralds significant changes in behaviour, which project on the mode of performance of social and professional roles in various types of organisations (e.g. an employee or a client). This affects, among others, de-materialisation of goods in the form of photos and video recordings, sharing a greater volume of content, creation of image in the social media, as well as the phenomenon of distributed memory, i.e. storage of memories on external memory media (Belk, 2013). Younger people learn technological novelties easier and quicker, while assuming the role of consumers they seem to be better informed, more often communicating with other consumers, notifying higher expectations with respect to digital services (Gray, Sawy, 2015) and demanding the organisations to meet their expectations half-way. Such communities will become an important group of consumers or stakeholders, while their needs pose a growing challenge for the organisations servicing them in various areas. Interest of the so-called digital consumers in the possibility of socialised joint-creation of services, goods and values that are offered to them is very characteristic. They willingly assume the roles hitherto reserved for the employees of organisations, i.e. advisers, testers, reviewers or client service employees (Mazurek, Tkaczyk, 2016).

Communities united by a joint interest and relational communities, relying on similar experiences that often function as virtual communities, exert a growing impact on the functioning of organisations. One may venture saying that skilful formation of relations within such communities, as well as relations with organisations with which they interact, is decisive for their success (Dacko-Pikiewicz, 2022; Dacko-Pikiewicz, 2019). Hence, organisations functioning in digital economy should learn to read and use emotions that emerge in the virtual reality. Fundamental changes in the behaviour of individuals influence the market and social relations and lead to a metamorphosis of both the physical and the virtual reality (Sułkowski, Kaczorowska-Spychalska, 2018). According to G. Mazurek (Castells, 2003; Urry, 2000), quoting M. Castells and J. Urry, significant social transformations with which we are dealing today are caused by the networking of economy, quicker flows and virtualisation of relations, as well as rapid development of many decentralised Internet networks. At the same time, in the managerial approach, this affects the transformation of organisations which develop such features as agility, responsiveness or joint value creation.

The description above attests to the great potential and challenges generated by the development of digital technologies in organisations; however, it should definitely be treated only as a tool, and not as a goal of transformation. It should also be noted that digitisation, leading to multidimensional changes in organisations and in a broader socio-economic context, may generate a number of benefits, but also be a source of multiple threats. In reference books, this observation has been made by, among others, S.K. Reddy and W. Reinartz (2017), who draw attention to such consequences of the process of digitisation as: production of huge amounts of data, irreversible changes in the professional and daily life of people, growing expectations with respect to the generation of new intangible value for various groups of

recipients. Without doubt, the COVID-19 pandemic was a milestone in further accelerated development of digital technologies. The outbreak of the pandemic and the universal lock-down related to it triggered and accelerated progress in the area of digitisation, allowing for the use of broadly-understood technology for a radical improvement of an enterprise's efficiency or its coverage (Westerman, Bonnet, 2014). According to M. Rzeszewski, digital technologies entered the daily world on an unprecedented scale during the pandemic, becoming an inseparable part of the experience of many people – also in an imposed and unwelcome way. At the same time, such technologies became a cure for the current problems and poison replete with new social challenges (Rzeszewski, 2020). Digitisation allows for accomplishing many benefits and embracing many opportunities that are emerging, but it also causes threats and challenges which a modern organisation and its environment has to face. They are presented in Table 1.

**Table 1.**
*Potential benefits and threats resulting from digitisation for organisations and their stakeholders*

| Reference group | Opportunities and benefits | Threats and challenges |
|---|---|---|
| Organisations developing digital technologies, e.g. public institutions, enterprises, non-governmental organisations | Improved efficiency, performance, new methods of value creation, new possibilities of cooperation with various groups of stakeholders, new possibilities of knowledge transfer | Change or loss of existing configurations of value chains, new areas of competition, shortened product life cycles, growing demand for new value created with the use of digital technologies, risk of failure to meet the requirements set by digital technologies |
| Recipients of values created by the organisations with the use of digital technologies, e.g. clients and stakeholders | Lower prices and better access to new products, services and knowledge, new sensations | Cost of adjustment to the possibility of using new products, services and knowledge related to digital technologies, cost of education, cost of searching for information, loss of privacy |
| Individuals relying on digital technologies in professional and social life | Higher flexibility of employment, lower costs of work performance, higher degree of commitment to duties, growth of crowd-sourcing and crowd-working, easier sharing of resources, exchange, lease | Automation and other changes in work performance, digital exclusion, technological unemployment, comprehensive performance measurement, efficiency pressure, global competition at the labour market, weakening of interpersonal ties and integration at the work place, improved availability of products, services and knowledge, e.g. on-line education |
| Society | Better access to efficient and digitised administration, better quality of public sector services, greater availability of public information, higher public participation (on-line communication) | Changes in social communication and changes in social preferences, e.g. the mode of spending leisure time, the mode of handling transactions, digital exclusion causing marginalisation of certain social groups, society's desire to exert greater impact on public issues |

Source: own study based on Mazurek, 2019, p. 24.

As follows from Table 1, digitisation produces a number of changes in the functioning of organisations and stakeholders operating in their environment, including changes which may be deemed fundamental and having far-reaching effects. Digitisation blurs the borders of operation of organisations, as more and more processes take place outside of the structures of

organisations, in an organisational space with undefined borders, often within informal networks. These new conditions of operation, caused by a dynamic development of ICT technologies, primarily global Internet, are strongly dependant on new methods and tools supporting the processes of organisation management characteristic for the digital economy. Summing up, it may be concluded that the impact of digital transformation on an organisation, its environment and stakeholders is realised via:

- metamorphosis of an organisation towards adaptation of digital technologies to its operation on all possible fields of exploitation and improved efficiency in managing an organisation, among others by improvement of mechanisms to monitor its efficiency,
- changes in the process of product manufacturing, provision of services and offering other values at the market, e.g. knowledge,
- formation of relations with stakeholders with respect to fuller understanding of their needs, introduction of new channels for communicating with them and joint creation of values on which the stakeholders want to base the bond with the organization,
- strengthening the organisation's position in the environment, sector or socio-economic system based on the use of digital technologies, which have not yet been designed by the competing organisations.

Today, digital transformation refers not only to the technological aspects of an organisation's operation, but should also encompass its entire strategy, shaping the mode of thinking and perceiving the world by the managers of such organisation anew (Gregorczyk, Urbanek, 2020). Literature features the concept of 'digital leadership' (Ahlquist, 2014), which is used to define the leader of a team or an organisation relying on digital technologies, which is also helpful in the implementation of innovations. Digital leadership is one of the key attributes of digital organisations and these organisations which are learning to make efficient use of digital technologies. Several dozen features of digital leadership include innovative visionary, networking intelligence, digital intelligence, digital talent scout, role model, democratic delegative leading style, employee-orientation and social intelligence (Kreutzer, Neugebauer et al., 2017). Other important features are: openness, ability to adapt, agility, creativity, learning from mistakes and knowledge orientation (Klein, 2020). Digital leadership not only supports internal transformation of an organisation, including implementation of process or product innovations based on digital technologies, but may also play a vital role in shaping relations of an organisation with its stakeholders in the digital world. Wherever leaders of digital technologies are perceived as attractive partners in cooperation and in exchange of resources or values (e.g. such as knowledge), digital transformation and solidification of digital leadership may elevate an organisation to a much higher level of competitiveness within its environment. Thus, building the digital leaders' competence is nowadays one of the key educational challenges for universities cooperating with enterprises, which necessitate such leaders (Szczepańska-Woszczyna, 2020).

An impulse for establishing inter-organisational cooperation between science and economy in the area of joint studies on new digital technologies is the possibility of financing or co-financing them by the EU institutions (among others, the Horizon 2020 programme, COSME, Erasmus Plus, the International Visegrad Fund, etc.), as well as domestic ones (among others, programmes of the National Centre for Research and Development such as Infostrateg or the so-called 'fast track' of financing under the Smart Growth Operational Programme 2014-2020). An example of scientific cooperation between a university and an enterprise in the area of digitisation are projects pertaining to the Digital Innovation Hubs, which were selected in 2019 (https://przemyslprzyszlosci.gov.pl/...). This area of cooperation in development of digital technologies is one of the most promising, as studies show that probably approx. 60% companies implemented new digital solutions by 2020, while company expenses on systems supporting digital transformation in 2019 approximated USD 431 billion (https://itelligencegroup.com...).

Among European research initiatives related to digitisation, special attention should be paid to the European Institute of Innovation and Technology (EIT) (https://europa.eu...), which supports innovation by tightening cooperation between companies, research and educational institutions as part of the so-called communities of knowledge and innovation. One of the areas of the EIT activities is EIT Digital, focusing on digital products and services. Universities and enterprises may also commence joint research projects in the area of digitisation via the Joint Research Centre. It promotes independent research studies pertaining to the subjects of vital importance for the European integration (Mazur, 2020). In turn, as part of the European Research Area (https://ec.europa.eu...), the following initiatives are available: CORDIS (website with information about research projects financed by the European Union and their results), OpenAIRE (website that forms a network of generally accessible repositories, magazines and archives) and the EU Open Data Portal (databases shared by the EU institutions to be used for research and commercial purposes) (Mazur, 2020).

## 3. Directions and Determinants of Development of Digital Technologies in Enterprises

Technological changes are nowadays some of the key points of reference for enterprises which take innovative steps with an intention of improving the efficiency of their operation on the market, boosting competitiveness or satisfying the needs of their clients better. Digital transformation is one of the causes of increasing variability and unpredictability of market determinants in which the enterprises are operating. G. Mazurek (2016) defines the following key features of this phenomenon:

- the degree of complexity of digital transformation exceeds the level characterising implementation of new IT solutions,
- the effects of digital transformation and its potential benefits are related to going beyond the classic organisational borders and contribute to the networking of an enterprise,
- the basis of the process of transformation is the digitised client and the client's experience and, to a lesser degree, infrastructure,
- links among various innovative solutions in the physical and digital space emerge as a result of coupled effects of various technologies.

Digital transformation shapes the specific environment for modern companies, which determines, to a significant degree, not only their actions, but also their competitiveness. It is known as Industry 4.0, the 4th Revolution, Internet of Things or SMART, Industry Revolution 4.0 (IR 4.0). Two realities permeate in this environment: the physical reality (PR) and the Virtual Reality (VR) (Adamik, Nowicki, 2017), but it is also conducive to intense development of network cooperation or virtual network. The most dynamic development refers to cyber-physical systems (CPS), big data analytics (BDA), Internet of Things (IoT), Internet of Services (IoS), Cooperation, Partnering and Team Working (Adamik, 2016), Strategic Partnering (SP), Knowledge Partnering (KP), Cooperation, but also Machine-to-Machine (M2M) Communication, Artificial Intelligence and Neural Networks (Adamik, 2018).

The majority of enterprises treat digital transformation as the inevitable necessity, while the need of facing it is dictated by the instinctive desire to retain the position in the sector, and in particular at the market serviced by the enterprise, among clients and other stakeholders to which the enterprise is related. Hence, digital transformation is used to accomplish visibly better results of operation (McKeown, Philips et al., 2003), which may be understood as reduction in costs or accelerated performance of tasks (Kane, Palmer et al., 2015) or streamlining of operational activities (Fitzgerald, Kruschwitz et al., 2014).

According to P. Adamczewski (2017), digital technologies determine organisational changes in the area of formation of relations with clients and contracting partners (better understanding of their needs, extension of communication channels) and modelling of an organisation's actions within the scope of generation of products and services delivered to the market. According to G. Mazurek (2019), technology should offer an added value primarily to the clients, yet it also requires focus on two supplementing activities: formation of a value proposal for the client anew and re-designing activities with the use of digital solutions, allowing for furnishing the clients with the highest level of interaction and cooperation (Berman, 2012).

Development of digital economy and all the consequences thereof are thus changing the modes of operation of enterprises, as well as affecting the life-cycle of various business models (among others, they accelerate the ageing processes of products). In other words, digitisation and evolution of ICT technologies are constantly contributing to the increased application of business process IT enhancement, yet enterprises should carefully think the mode of their

operation through in the context of digital challenges of the future (Tapscott, 2008; Poznańska, Szczepańska-Woszczyna, et al., 2022). From the point of view of an enterprise, technology cannot set the directions of development, but it has to become adjusted to the enterprise's strategy, its potential and these areas that require support on the organisational level. Such support most often refers to (Adamczewski, 2016):

- technical infrastructure (hardware),
- system and communication infrastructure,
- application software,
- integration of business processes with external contractors.

Digital transformation is not only a layer of tooling, but a thorough change within the organisation pertaining to management, mode of operation, values cherished or communication with stakeholders, including clients (Kotelska, Lis, 2022; Lis, Kotelska, 2022). As stated by G. Mazurek, the scale and extensiveness of digital transformation in an enterprise is often so great that implementation of new business models gives rise to a number of challenges and problems with ensuring their complementarity with the ones on which the enterprise relied earlier (Mazurek, 2019).

Digitisation is a process ushered by the response to the questions: 'What is the level of competitiveness of an organisation operating in a traditional business model?' and 'Whether and to which scope is it necessary to launch actions conducive to the development of organisations, the effect of which is going to be an organisational hybrid (combination of a process model with elements of digitisation) and eventually a digital model of business?' (Cieśliński, 2020). Setting and anchoring an organisation in a digital environment requires its transformation and is a process that has multiple interim stages. On the level of every sector or market, it is possible to designate leaders, i.e. enterprises most active and efficient with respect to innovation, where technological changes are implemented faster than in other companies. Transformation directions of these companies blaze the trail for others, which are following the leaders at a various pace. However, it must be assumed that some enterprises, due to various reasons, will never implement the process of full transformation, but will stop at some of its interim stages. This may be follow from numerous factors, e.g. inner barriers for development of innovations, lack of capital or change in the business model. However, it may be assumed that systematically performed digitisation processes allow a company to accomplish digital maturity which is conducive to the reliance of organisations on business and organisational models designated by highly advanced technologies, e.g. Industry 4.0. The development of Industry 4.0 also leads to a change in business models from product orientation to service orientation, e.g. offering the best on-line service for performance of a given fragment of production process as part of a company's expertise (Gajdzik, Grabowska, 2018). The source of value is the combination of network links based on cooperation (Porter, 2006) and thus integration is of vital importance in business activities in line with the concept of Industry 4.0, i.e. a broad range of flexible cooperation among various entities, as only cooperation among participants allows for meeting all the expectations of a recipient at a given time.

Industry 4.0 comprises digital management and production tools and tools allowing for the use of Internet and social media for the purpose of integration of smart machines, systems and introduction of changes to production processes, aimed at increasing efficiency of production and introduction of possibilities of flexible changes in product assortment. Industry 4.0 refers not only to technologies, but also to new modes of work and people's role in an organisation. Cognitive challenges pertaining to the implementation of a business model based on the Industry 4.0 concept in enterprises are presented in Fig. 1.

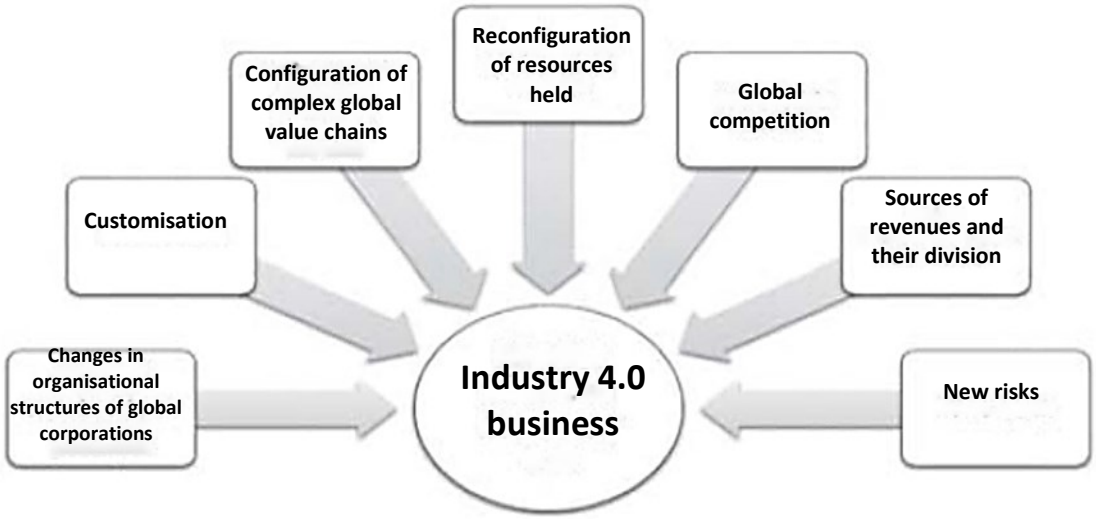


**Figure 1.** Structure of a business model based on the Industry 4.0 concept.

Source: Frankowska, Malinowska, Rzeczycki, 2017, pp. 97-109.

The analysis of the extent and the nature of issues comprising the business model presented above shows that the main factors allowing for development of Industry 4.0 are: access to proper data and holding tools for their analysis. Implementation of technological solutions in the area of Industry 4.0 may become an impulse for multiple beneficial changes in an enterprise, as presented in Fig. 2.

| Development opportunities | Description |
|---|---|
| Growth of productivity | Industry 4.0 allows to optimise the production process, reduce the downtime, allocate the resources better and create new products |
| Development of new sectors | Development of new sectors thanks to suppliers of Industry 4.0 solutions and companies implementing such solutions |
| Innovative economy | Economy becoming increasingly innovative, allowing for expansion of technology abroad |
| Attractiveness for investors | High employee competence and vigorously developing innovative economy attracts investors when the mechanisms are adequate |
| New work places with high added value | New work places are being created, focused around automation and IT and new sectors related to, among others, cooperation of robots and people |
| Drop in production costs | Improved quality of products and drop in stock reduce costs of production |
| Efficient use of materials and energy | Rational use of materials and improved energy efficiency go hand in hand with sustainable development |
| Consumers' needs met in a more adequate way | Custom-made products produced in small batches (mass customization) |

**Figure 2.** Enterprise development possibilities based on Industry 4.0.

Source: Buła, Schroeder, 2020.

Organisational modelling of the processes of embedding and anchoring of organisations in the new 4.0 business models is a process that starts with procurement of data (PD) and subsequently their transformation (cognitive and/ or machine) to the form of information (I). The outcome of the process of organisational modelling is knowledge and its diffusion (DK) among the organisation's stakeholders (Cieśliński, 2020). Figure 3 presents a management model of organisational modelling from the digital perspective, using the terms outlined above.

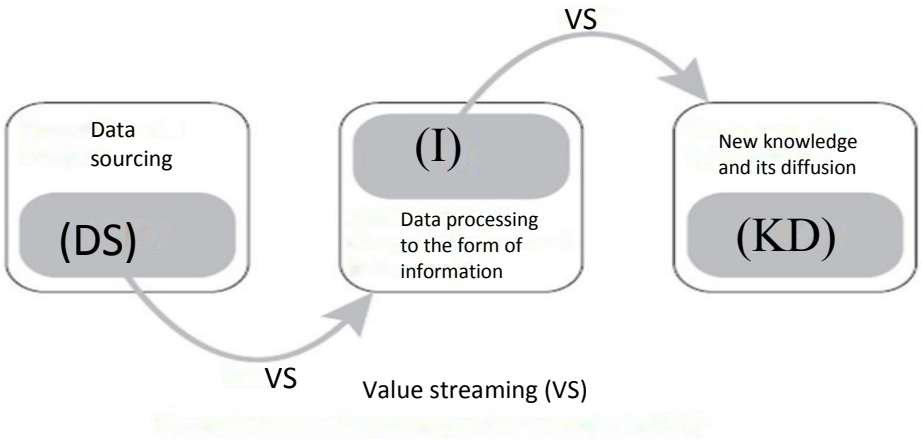


**Figure 3.** Organisational modelling management outline from the digital transformation perspective. Source: Cieśliński, 2020.

According to W. Ciesielski, a new business model requires linear progress: from birth, through growth, to improvement; nevertheless, an organisation's reliance on new digital technologies disrupts this ordered process. Organisations which are at a stage of growth and which increase the significance of IT systems in business processes are thus shaping their core of organisational development towards digitisation. A model approach to digital transformation of an enterprise comprises stages presented in Table 2.

**Table 2.**
*Stages of transition of an enterprise into a business model based on digital transformation*

| Name of stage | 1. Digital reality | 2. Digital ambitions | 3. Digital potential | 4. Digital readiness | 5. Digital implementation |
|---|---|---|---|---|---|
| Description | Procuring knowledge about digitisation and analysis of clients' requirements for the purpose of creating a value chain with the participation of various stakeholders, e.g. clients, universities, etc. | Determination of digital ambitions of an enterprise and specification of a new business model based on digital transformation. | Use of best available practices pertaining to digital transformation, determination of digital potential of a new business model of an enterprise and appointment of digital transformation ambassadors. | Evaluation of adequacy of alignment of a digital business model with respect to the fulfilment of clients' and other stakeholders' expectations, along with possibilities of meeting the designated targets. | Implementation of the new business model at all areas of operation of an enterprise, development of a digital network for value creation and incorporation of business partners and other stakeholders into this process. |

Source: own study based on Mazurek, 2019, p. 74.

Three critical factors of embedding organisations in digital business models are distinguished (Cieśliński, 2020). The first is the streaming of data, information and knowledge as an element allowing for extension of value chains. Streaming consists in the use of modern technologies and Internet to manage the value flows in an organisation. The second element is gamification, which improves the efficiency of teamwork and allows for better monitoring of task performance efficiency. The last element, i.e. machine processing, influences the process of automatic, as well as cognitive data processing, with respect to the inventive creation of new knowledge and its subsequent diffusion to entities making business decisions and cooperating with an organisation (Cieśliński, 2020).


**Figure 4.** Critical factors for embedding and anchoring organisations in digital business models.
Source: Cieśliński, 2020, p. 320.

A common element for all three factors used for embedding the organisations in digital business models is their relationship with knowledge, used in the process of digital transformation in many diverse dimensions and applications:

- as a resource in a process (next to data and information),
- as a basis for evaluation of process efficiency (as part of control activities),
- as a process outcome (a value which a company jointly creates together with stakeholders during the application of digital technologies).

Knowledge is the basis for implementing modern technologies in an enterprise, both based on own invention, but also on good practice deriving from the environment. Hence, knowledge has key application in the digital transformation as the resource which an enterprise contributes to the process or procures from the stakeholders cooperating with it, but also develops jointly with them, among others by joint learning. Integration of knowledge pertaining to the business environment, familiarity with new technologies that may support the manufacturing of products and services, and the possibility of admitting them to the new markets, is the main opportunity for an enterprise to accomplish a competitive advantage, among others on account of innovations. A great dispersion of innovations in the business eco-systems and a variety of organisations cooperating within them changes the nature of the technological evolution (Iansiti, Levien, 2004). In the future, not so much the leading enterprises engaged in the

technological race, but inter-organisational and diverse networks of cooperation embedded in business eco-systems, will be its driving force.

Digital technologies implemented by enterprises are based on digital solutions generally defined as SMAC, i.e. social media, mobility, big data analytics and cloud computing (Adamczewski, 2017). These four pillars on which the new business models rely may be characterised as follows (Adamczewski, 2017):

1. Social: social networks breaking the barriers of information flow among people and acting as platforms that enable quick and efficient exchange of knowledge, improving interactions with clients and offer greater capacity for exchange of experiences and problem solving.
2. Mobile: mobile devices (smart phones and tablets) that increase the efficiency of the companies' outreach to clients, used for on-line marketing, processing of transactions and any forms of communication, among others via websites and applications.
3. Analytics: analytical tools, using advanced algorithms that allow for understanding behaviour and preferences of clients that shore up client loyalty, improve processes of product development and service provision, facilitate business decisions.
4. Cloud: cloud computing technology, offering tools that enable efficient capturing of information and efficient management of organisations. Use of tools available in the cloud allows the organisations to reduce costs, overcome geographical barriers and access data at any time and place.

Next to technologies generally known as the SMAC, companies most often implement solutions in the area of automation and robotisation aligned to the profile of their operation (Adamczewski, 2016), yet apart from it, at least several dozen digital technological solutions which enjoy growing popularity among enterprises may also be listed. They are presented below, together with a brief characteristic of the possibility of being used in business, with an assumption that practically each of these technologies requires adaptation to the conditions of operation of sectors and industries, as a result of which product, process, organisational and marketing innovations are created in companies.

At the present moment, the most popular are solutions based on automation and robotisation of production. Automation consists in activities carried out independently by a machine, which previously were or could have been carried out by a man, but also these that are too difficult to perform by a man (Lis, Bhatt, 2021). As a result of work automation, man only performs supervisory and control functions in reference to machines and their work. Automation may refer to the entire process of manufacturing or some of its stages that may be supplemented with people's work (Lemański, 2020). Robotisation is a form of production automation which is related to the substitution of man by a robot (Grzeszak, Sarnowski et al., 2019). Apart from industrial robots that more and more often substitute people in work performed in difficult conditions, mobile robotics is dynamically developing. Modern robots are characterised by diverse structures, dependant on their intended use. The level of their autonomy is going to be

increased, in particular the mode of thinking, moving and behaving (Kowalczuk, Czubenko, 2015). The commonness of automation and robotisation in industrial activities and in daily life results in development of these solutions both in simple and more complex professional activities (e.g. a humanoid robot substituting a reception desk worker at a hotel or a seller in a store, holograms offering information or advice to clients) and home activities (e.g. humanoid robots caring for the elderly or disabled persons or, for example, smart vacuum cleaners and lawnmowers). Solutions aimed at automation of managerial processes (e.g. servicing of electronic mail, processing of parts of financial transactions) are also implemented.

Irrespective of the industry, more and more companies are reaching for solutions in the area of cyber-security which encompass, in a broad range, technologies intending to offer better protection of the ICT networks, devices, programmes and data from hackers' attacks, damages or unauthorised access. They encompass all tools and systems that prevent damages, are used for protection and allow for restoration of capacity for correct functioning of computers, systems of electronic connectivity or communication services in the cyber-space. They aim to protect the electronic communication to ensure confidentiality with simultaneous authentication of authorised persons (Górka, 2017; Michałek, Pachucki, 2021).

Other digital solutions gaining popularity in business are based on machine learning, i.e. focused on teaching computers how to learn from data and improve, along with acquisition of experience. These technologies encompass solutions allowing the computers to perform tasks for which they have not been programmed earlier. Machine learning leads to the creation of algorithms, which are subsequently trained with respect to finding models and correlations in big data sets and making the best decisions and formulating forecasts based on the results of such analysis. Systems that use machine learning become more and more efficient, while better access to data leads to an increase in their accuracy (Alafif, Tehame et al., 2021).

In turn, big data systems allow for the use of computing potential and technologically advanced software to capture, process and analyse data which are characterised by significant volume, quick generation and value (McAfee, Brynjolfsson, 2012). They are used for sets of data which are so bulky, complex and deriving from diverse sources that their processing requires new technologies, such as artificial intelligence. The *big data* system enables very rapid data capturing (in a time approximate to real time) and their analysis and assessment for drawing new conclusions.[1] Such systems also allow for broadly understood data aggregation and are used more and more often as an efficient tool supporting decision-making processes.

[1] *Big Data: Bringing Competition Policy to the Digital Era*, Directorate for Financial and Enterprise Affairs, Competition Committee, 26 April 2017, https://one.oecd.org/document/DAF/COMP/M(2016)2/ANN4/FINAL/en/pdf, 15.07.2021, https://www.europarl.europa.eu/news/pl/headlines/society/20210211STO97614/big-data-definicja-korzysci-wyzwania-infografika, 15.07.2021.

The technological solution of *edge computing* focuses on efficient modes of data processing, delivered in huge amounts by smart items connected to the Internet as part of the so-called Internet of Things. It allows for the initial processing of data on the so-called edges of the network, which are any computing and network resources located at the interface between sources of data and centres of data, e.g. in cloud computing (Shi, Cao et al., 2016). *Edge computing* allows for an increase in speed and safety of data processing, consisting – among others – in transfer of the computing capacity closer to the place of data generation (Satyanarayanan, 2017).

*Blockchain* is a distributed ledger, containing a continually accruing amount of information (records) grouped into blocks and combined in a way that every next block contains a timestamp of its creation and a link to the previous block which is a coded 'summary' (hash) of its content (Piech, 2016). Thanks to the application of such solution, it is much easier to document transactions, track resources and build trust (Jacobovitz, 2016), as well as securely store information based on creation and recording of the full path (chain) of data flow in an organisation.

*Cloud computing* consists in delivery, via computing services of, e.g., databases, networks, software, etc., to offer quicker innovations, flexible resources and economies of scale (Xun, 2012). The technology assumes storage of data, files, applications, software and IT systems in the cloud, i.e. on servers located outside of the local network held by an external supplier. This is an increasingly common and available solution, offering a number of benefits to organisations, from lower costs to data security guarantees (Voorsluys, Broberg et al., 2011).

A *chatbot* is an application communicating with the recipients in the form of dialogue, whose task is to simulate an interactive conversation with any interlocutor and to reduce the load on the administrator of the on-line customer service centre, as well as to assist communication in the social media (Szymański, Józwiak, 2018). Tools of this type are used for conversations with the use of a computer (e.g. virtual consultants offering advice or answers to questions frequently asked by clients) and they greatly facilitate work in industries where the same operations are carried out with many clients, in relation to which it is possible to foresee typical procedures which are entrusted to such applications.

Virtual Reality (VR) is a 3D environment created by computers, allowing the users to move and to interact, which stimulates one of five human senses (Berbeka, 2016). VR solutions rely on computer simulations which create images of physical or virtual reality, e.g. computer simulations of objects, spaces or events. They are applied, e.g., in design, modelling of decision making or behaviour studies. In turn, augmented reality (AR) is a system used to supplement the reality with virtual, interactive elements located in it, which are an intermediate stage between the real world and the virtual reality. In this technology, impact on the senses of sight, hearing and touch is applied, yet there are also concepts of impacting other senses (Skórska, 2017). The AR-type solutions allow for creation of computer simulations that combine the real world with computer-generated images (e.g. imposing 3D graphics in real time on a camera image).

The Internet of Things (IoT) is an eco-system where objects may communicate among themselves via man or without man's participation (Grodner, Kokot et al., 2015). These solutions furnish the devices with smart features, e.g. by connecting them to the Internet (e.g. smart fridges where the content can be checked with the use of a smartphone app). The scope of application of the Internet of Things is extensive both in the sphere of economy and daily life. The Internet of Everything, i.e. a network connecting people, processes, data and objects, also has a great potential. The next stages of technological development, including cloud computing and big data, will allow for using this potential to a greater degree. At the present moment, only 1% of objects in the physical world are connected, but the potential is far greater. The Internet of Everything generates benefits not only for enterprises and their clients, but also for countries, cities and their residents, among others due to the fact that it increases productivity and revenues of the public sector and improves the quality of public services (Kolek, 2019).

Artificial Intelligence (AI) comprises systems or machines simulating human intelligence for the purpose of task performance and successively improving their operation based on the compiled information (Acemoglu, Restrepo, 2019). These are tools materially supporting the making of managerial decisions in various spheres of operation of organisations, including marketing, production and logistics.

Experience design is an interdisciplinary action comprising elements of psychology, ergonomics, art, utility, industrial design and technology. It allows for forming an enterprise's relations with various stakeholders (including clients) around a product or a service (Benyon, 2019), via information systems for ordering, analysing and evaluating the hitherto reciprocal experiences. The process aims to design a product or a service that allows the user for intuitive use thereof. Thanks to it, the user's attention is fully devoted to the performed activity and not to thinking how to use a product to accomplish a specific goal.

The 5G technology is the most sophisticated technology in wireless communication. It is most probably going to revolutionise the entire area of wireless networks, offering a possibility of efficient and safe communication wherever wireless communication cannot be replaced (Korzeniewska, Krawczyk, 2019). It forms a realm of solutions based on mobile communication with multiplied (above-standard) transfer of data and may be used in numerous spheres of life, e.g. remote treatment of people by monitoring vital signs, remote control of facilities, e.g. cars, etc.

Summing up, diverse directions and possibilities of making use of technical progress have opened up before enterprises of the digital era. Implementation of the technologies described above requires a number of requirements related to the process of digital transformation to be met, the result of which should be accomplishment of the highest possible level of digital maturity by an enterprise and development of inter-organisational relations which offer full access to knowledge indispensable in the process of innovation creation.

## 4. Impact of Digital Transformation on the Process of Establishing and Reinforcing Inter-Organisational Cooperation from the Perspective of Own Studies

To carry out a research procedure pertaining to the determination of impact which knowledge about digital technologies exerts on the companies' willingness to establish and to reinforce ties, it was necessary to define the components of these technologies. These components were prepared on the basis of properly selected statements. The respondents had the task of assessing a set of 18 solutions from the area of digital technologies. These were solutions that the representatives of entities covered by the study would like to get to know better or apply in their enterprise in the next five years. 350 persons, representatives of enterprises, with whom interviews were carried out, offered responses with the use of a seven-grade scale. The majority of the respondents (depending on the statement: 57-79%) expressed interest in the use of presented solutions; a different opinion was expressed by 7-21% of the respondents. Average grades divided into micro, small, medium-sized and large enterprises are presented in Figure 5.

It follows from the performed CATI interviews that the representatives of companies covered by the study would be most willing to get to know solutions aimed at better protection of IT networks, devices, programmes and data from hackers' attacks, damages or unauthorised access, hence solutions related to cyber-security (in total 79% of positive indications, average grade at 5.63). An equally high share of positive responses (i.e. 79%) was given to the solution pertaining to the IT systems allowing capturing and analysing data deriving from multiple diverse and distributed sources and their management, e.g. big data (average grade of 5.46). In turn, 77% of the respondents would like to learn or implement solutions aimed at automation of managerial processes, e.g. e-mail handling, processing a part of financial transactions, i.e. process automation, robotisation (average grade 5.35) – most often, these are large organisations (89%) and entities cooperating with at least six universities (100%). Almost 75% of the respondents are interested in solutions allowing for reinforcement of relations linking organisations with clients via IT ordering systems, analysis and assessment of hitherto experiences, i.e. new experience design (average grade 5.40). It also follows from the performed studies that 74% of company representatives would like to learn or apply solutions that allow for safe storage of information based on creating and saving a full path (chain) of data flow, i.e. blockchain (average grade of 5.39) – most often, these are entities cooperating with six or more universities (100% in this group of entities). The same share of positive responses also pertained to a solution related to IT systems that support decision-making in an organisation, e.g. marketing, based on artificial intelligence – the highest result was recorded among small companies that have from 10 to 49 employees (79%).

| No. | Statement (variable)<br>Would you like to get to know or apply these solutions in your enterprise in the next five years? | Average grades on the scale from 1 to 7<br>(where 1 means definitely no and 7 means definitely yes) |
|---|---|---|
| 1 | IT systems supporting decision-making in an organisation, e.g. marketing (artificial intelligence) | |
| 2 | IT systems allowing for capturing, analysis and management of information deriving from multiple diverse and distributed sources (*Big Data*) | |
| 3 | Solutions focused on automation of managerial processes (e.g. e-mail handling, processing of financial transactions) (process automation, robotisation) | |
| 4 | Solutions allowing for reinforcement of relations between organisations and clients via IT systems to order, analyse and evaluate mutual experiences | |
| 5 | Solutions enabling an increase in speed and safety of data processing consisting – among others – in transfer of the computing capacity closer to the place of data generation (*edge computing*) | |
| 6 | Solutions allowing for safe storage of information, relying on creation and saving a full path (chain) of data flow (*blockchain*) | |
| 7 | Solutions enabling storage of data, files, applications, software or IT systems on external supplier's servers | |
| 8 | Solutions aimed at better protection of IT networks, devices, programmes and data from hackers' attacks, damages or unauthorised access | |
| 9 | IT systems enabling computer assisted conversations (e.g. virtual consultants offering advice or answering questions of clients, *chatbot)* | |
| 10 | Solutions that substitute people in simple professional activities (e.g. holograms offering information or advice to clients) | |
| 11 | Solutions that substitute people in complex professional activities (e.g. a humanoid robot replacing a reception desk assistant in a hotel or a shop assistant) | |
| 12 | Solutions that substitute people in simple household tasks (e.g. smart vacuum cleaners, smart lawnmowers) | |
| 13 | Solutions that substitute people in complex household activities (e.g. humanoid robots taking care of elderly or disabled people) | |
| 14 | Solutions based on mobile communication with multiplied (above-standard) data transfer (e.g. remote treatment of people by monitoring their vitals) | |
| 15 | Solutions providing devices with smart features, e.g. by connecting them to the Internet (e.g. smart fridges where the content can be checked the use of a smartphone app) | |
| 16 | Solutions focusing on the so-called machine learning (e.g. allowing a computer to perform tasks for which it has not been programmed before, machine learning) | |
| 17 | Solutions enabling computer simulation which create images of physical or virtual reality, e.g. computer simulations of objects, spaces or events | |
| 18 | Solutions enabling computer simulation that combine the real world with computer-generated images (e.g. superimposing real-time 3D graphics on a camera image). | |

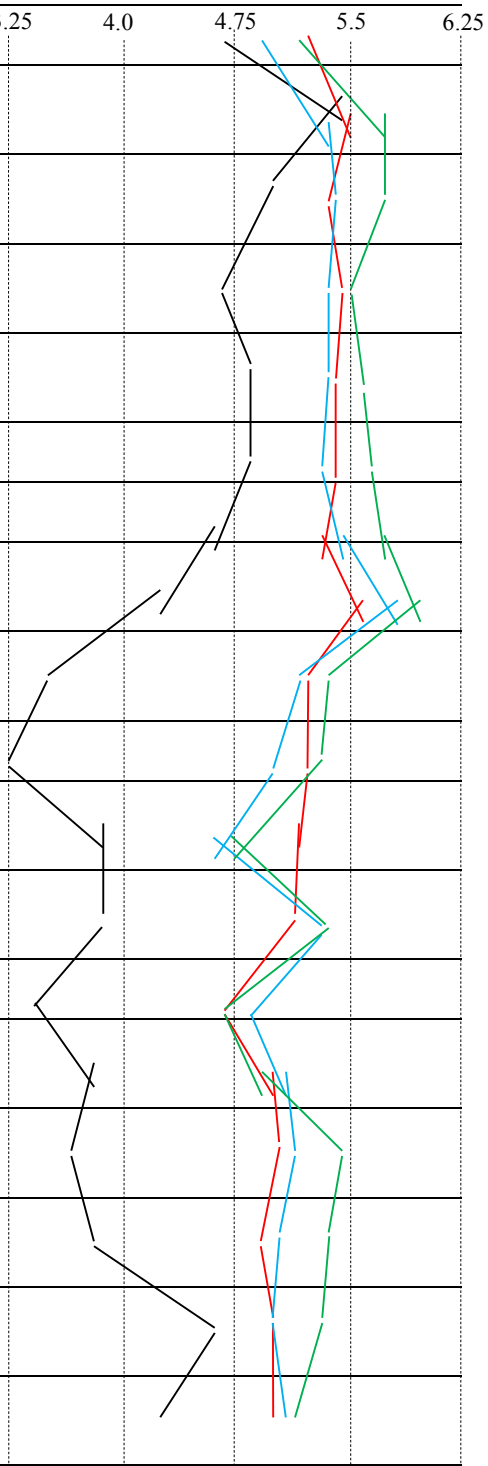


**Figure 5.** Interest of companies covered by the study in solutions from the realm of digital technologies (black line denotes micro, red line – small, blue line – medium-sized and green line – large companies).

Source: author's own study.

It follows from information presented in Fig. No. 5 that interest in solutions in the area of digital technologies is correlated with the size of a company measured with the number of employees. In general, one may conclude that the lowest interest in digital technologies was recorded in the group of micro-companies. This observation does not come as a surprise, because smallest entities have specific needs and limited potential with respect to implementing the presented technological solutions.

Next, eighteen statements (Table 3) were used to measure the power of impact of knowledge about individual digital technologies in the process of forming long-term inter-organisational relations. The statements were aligned to the seven-degree Likert scale, ranging from the 'strongly disagree' (1) to 'strongly agree' (7) answers. The basic descriptive statistics for all eighteen statements are presented in Table 3.

**Table 3.**
*Basic descriptive statistics for statements pertaining to digital technologies*

| No. | Statement (variable)<br>Would you like to learn or apply these solutions in your enterprise in the next five years? | Statistics | Value | Standard error |
|---|---|---|---|---|
| 1 | IT systems supporting decision-making in an organisation (e.g. artificial intelligence) [P11a] | Average | 5.1343 | 0.06678 |
| | | Median | 5.0000 | - |
| | | Variance | 1.561 | - |
| | | Standard deviation | 1.24928 | - |
| | | Skewness | -0.513 | 0.130 |
| | | Kurtosis | 0.242 | 0.260 |
| 2 | IT systems allowing for capturing, analysing and management of data deriving from multiple diverse and distributed sources (*Big Data*) [P11b] | Average | 5.4343 | 0.06985 |
| | | Median | 6.0000 | - |
| | | Variance | 1.708 | - |
| | | Standard deviation | 1.30679 | - |
| | | Skewness | -0.960 | 0.130 |
| | | Kurtosis | 0.818 | 0.260 |
| 3 | Solutions focused on automation of managerial processes, e.g. e-mail handling, processing of financial transactions (process automation, robotisation) [P11c] | Average | 5.3600 | 0.07487 |
| | | Median | 6.0000 | - |
| | | Variance | 1.962 | - |
| | | Standard deviation | 1.40061 | - |
| | | Skewness | -1.013 | 0.130 |
| | | Kurtosis | 0.845 | 0.260 |
| 4 | Solutions allowing for reinforcement of relations connecting organisations with clients via IT systems of ordering, analysis and evaluation of mutual experiences (new experience design) [P11d] | Average | 5.3600 | 0.07595 |
| | | Median | 6.0000 | - |
| | | Variance | 2.019 | - |
| | | Standard deviation | 1.42092 | - |
| | | Skewness | -0.715 | 0.130 |
| | | Kurtosis | -0.077 | 0.260 |
| 5 | Solutions enabling an increase in speed and safety of data processing consisting – among others – in transfer of the computing capacity closer to the place of data generation (*edge computing*) [P11e] | Average | 5.3057 | 0.07764 |
| | | Median | 6.0000 | - |
| | | Variance | 2.110 | - |
| | | Standard deviation | 1.45248 | - |
| | | Skewness | -0.899 | 0.130 |
| | | Kurtosis | 0.431 | 0.260 |

Cont. table 3.

| | | | | |
|---|---|---|---|---|
| 6 | Solutions allowing for safe storage of information, relying on creation and saving a full path (chain) of data flow (*blockchain*) [P11f] | Average | 5.3000 | 0.07896 |
| | | Median | 6.0000 | - |
| | | Variance | 2.182 | - |
| | | Standard deviation | 1.47714 | - |
| | | Skewness | -0.855 | 0.130 |
| | | Kurtosis | 0.326 | 0.260 |
| 7 | Solutions allowing for storage of data, files, applications, software or IT systems on external supplier's servers (*cloud computing*) [P11g] | Average | 5.2743 | 0.07907 |
| | | Median | 6.0000 | - |
| | | Variance | 2.188 | - |
| | | Standard deviation | 1.47924 | - |
| | | Skewness | -0.769 | 0.130 |
| | | Kurtosis | 0.086 | 0.260 |
| 8 | Solutions aimed at better protection of IT networks, devices, programmes and data from hackers' attacks, damages or unauthorised access (cyber-security) [P11h] | Average | 5.5543 | 0.08105 |
| | | Median | 6.0000 | - |
| | | Variance | 2.299 | - |
| | | Standard deviation | 1.51636 | - |
| | | Skewness | -1.096 | 0.130 |
| | | Kurtosis | 0.665 | 0.260 |
| 9 | IT systems enabling computer-assisted conversations, e.g. virtual consultants offering advice or answering questions of clients, *chatbot* [P11i] | Average | 5.0086 | 0.08569 |
| | | Median | 5.0000 | - |
| | | Variance | 2.570 | - |
| | | Standard deviation | 1.60316 | - |
| | | Skewness | -0.698 | 0.130 |
| | | Kurtosis | -0.121 | 0.260 |
| 10 | Solutions that substitute people in simple professional activities, e.g. holograms offering information or advice to clients [P11j] | Average | 4.8914 | 0.08874 |
| | | Median | 5.0000 | - |
| | | Variance | 2.756 | - |
| | | Standard deviation | 1.66015 | - |
| | | Skewness | -0.658 | 0.130 |
| | | Kurtosis | -0.304 | 0.260 |
| 11 | Solutions that substitute people in more complex professional activities, e.g. a humanoid robot substituting a reception desk assistant in a hotel or a shop assistant [P11k] | Average | 4.7057 | 0.09114 |
| | | Median | 5.0000 | - |
| | | Variance | 2.907 | - |
| | | Standard deviation | 1.70511 | - |
| | | Skewness | -0.500 | 0.130 |
| | | Kurtosis | -0.586 | 0.260 |
| 12 | Solutions that substitute people in simple household tasks, e.g. smart vacuum cleaners, smart lawnmowers [P11l] | Average | 5.0257 | 0.08906 |
| | | Median | 5.0000 | - |
| | | Variance | 2.776 | - |
| | | Standard deviation | 1.66609 | - |
| | | Skewness | -0.733 | 0.130 |
| | | Kurtosis | -0.195 | 0.260 |
| 13 | Solutions that substitute people in complex household chores, e.g. humanoid robots taking care of elderly or disabled persons [P11m] | Average | 4.6543 | 0.09356 |
| | | Median | 5.0000 | - |
| | | Variance | 3.064 | - |
| | | Standard deviation | 1.75029 | - |
| | | Skewness | -0.548 | 0.130 |
| | | Kurtosis | -0.559 | 0.260 |
| 14 | Solutions relying on mobile communication with multiple (above-standard) data transfer, e.g. remote treatment of people by monitoring their vitals, remote control of facilities, 5G [P11n] | Average | 4.9314 | 0.08755 |
| | | Median | 5.0000 | - |
| | | Variance | 2.683 | - |
| | | Standard deviation | 1.63798 | - |
| | | Skewness | -0.708 | 0.130 |
| | | Kurtosis | -0.114 | 0.260 |

Cont. table 3.

| | | | | |
|---|---|---|---|---|
| 15 | Solutions providing the devices with smart features, e.g. by connecting them to the Internet, e.g. smart fridges where the content can be checked the use of a smartphone app (Internet of Things, IoT) [P11o] | Average | 4.9914 | 0.08934 |
| | | Median | 5.0000 | - |
| | | Variance | 2.794 | - |
| | | Standard deviation | 1.67141 | - |
| | | Skewness | -0.701 | 0.130 |
| | | Kurtosis | -0.243 | 0.260 |
| 16 | Solutions focused on the so-called machine learning, e.g. allowing a computer to perform tasks for which it has not been programmed before, machine learning [P11p] | Average | 4.9029 | 0.08462 |
| | | Median | 5.0000 | - |
| | | Variance | 2.506 | - |
| | | Standard deviation | 1.58313 | - |
| | | Skewness | -0.763 | 0.130 |
| | | Kurtosis | -0.002 | 0.260 |
| 17 | Solutions that enable computer simulations which create images of physical or virtual reality, e.g. computer simulations of objects, spaces or events (virtual reality) [P11r] | Average | 4.9457 | 0.08725 |
| | | Median | 5.0000 | - |
| | | Variance | 2.665 | - |
| | | Standard deviation | 1.63238 | - |
| | | Skewness | -0.807 | 0.130 |
| | | Kurtosis | -0.035 | 0.260 |
| 18 | Solutions that enable computer simulations that combine the real world with computer-generated images, e.g. superimposing real-time 3D graphics on a camera image, augmented reality [P11s] | Average | 4.9600 | 0.08417 |
| | | Median | 5.0000 | - |
| | | Variance | 2.480 | - |
| | | Standard deviation | 1.57473 | - |
| | | Skewness | -0.819 | 0.130 |
| | | Kurtosis | 0.061 | 0.260 |

Source: author's own study.

Eighteen variables (see Table 3) were taken into account in the factor analysis. As a result of the performed analysis, three factors were identified, which significantly clarify the variability observed in the input data set. Three distinguished factors account for almost 74.1% of the variability of the input data set. This means that reduction of the 18-dimension set to the 3-dimension set described with the distinguished factors results in a loss of only approx. 25.9% of full information from the input set. Some variables (5) were rejected due to no possibility of assigning a given variable to a specific factor (similar load values in the case of both components). Using the Varimax orthogonal rotation, the final distribution of factor loads is presented in Table 4.

**Table 4.**
*Distribution of factor loads for variables in the area of digital technology*

Factor distinguishing method – principal factors Rotation method – Varimax with Kaiser normalisation
a. the rotation was convergent in 3 iterations.

| Statement (variable) | Factor | | |
|---|---|---|---|
| | **1 Process automation and monitoring** | **2 Data integration and big data analytics** | **3 Protection and cyber-security** |
| Solutions substituting people in complex professional activities, e.g. a humanoid robot substituting a reception desk assistant in a hotel or a shop assistant | **0.834** | | |
| Solutions substituting people in complex household chores, e.g. humanoid robots taking care of the elderly or persons with disabilities | **0.832** | | |
| Solutions that enable computer simulations which create images of physical or virtual reality, e.g. computer simulations of objects, spaces or events (virtual reality) | **0.784** | 0.405 | |
| Solutions substituting people in simple household tasks, e.g. smart vacuum cleaners, smart lawnmowers | **0.751** | 0.301 | |
| Solutions that enable computer simulations that combine the real world with computer-generated images, e.g. superimposing real-time 3D graphics on a camera image in real time, augmented reality | **0.738** | 0.458 | |
| Solutions based on mobile communication with multiplied data transfer, e.g. remote treatment via vital sign monitoring, remote control of facilities, 5G technology | **0.730** | 0.389 | |
| Solutions focused on the so-called learning of machines, e.g. allowing a computer to perform tasks for which it has not been programmed before, machine learning | **0.722** | 0.398 | |
| Solutions furnishing the devices with smart features, e.g. by connecting them to the Internet, e.g. smart fridges where the content can be checked the use of a smartphone app, Internet of Things | **0.713** | 0.327 | 0.360 |
| Solutions substituting people in simple professional activities, e.g. holograms offering information or advice to clients | **0.679** | | 0.533 |
| IT systems supporting decision-making in an organisation (e.g. marketing, artificial intelligence) | | **0.817** | |
| IT systems allowing for capturing analysing and managing information deriving from multiple diverse and distributed sources (Big Data) | | **0.798** | |
| Solutions allowing for reinforcement of relations between organisations and clients via IT systems of ordering, analysis and evaluation of mutual experiences (new experience design) | 0.330 | **0.696** | 0.356 |
| Solutions aimed at better protection of IT networks, devices, programmes and data from hackers' attacks, damages or unauthorised access (cyber-security) | | 0.444 | **0.743** |

Source: author's own study.

It follows from the results contained in Table 4 that thirteen out of eighteen input variables were assigned to three factors. The variables are moderately strong and strongly bound to each factor. The following factors have been distinguished:

- factor 1: interest in solutions in the area of process monitoring and automation – the factor comprises knowledge related to monitoring and automation and substituting people in household and professional activities,

- factor 2: interest in data integration and big data analytics – solutions comprising knowledge related to capturing, integration and processing of large sets of data as support in the decision-making proces,
- factor 3: interest in cyber-security and protection of data – issues related to knowledge about network protection, e.g. from a hacker's attack or another type of unauthorised access.

Similarly to variables in the area of digital technologies in reference to variables describing the enterprises' willingness to establish and to reinforce inter-organisational bonds, an exploratory factor analysis was carried out with the use of the principal component method and orthogonal Varimax rotation with the use of SPSS. All the assumptions remained unchanged. In effect, the KMO sampling adequacy ratio reached 0.933. The Bartlett Test of Sphericity for the studied set is on the B = 3818.933 level (df = 91, p-value = 0.000) – Table 5.

**Table 5.**
*The results of the KMO test and the Bartlett Test of Sphericity for variables pertaining to enterprises' inclination to establish and reinforce inter-organisational bonds*

| **Kaiser–Meyer–Olkin Measure of Sampling Adequacy** | | 0.933 |
|---|---|---|
| **Bartlett' s Test of Sphericity** | Approx. Chi-Square | 3818.933 |
| | df | 91 |
| | Sig. | 0.000 |

Source: author's own study.

Hence, it may be stated with absolute certainty that the use of factor analysis has been justified. The received results indicated their alignment to data – none of the scale items used were eliminated from the analysis. Taking into account the degree of clarification of the variability of the initial data set, two factors were detected explaining 67.4% of information for the full set of 14 observable variables. The variables are moderately bound to every factor. Some variables (7) were rejected on account of:

- no possibility of assigning a given variable to a specific factor (similar load values in the case of both components),
- statements that are insignificant or difficult to interpret in the context of establishment or reinforcement of bonds.

Thanks to the performed statistical procedure, it is possible to determine the degree to which the aforementioned variables (factors) are responsible for the willingness to establish or reinforce inter-organisational bonds, also with selected universities. Using the Varimax orthogonal rotation, the final distribution of factor loads is presented in Table 6.

**Table 6.**
*Distribution of factor loads for variables pertaining to the enterprises' inclination to establish and reinforce inter-organisational bonds and with selected universities*

Factor distinguishing method – principal factors. Rotation method – Varimax with Kaiser normalisation
a. the rotation was convergent in 3 iterations.

| Statement (variable) | Factor | |
|---|---|---|
| | 1 Bond reinforcement | 2 Bond establishment |
| I would like to pursue joint international projects also with selected universities | **0.810** | |
| I would like to create research and development projects also with selected universities | **0.781** | 0.398 |
| I would like to influence the educational offer, directions of teaching and curricula at selected universities | **0.764** | 0.305 |
| I would like to create joint international projects also with selected universities | **0.744** | 0.392 |
| I would like to use expert knowledge and counselling also from selected universities | | **0.775** |
| I would like to use results of studies carried out by selected universities for the sake of enterprise's development | 0.368 | **0.754** |
| I would like to use modern technologies popularised by selected universities | 0.409 | **0.728** |

Source: author's own study.

It follows from the data presented in Table No. 6 that seven out of fourteen input variables were assigned to two factors which may be described in the following manner:

- factor 1: willingness to reinforce inter-organisational bonds also with selected universities, focused on close cooperation and implementation of joint projects, requiring engagement of both parties, good recognition of the mode of organisation and processes, relations based on trust and reciprocal impact of both entities,
- factor 2: willingness to establish inter-organisational bonds, also with selected universities, encompassing simple forms of cooperation and use of expert university knowledge, not requiring significant engagement on the part of the enterprise and advanced cooperation.

The results of the performed factor analysis show that it was possible to generate three factors referring to the knowledge on digital technologies (1: Monitoring and process automation; 2: Data integration and big data analytics, 3: Protection and cyber-security), as well as two factors which clearly correspond to the 'Establishment of bonds' and 'Bond reinforcement' components, used to measure the force of impact of knowledge about digital technologies on the process of forming long-term relations among enterprises and selected universities at individual stages of such process. The factor loads adopt values testifying to moderately strong correlation between the observable input variables and the reduced factors.

## 5. Conclusion

Universities as organisations that have the indisputable potential for knowledge development are particularly predisposed to satisfying cognitive needs of other organisations within the scope of digital technologies (including enterprises), offering value that constitutes the core of services adopting diverse forms. At the same time, interest in the use of technologies of this type is growing at the universities and in enterprises that operate in various fields, which additionally intensifies the necessity of exploring this subject. Digital transformation leads to a situation where knowledge about digital technologies becomes a key element in the process of forming long-term inter-organisational relations.

The performed direct studies offered a basis for defining eighteen statements identifying knowledge about individual digital technologies, which in the opinion of the interviewed managers may be of significance in the process of forming long-term inter-organisational relations. Next, a factor analysis was carried out that allowed for reducing the prepared set of solutions from the area of digital technologies to three factors focusing knowledge on process automation and monitoring, integration of data and big data analytics and protection of data and cyber-security, which allows for concluding that the primary purpose of the paper has been accomplished.

According to the authors, the factors above have a stimulating impact on the company's willingness to establish and reinforce inter-organisational cooperation. These assumptions were confirmed by the estimation of parameters in two subsequent factors corresponding to them: 'Establishment of relations' and 'Reinforcement of relations', from which it follows that all three distinguished factors that focus knowledge about digital technologies (1: Process automation and monitoring, 2: Data integration and big data analytics, 3: Protection and cyber-security) have a uni-directional, positive impact on the enterprises' willingness to establish and reinforce inter-organisational cooperation, which in turn confirms the main hypothesis adopted in the paper. The extensive range of the issues analysed in the paper thus induces the authors to conclude that the main research problem has been settled.

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# PROFITABILITY OF MEDICAL ENTITIES IN POLAND FOLLOWING OWNERSHIP TRANSFORMATIONS

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**Purpose:** The paper aimed to analyze the profitability of the ten selected healthcare units in Poland before and after ownership transformation. Source data used for calculations came from the financial statements of the examined healthcare units.
**Design/methodology/approach**: The paper focuses on ratio analysis, i.e., profitability, which facilitates the evaluation of the studied hospitals in two periods, 'before transformation' and 'after transformation'. A method of scientific cognition was used (1): an analysis of the subject literature, a method of obtaining empirical data (2): an analysis of the content of internal documentation of the analyzed healthcare entities (hospitals), and a method of analysis of the obtained empirical material (3): indicator analysis. Undertaken research contributed to the formulation of the research objective: *Is there an improvement in the profitability of medical entities (hospitals) in Poland following ownership transformation?* Referring to the presented research problem, the author formulated the following hypothesis: *There is an improvement in the profitability of the examined healthcare entities in Poland.*
**Findings:** The study's results allow the author to verify the research hypothesis. The spatial scope of the analysis refers to the territory of Poland with a focus on three selected provinces: Lesser Poland (małopolskie), Kuyavia-Pomerania (kujawsko-pomorskie), and Lubusz (lubuskie). The time scope of the study covers three years before the transformation of a given 'SP ZOZ' (Independent Public Healthcare Institution) into a commercial law company and three years after the transformation. The subject scope of the evaluation includes: hospitals subordinate to local government units (LGUs) transformed into commercial law companies. The subject scope of the evaluation is the profitability of hospitals.
**Research limitations/implications**: The results obtained are of great practical importance for managers, shareholders and other stakeholders in the health care sector. Nevertheless, the proposed considerations certainly do not exhaust all possible solutions and may be the subject of further research and scientific discussions. In the future, the author plans to expand the research results with the criterion of social effectiveness (quality of services provided and patient satisfaction with the services of medical entities).
**Practical implications:** The results of the work can become an incentive for executives, managers and investors, as they indicate an improvement in the profitability of hospitals.
**Social implications:** The implementation of the research results will contribute to increasing public awareness of the functioning of hospitals.

**Originality/value:** The number of studies on the financial performance of medical entities is insufficient. All the more, the research results presenting the evaluation of the financial situation of the transformed entities are extremely valuable. The results from the conducted research indicate an improvement in the profitability of the examined medical entities (hospitals). In connection with this fact, legal changes resulting from normative acts (reforms in the healthcare sector) were also justified. The choice of topic results from the personal interests of the author.

**Keywords:** economy, public and non-public healthcare entities, profitability of hospitals.

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

## 1. Introduction

The priority task of the healthcare system is to respond to the health needs of society while ensuring the effective use of available resources. The paper aimed to present a profitability analysis of ten selected medical entities in Poland, focusing on three selected provinces – Lesser Poland (małopolskie), Kuyavia-Pomerania (kujawsko-pomorskie), and Lubusz (lubuskie) – before and after ownership transformation. The source data used for calculations came from the financial statements of the healthcare entities. The authors obtained the data through cooperation with one of the largest private investors in local government hospitals in Poland. Currently, the two largest in Poland are: EMC Instytut Medyczny S.A. of Wrocław and Grupa Nowy Szpital Sp. Z o.o.

There is a shortage of studies on the profitability of hospitals after ownership transformations in Polish subject literature. Authors in the Polish literature indicate the problem of modern health economics, which is the assessment of the financial condition of hospitals, due to the limited availability of relevant medical statistics that enable reliable research (Wielicka-Gańczarczyk, 2015, pp. 505-516). The article focuses on the indicator analysis, i.e., profitability, which enables the evaluation of the examined hospitals in two periods: before and after transformation. The examined Independent Public Healthcare Institutions (SP ZOZ) were transformed into Non-Public healthcare Insitutions (NZOZ), changing the legal form of the entity into a commercial law company, namely a limited liability company. The time frame of the analysis is from 2002 to 2018, which includes three years before the transformation of a given SP ZOZ into a capital company and three years after the transformation. To justify the choice of the topic, the authors paid particular attention to the most relevant issue, which is the healthcare reforms implemented from 1991 to 2018.

Moreover, the fact that further changes were introduced in December 2021, through the bill of 29 December 2021 on modernization and improvement of efficiency of hospitals (accessed 01.02.2023), although it goes beyond the analyzed time horizon (2002-2018), has a significant impact on the study of profitability of medical entities in Poland. The determinant of a country's

effectiveness is the economic indicators at an optimal level and the widely understood social good. Hence, it is essential to improve access to medical services effectively. Therefore, the process of privatization and commercialization in the Polish healthcare sector seems to be necessary and worth undertaking, if only to secure the population's health in a given region. The results of studies in this area prove that transforming hospitals into private institutions is a good move.

## 2. Literature Review and Theory Development

The processes of both privatization and commercialization have been an integral part of transformations within the Polish healthcare sector in the last decade. Under Polish commercial law, these concepts were defined in the relevant Act of 1996 (Journal of Laws 1996, No. 118, item 561, as amended). Under this law's provisions, commercialization consists of 'transforming a state-owned enterprise into a company without changing its ownership structure. Regarding privatization, the legislator distinguished two forms: direct privatization (sale of a state-owned enterprise) and indirect privatization (sale of Treasury-owned shares in companies). Although the Act refers to state-owned entities, commercialization is commonly accepted as transforming a public entity into a commercial law company while maintaining the existing ownership structure (Dubas, Szetela, 2013, p. 39). Privatization, on the other hand, refers to a change in the ownership of a commercialized entity through the sale of most or all of its shares. In the international literature, privatization is also referred to as a set of mechanisms that aims not only to encourage the private sector to actively participate in the financing and delivery of public services, but also includes the introduction of private sector management principles in this area (Saltman, Bankauskaite, Vrangbaek, 2007, p. 246). The increase in the share of the private sector in the supply of healthcare services is the main effect of the so-called 'founder privatization' that has taken place in Poland over the last ten years. Unlike the two previously mentioned forms (i.e., direct and indirect), it does not involve a transformation of the ownership structure of an entity/institution belonging to the public sector (Dubas et al., p. 39) but the independent creation of entirely new non-public entities. Founder privatization has contributed to the faster development of the private sector in primary healthcare (e.g., group and individual medical practices). In the broader sense of healthcare, we deal with various forms of privatization. However, it should be remembered that when it comes to hospitals, which are the basis of inpatient treatment, indirect privatization with the participation of entities subordinate to local government units plays a key role here. The two concepts in question are separate processes, as commercializing public hospitals may be the first step toward privatization. The existing legislation contains incentives (i.e., financial motives) to encourage the founding bodies to commercialize public hospitals. Thus, the issue concerning their privatization is an independent and individual decision of the founding institution (Horosz, 2012, pp. 42-58).

The share of public and non-public entities reflects the commercialization scale in the inpatient care sector. Most public entities operate in the form of SP ZOZ, and their owners (founding bodies) are ministers, central government administration bodies, provincial governors, local government units (LGU), public medical universities, and the Medical Centre for Postgraduate Education. Non-public entities function in the form of companies. They are owned primarily by natural or legal persons (national and foreign), employers, foundations, trade unions, professional self-governments, associations, churches, religious associations, or companies that do not have legal personality (Dubas et al., p. 40). Such a classification in available statistics has been in force since the 1990s. It helps assess the scale of commercialization of public hospitals. Still, on the other hand, it poses difficulties in assessing the degree of privatization, which can be explained by the fact that in the group of non-public hospitals, there are also healthcare providers that operate as companies, where local government units have a majority or total share. These units are often referred to as 'non-public local government units'; the name indicates that it juxtaposes two opposing notions (Dubas et al., p. 41). On the one hand, its name suggests that it is the local government unit because it belongs to the element of public administration. On the other hand, it is non-public because a company is not mentioned in it – the current legal regulations contain a closed catalog of organizational and legal forms where a public provider of health services can function.

Healthcare system reform is a long, labor-intensive, complex social, economic, and political process. Due to the importance of changing the legal form of medical entities, the authors also paid attention to the following reforms in the health sector:

- Act of 30 August 1991 on Healthcare Institutions (Journal of Laws of 1991, No. 91, item 408 as amended, repealed on 1 July 2011).
- Act of 6 February 1997 on National Health Insurance (Journal of Laws of 1997, No. 28, item 153 as amended).
- Act of 23 January 2003 on National Insurance in the National Health Fund (Journal of Laws of 2003, No. 45, item 391).
- Act of 15 April 2011 on Medical Activity (Journal of Laws 2011, No. 112, item 654 as amended).
- Act of 10 June 2016 amending the Act on Medical Activity and certain other acts (Journal of Laws of 2016, item No. 1638 as amended).
- Act of 23 March 2017 amending the Act on Healthcare Services Financed from Public Funds, the so-called hospital network (Journal of Laws 2017, item 844).
- Act of 27 October 2017 on Primary Healthcare (Journal of Laws 2017, item 2217),
- Act of 10 May 2018 on the Protection of Personal Data (Journal of Laws 2018, item 1000).
- Draft Act of 29 December 2021 on Modernizing and Improving the Efficiency of the Hospital System.

Due to the importance of the subject matter of the article, it is crucial to distinguish the three healthcare system reforms that focus on changes concerning ownership transformations, namely:

- The Act of 30 August 1991 on Healthcare Institutions – the reform of the healthcare system after 1989 was concurrent with the rapid transition from a centrally planned economy to a market economy. The first changes were not radical and were introduced in 1991-1998. They focused on issues related to the decentralization of healthcare and the approval of the so-called founding privatization of clinics and specialist medical practices. During this period, the most significant change was providing state hospitals with accountability and autonomy in budget management (Journal of Laws 1991, No. 91, item 408 as amended, repealed on July 1, 2011).
- Act of 15 April 2011 on Medical Activity – the next stage of the healthcare reform was the introduction of the Act on Medical Activity, which came into force on 1 July 2011. The Act paved the way for transforming public hospitals into commercial law companies. The Act on Medical Activity is a continuation of earlier attempts to commercialize public hospitals to reduce their debts and improve their management. The Act on Medical Activity regarding the transformation of Independent Public Healthcare Institutions (SPZOZ) into companies guarantees complete continuity of activities in the new organizational and legal form. Transformations are performed with the participation of the entity forming SPZOZ, i.e., local government (province, poviat, commune) or medical university.The main incentive for the transformation is the possibility of obtaining partial write-offs of public liabilities of the medical entity, as well as the possibility of receiving a special-purpose subsidy from the state budget by the forming entity. However, the act brings about a noticeable change in nomenclature, as the notion of 'healthcare institutions' has been replaced with the notion of 'medical entities' (Journal of Laws, 2011, No. 112, item 654 as amended).
- Act of 10 June 2016 amending the Act on Medical Activity and certain other acts – Another systemic healthcare reform initiated the Law on Medical Activity amendment, which came into force on 15 July 2016. It halted the commercialization and privatization of public hospitals by prohibiting the sale of stocks and shares in capital companies with State Treasury participation. One of the most important changes in this amendment was the abandonment of the transformation of SPZOZ into commercial companies (Journal of Laws 2016, Item No. 1638, as amended).

Therefore, the analyzed time horizon of the examined medical entities was justified. According to the information contained in the report of the Supreme Chamber of Control of 2015 (SCoC), the Act on Medical Activity adopted in 2011 provided for the possibility of obtaining support for entities transforming Independent Public Healthcare Institutions (SP ZOZ) into capital companies (SCoC, 2022). Unlike the Act on Medical Activities, the Act on healthcare Institutions enabled the transformation of SP ZOZ into a capital company

without requiring its prior liquidation. In connection with this situation, there appeared the possibility of preserving the legal continuity of the entity functioning in different legal forms. According to data on the Ministry of Health website, from the beginning of 2011 to the end of April 2014, the number of hospitals increased from 984 to 1,078 (Ministry of Health, 2022). Independent Public Health Care Institutions (SP ZOZ) transformed into companies at the level of 174 hospitals. The organizational and legal form based on the Act on Healthcare Institutions of 1991 was changed in 125 hospitals, thus resulting in the establishment of private entities. Forty-nine hospitals were subjected to the 2011 Act on Medical Activities, creating the possibility of transforming a public entity into a commercial company. In turn, the World Health Organization reports that in 2016 there were 926 hospitals in Poland, including the majority of public hospitals (462) operating in the form of SP ZOZ (Sowada, Sagan, Kowalska-Bobko, 2019). According to the Ministry of Health, at the end of 2020, there were 575 public hospitals in Poland, defined as healthcare entities providing hospital services, functioning in the form of independent public healthcare institutions (428), research institutes (14), and capital companies (133), of which 125 with 100% state capital) with majority Treasury share, local government units, or medical universities (joint-stock companies) (Ministry of Health, 2022). Therefore, one can conclude that the number of medical entities (hospitals) before and after the transformation is not sufficiently estimated.

## 3. Materials and Methods

Medical institutions' periodic reports on their activities rely mainly on the balance sheet, income statement, and financial flow statement (if a certified financial auditor audits the report). The analysis of economic indicators acts as a compliment to financial reporting (Wielicka-Gańczarczyk, 2015, p. 507). Indicator analysis allows one to study the interdependencies between the various elements that appear in financial statements, thus making it possible to assess an enterprise's financial standing (Pomykalska, Pomykalski, 2007, p. 66). The analysis comprises the calculation of particular relations between data found in the balance sheet or profit and loss account and then comparing the obtained quantities with the base quantities or the quantities of other enterprises (Kotowska, Uziębło, Wyszkowska-Kaniewska, 2013, p. 57). When conducting comparative studies, medical entities often face the fundamental dilemma of which entity to compare themselves with, as choosing the best one is difficult due to the poor financial condition of most businesses.

Various methods can be used to assess the financial condition. However, in practice, the indicator method is most often used, as it is of fundamental importance for the synthetic assessment of the asset and financial situation. A good selection of indicators allows one to illustrate the mutual relationships, which are defined by economic values, resulting in the

possibility of assessing the financial condition. The indicator analysis includes a wide range of measures designed to evaluate the financial situation of an economic unit. With their help, it is possible to characterize various economic aspects of entities' activities synthetically. Regardless of the sector, the four primary groups of indicators used to assess an enterprise's financial condition are most often distinguished, i.e., profitability, debt, liquidity, and turnover (Perechuda, Kowalewski, 2008, p. 156). Due to the article's purpose, the research was narrowed down to the profitability analysis of the ten selected medical entities in Poland before and after ownership transformation. To achieve the article's principal objective, the authors made a collective overview presented in Table 1 and unified the group of indicators according to which the research was conducted.

**Table 1.**
*Profitability indicators*

| Indicator | Formula |
|---|---|
| Return on Sales (ROS) | $\frac{Net\ profit}{Sales} * 100\%$ |
| Return on Assets (ROA) | $\frac{Net\ profit}{Total\ assets} * 100\%$ |
| Return on Equity (ROE) | $\frac{Net\ profit}{Equity} * 100\%$ |

Source: Nowak, 2005, pp. 165-188.

As can be seen, profitability ratios are profit to invested capital. When medical entities show a positive value of profitability in all tested aspects with the help of the presented indicators, it should be read as a positive effect for the institution's benefit. Return on sales (ROS) examines a business's profitability (Gabrusewicz, 2014, p. 302). The profit margin ratio determines the level of earnings on the business activity, and its value is a specific characteristic of a business entity because it depends on the type of activity. It is indicated that manufacturing activity brings a higher profit margin than trade and service activity. This difference is due to the length of the operating cycle and the cost of freezing the capital. A higher level of this ratio implies a more favorable financial situation for the company. ROA shows the effectiveness of using assets at the company's disposal. It is a measure used to evaluate managers of business entities. It informs how much profit is generated by one unit of money engaged in assets; the higher the ratio value, the higher the efficiency of the use of assets by the enterprise (Gabrusewicz, 2014, p. 312). Return on equity (ROE) shows the return on capital invested by the owners of the economic entity and the capital earned during its operation.

A higher measure value indicates a more profitable situation for the company (Perechuda, Kowalewski, 2008, p. 159). The spatial scope of the analysis refers to the territory of Poland with a focus on three selected provinces: Lesser Poland (małopolskie), Kuyavia-Pomerania (kujawsko-pomorskie), and Lubusz (lubuskie), including an analysis of ten medical entities.

Table 2 presents the results for hospitals, focusing on the number of healthcare entities in the studied provinces, accounting for the analysis period, and the change in legal form from SP ZOZ to NZOZ.

**Table 2.**
*Research results on the profitability of medical entities in Poland after ownership transformations*

| Province (number of hospitals) | Analysis period | PROFITABILITY (%) SP ZOZ (before transformation) | | | PROFITABILITY (%) NZOZ (after transformation) | | | | | IMPROVEMENT/ NO IMPROVEMENT/ INCONCLUSIVE RESULT |
|---|---|---|---|---|---|---|---|---|---|---|
| **Lesser Poland (małopolskie)** | | | | | | | | | | |
| 1 | 2010-2011, 2012-2013 | | | | **10** | **11** | **12** | **13** | | IMPROVEMENT |
| ROS | | | | | 3.72 | 16.42 | 20.94 | 3.43 | | |
| ROA | | | | | 21.03 | 9.68 | 10.63 | 12.88 | | |
| ROE | | | | | 97.79 | 201.80 | 53.58 | 54.76 | | |
| **Kuyavia-Pomerania (kujawsko-pomorskie)** | | | | | | | | | | |
| 1 | 2002-2004, 2005-2006 | **02** | **03** | **04** | **05** | **06** | | | | IMPROVEMENT |
| ROS | | -16.82 | -31.07 | -13.15 | 11.83 | 12.48 | | | | |
| ROA | | -54.60 | -72.06 | x | 3.95 | 3.34 | | | | |
| ROE | | -38.48 | -40.2 | -17.56 | 9.38 | 5.8 | | | | |
| 2 | 2004-2006, 2009-2010 | **04** | **05** | **06** | **09** | **10** | | | | IMPROVEMENT |
| ROS | | -7.8 | -16.62 | -22.33 | 3.2 | 3.5 | | | | |
| ROA | | -20.48 | -43.20 | -49.13 | 17.8 | 20.2 | | | | |
| ROE | | -100.94 | x | x | 7.53 | 9.3 | | | | |
| 3 | 2006-2008, 2009-2011 | **06** | **07** | **08** | **09** | **10** | **11** | | | IMPROVEMENT |
| ROS | | -4.46 | 13.66 | -6.98 | 1.25 | 4.01 | 6.5 | | | |
| ROA | | -17.11 | 66.93 | -12.51 | 10.96 | 17.8 | 19.44 | | | |
| ROE | | -11.36 | -90.67 | x | 35.20 | 37.7 | 38.9 | | | |
| **Lubusz (lubuskie)** | | | | | | | | | | |
| 1 | 2004-2006, 2007-2008 | | | | **04** | **05** | **06** | **07** | **08** | IMPROVEMENT |
| ROS | | | | | 1.4 | 1.2 | 2.3 | 2.89 | 9.71 | |
| ROA | | | | | 1.8 | 1.6 | 3.4 | 4.49 | 14.4 | |
| ROE | | | | | 2.7 | 2.4 | 4.4 | 6.15 | 19.71 | |
| 2 | 2003-2005, 2008-2010 | **03** | **04** | **05** | **08** | **09** | **10** | | | IMPROVEMENT |
| ROS | | -27.99 | -7.64 | -5.97 | 11.34 | 13.24 | 14.52 | | | |
| ROA | | -55.91 | -36.18 | -43.14 | 44.75 | 47.05 | 60.19 | | | |
| ROE | | x | -30.76 | -15.38 | 11.85 | 11.73 | 18.44 | | | |

Cont. table 2.

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 3 | 2004-2006, 2008-2010 | **04** | **05** | **06** | **08** | **09** | **10** | | | IMPROVEMENT |
| ROS | | - 52.39 | -36.01 | -43.12 | 7.17 | 5.06 | 1.26 | | | |
| ROA | | -54.86 | -38.51 | -43.28 | 37.89 | 8.07 | 1.85 | | | |
| ROE | | -25.62 | -15.16 | -13.99 | 93.75 | 41.40 | 9.44 | | | |
| 4 | 2005-2006, 2009-2011 | **05** | **06** | | **09** | **10** | **11** | | | IMPROVEMENT |
| ROS | | -23.2 | 0.05 | | 7.39 | 4.36 | 0.94 | | | |
| ROA | | -31.04 | 0.08 | | 29.76 | 14.61 | 1.56 | | | |
| ROE | | -53.27 | -13.45 | | 48.63 | 24.46 | 6.06 | | | |
| 5 | 2005-2007, 2011-2013 | **05** | **06** | **07** | **11** | **12** | **13** | | | INCONCLUSIVE |
| ROS | | -1.20 | -4.75 | 4.56 | -9.44 | -14.03 | -8.82 | | | |
| ROA | | -2.21 | -8.93 | 9.59 | -77.65 | -25.62 | -63.85 | | | |
| ROE | | -0.29 | -18.77 | -36.29 | 82.01 | 16.18 | 22.17 | | | |
| 6 | 2007-2008, 2011-2012 | **07** | **08** | | **11** | **12** | | | | INCONCLUSIVE |
| ROS | | -2.71 | -4.85 | | -0.07 | -0.01 | | | | |
| ROA | | -7.53 | -14.17 | | -0.50 | -0.05 | | | | |
| ROE | | -112.38 | -123.14 | | 0.43 | 0.5 | | | | |

Source: Authors' compilation based on the material collected and financial statements.

Eight out of ten healthcare entities under study showed a definite improvement in profitability after the transformation into a commercial law company. Often this improvement was due to making a profit or diminishing a loss that existed prior to the transformation into NZOZ entities. In two entities before the transformations, there was a profit in individual entities and a loss in others. After transformations, in some cases, the activity became profitable, whereas, in some companies, it was still loss-making. It should be added that the profitability of two medical entities, i.e., one from Lesser Poland province (no. 1) and the other from Lubusz province (no. 1), was examined based on data from the period after the introduction of corrective measures, as the authors had no data from the period before the transformation. Nevertheless, in this case, it was also possible to make a comparison from the perspective of the three examined years. The analysis results showed a positive trend - the examined NZOZs showed improvement in profitability. Therefore, in the case of two healthcare entities from Lubusz province (No. 5 and 6), it was challenging to indicate improvement in profitability unequivocally.

## 4. Conclusions

As a rule, ratio analysis is carried out using a more comprehensive range of measures, but we opted for the ones that can be synthetically evaluated. The profitability indicators provide a basis for a successful future prognosis, giving the institution the possibility of stable development. The results of the performed research indicate an improvement in the profitability

of the examined medical entities (hospitals). Full implementation of corrective plans by the company in the analyzed time horizon contributed to an increase in the size of profitability indicators. It means that the transformation of each medical entity was a good solution for the further functioning of the institution. Before the transformation, the examined healthcare entities were underfinanced. Moreover, they generated substantial financial losses (costs greater than revenues), which would have probably led to the liquidation of SPZOZs. Ownership transformations of the analyzed healthcare entities contributed to their further functioning in a given region, thus creating opportunities for the public to access healthcare services. One should also remember that profitability is a crucial issue analyzed by an investor when deciding on investing their capital. It determines whether the entity is profitable or whether it is underperforming. Our analysis shows that SP ZOZs were operating at a loss, as almost all profitability indicators were negative. The healthcare system has been in constant evolution for over 20 years. The goal of enforcing the changes described above is to build an efficient and well-functioning system. Regrettably, reforms in the healthcare sector undergo frequent changes. Nevertheless, the topic under discussion is essential, if only due to the introduction of the changes under the draft Act of 29 December 2021 on Modernizing and Improving the Efficiency of the Hospital System. The draft assumes, among other things, that hospitals should be examined according to four ratios: operating profitability, quick ratio, maturing liability to income, and total liability to income. The draft of the above act was rejected by public consultations. Therefore, further work on the preparation and implementation of reforms will be of key importance.

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# NUDGING IN THE WORKPLACE: MOVING BEYOND THE TRADITIONAL MANAGEMENT TOOLBOX

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**Purpose:** The purpose of the paper is to establish how nudging can be used to influence workplace behaviour: what behaviours at work nudges are targeted at, what types of nudges are used and what are the factors that affect effectiveness of nudges applied in the workplace, i.e. is nudging in the workplace any different than nudging people's domestic and private lives.
**Design/methodology/approach**: A systematic literature review has been conducted in line with the PRISMA guidelines using Web of Science and Scopus databases.
**Findings:** When nudges are implemented in the corporate context they are frequently used to: improve employees' health and wellbeing, improve employees' communication and performance, ensure safety culture at work, and promote pro-environmental behaviours. The following nudges are discussed as the most promising for managerial applications: descriptive social norms to encourage employees to knowledge sharing and re-use, reminders - to reduce sedentary behaviour in the workplace or ensure safety culture at work, and defaults in corporate conservation programmes. Starting dispositions of individuals (employees), situational factors and cultural variations are identified as the three factors affecting the effectiveness of nudges in a workplace.
**Originality/value:** The paper provides a literature review which evaluates the state of knowledge on nudging in the workplace, indicates management implications when and how nudges can be applied to influence work behaviour and outlines promising avenues for future research.

**Keywords:** nudging, behavioural science, workplace nudging, workplace management, change management.

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

## 1. Introduction

It is one thing to make a decision, and it is another to implement it within the organisation. There is a variety of management tools to do so. One of the less obvious is nudging. It might be particularly relevant for fostering safety culture or reducing impact of a company on environment by e.g. lowering energy consumption.

In recent years nudging has gained traction and is increasingly incorporated into public policy around the world to help achieve policy goals (Beshears, Kosowski, 2020). Literature is full of success stories of applying nudges to change behaviour in a wide range of domains: e.g. education (Weijers, 2021), public health (Ledderer et al., 2020), or promoting pro-environmental practices (Wee et al., 2021). No wonder that private sector managers have become interested in using this approach to pursue commercial and marketing goals (Caldwell, 2018). However, nudging inside companies is still an emerging research topic (Stieler, Henike, 2022; Rauscher, Zielke, 2019; Ruehle 2019). Literature review on nudging in the workplace or other third-party environments are hard to be find. Exemptions relate to eating behaviour in the workplace (Allan et al., 2017), promotion psychical activity and wellbeing of employees (Forberger et al., 2022; Colenberg, Jylhä, 2022) and saving energy in the workplace (Staddon et al., 2016), and is mainly conducted for other than managerial purposes. Thus, this paper aims to fill the gap and review the state of the art of applying nudges in the workplace, identify opportunities and challenges of nudging application when private organisations play a role of nudging agents. Of special interest is the question - is nudging in the workplace any different than nudging people's domestic and private lives.

A systematic literature review has been conducted in line with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA). A total of 54 eligible studies were identified from acknowledged databases: Web of Science (WOS) and SCOPUS. The review has been guided by the following research questions: (1) What behaviours at work nudges are targeted at?, (2)What types of nudges are used?, and (3) What are the factors that affect their effectiveness?

The article is structured as follows. Following an introduction, the idea behind nudging is explained, i.e. how nudges differ from the traditional management tools. The next section contains the research methodology used in the review. Then, the results of the review are presented. Finally, we conclude by indicating management implications when and how nudges can be applied to influence work behaviour and outlining promising avenues for future research.

## 2. Nudging as a management tool

The nudging approach in public policy was widely embraced thanks to the work of Thaler and Sunstein (2008) "Nudge: Improving decisions about health, wealth, and happiness". The authors claimed that small changes made in the environment in which individuals make decisions can effectively alters people behaviour in a predictable way at a relatively low cost. Such a modification in "choice architecture" may entail changing the language used to describe the available options, the format in which the options are presented, or the process by which the options are selected. However, to qualify as "nudges," these strategies cannot mandate or forbid options, nor meaningfully change the economic incentives attached to them (Beshears, Kosowsky, 2020).

Nevertheless, the underpinnings of the nudging approach can be traced back to work of such behavioural economists as Herbert Simon (1955, 1957) on bounded rationality or Daniel Kahneman and Amos Tversky (1974, 1979, Kahneman 2011) on cognitive biases and heuristics. Simon proposed the concept of bounded rationality according to which individuals satisfice, (this is an amalgamation of the words satisfy and suffice), rather than maximise due to their limited cognitive and information-processing abilities, time constraints and incomplete knowledge. For that reason, they are not able to evaluate all potential alternatives and their consequences. They limit they search to only a few options to make decisions that are 'good enough' to meet their aspiration level. Thus, he departed from the assumptions of perfect rationality and homo economicus. Furthermore, against this backdrop, he demonstrated how organisations influence individual decision-making by assigning roles, channeling attention of the decision-maker, establishing operating rules and communication mechanisms, so individual actors become parts of a collective endeavour to achieve organizational goals (Schwarz et al., 2022). However, not only individuals face limitations on their ability to process information but decision-making differs under conditions of uncertainty and/or risk, because people react in such situations at the level of cognitive assessment as well as a level of emotional reaction (Tversky, Kahneman, 1974). This research direction has provided a deeper understanding of how people, in fact, think, choose, act and interact, frequently deviating from normative theories of rational choice. These deviations are referred to in the literature as 'cognitive biases. Two discoveries of cognitive psychology are particularly relevant from the point of view of the topic of this article. First, it is Dual Process Theory (DPT) (Kahneman, 2011), which posits that on a daily basis people use two systems of thinking. System 1 means quick, intuitive thinking. It works automatically, with minimal cognitive effort and basically without our conscious control. This system is based on mental shortcuts, the so-called heuristics. They save time, energy and attention. However, they come at a price - they are inaccurate and can lead to errors. System 2, in turn, involves slow, reflective thinking. It allows to make more informed decisions, but requires effort and focus of attention. These two systems work interchangeably.

While making decisions every day, human mind is constantly faced with the choice - saving time and energy, or greater precision. The second important discovery of cognitive psychology is that human failures in decision making are systematic, i.e. people in their limited rationality are quite predictable (Olejniczak, Śliwowski, 2014). And exactly on these premises the nudging approach is based. It differs from traditional policy and management tools in that it takes account of human cognitive biases and is designed to capitalise on them in order to increase the impact of policy and management tools. On the other hand, however, nudges differ from marketing 'tricks' in the intention behind their design. Nudges are considered as libertarian paternalism. 'Libertarian' as alternative options are still attainable, 'paternalism' as it is based on the idea that certain choices are better than others to improve well-being in the long run. Hence, one of the underlying assumptions of nudging is that people are basically in agreement with the goals pursued by the nudge interventions (Venema, Van Gestel, 2021).

## 3. Methods

The following research questions were raised to identify state of the art of the application of nudging in the workplace:

RQ1: What behaviours at work nudges are targeted at?

RQ2: What types of nudges are used to influence work behaviour?

RQ3: What are the factors that affect effectiveness of nudges applied in the workplace?

To address above research questions, the systematic literature review has been conducted in line with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The PRISMA checklist and the diagram ensure the transparency of the review process by depicting the flow of information through the different phases of the review process, mapping out the number of records identified and excluded, along with the reasons for exclusions (Page et al., 2021).With regard to data collection – two acknowledged electronic databases were used, namely: Web of Science and Scopus (Sánchez-Camacho et. al., 2022; Wee et al., 2021). The following search string was defined: (nudg* OR "choice architecture" OR "behavio?ral insights") AND (employee? OR workplace OR oragni?ation), within the fields: article title, abstract and key words. The research yielded 333 records.

The inclusion and exclusion criteria adopted in the review are provided in Table 1.

**Table 1.**
*The inclusion/exclusion criteria applied in the literature review*

| Inclusion criteria | Exclusion criteria |
|---|---|
| IC1: Full papers published from 2013 onwards. | EC1: Papers published before 2013 or meeting abstracts, editorials, notes, letters or conference reviews. |
| IC2: Written in the English language. | EC2: Written in a language other than English. |
| IC3: Related to nudging of employees. | EC3: No nudging or nudging is not targeted at employees, but has general application. |
| IC4: Nudging technique is designed and implemented at an organisational level. | EC4: Nudging technique is used to meet public policy goals and an organisation only plays a role of an intermediary. |
| IC5: Reporting empirical research. | EC5: Purely theoretical or conceptual papers. |

Source: Own elaboration based on the literature review.

The review process based on the PRISMA diagram is presented in Figure 1.

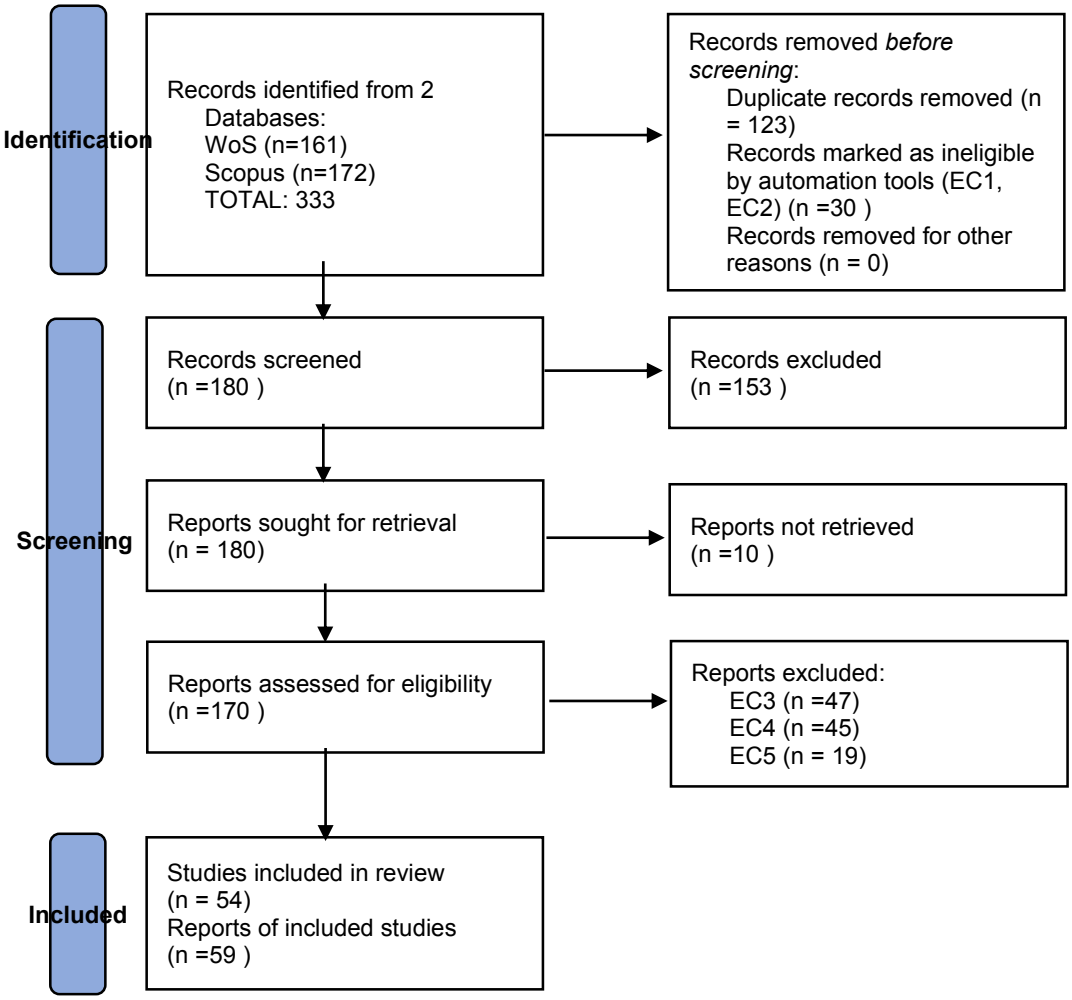


**Figure 1.** The review process based on the PRISMA diagram.

Source: Own elaboration using the PRISMA template.

# 4. The results of the review

## 4.1. Targeted work behaviour and nudging techniques used

Work-based nudge interventions under review were targeted at various work behaviours which can be grouped into the following main categories: (1) improving employees' health and wellbeing, (4) improving employees' communication and performance, (2) ensuring safety culture at work, (3) promoting pro-environmental behaviours. They are presented in Table 2.

**Table 2.**
*Behaviours at work at which nudges are targeted at*

| Work behaviour | Literature |
|---|---|
| Improving employees' health and wellbeing<br>1. healthier food options (16 studies) | Meeusen et al. (2023); Gavrieli et al. (2022); Rosi et al. (2022); Rantala et al. (2022); Rantala et al. (2021); Jia et. al. (2022); Immink et al. (2021); Montagni et al. (2020); Walker, Flannery (2020); Vasiljevic et al. (2019); McCurley et al. (2019); Velema et al. (2017); Hollands et al. (2018); Allan et al. (2017) - systematic review on nudging targeted at eating behaviour in the workplace; Baskin et al. (2016); Wilson et al. (2015) |
| 2. more psychical activity, reducing sedentary work (8 studies) | Barbar et al. (2023); Cooley et al. (2022); Mamede et al. (2021); Forberger et. al. (2022) – literature review; Haile et al. (2020); Van der Meiden et al. (2019); Venema et al. (2018); Avitsland et al. (2017) |
| 3. others (3 studies) | Colenberg, Jylhä (2022) – literature review on workplace design features that have positively influenced workers' well-being; Sinha, Jain, (2022) – increasing vaccination rates at the workplace; Takebayashi et al. (2022) - reducing obesity by promoting workers' regular self-weighting |
| improving employees' communication and performance (13 studies) | Stieler, Henike (2022); Belle, Cantarelli (2021); Van Toorn et al. (2022); Lomborg (2022); Bulte et al. (2021); Pfeiffer et al. (2020); Sharevski (2020); Kosmyna, Maes (2019); Dianoux et al. (2019); Kretzer, Maedche (2018); Bashirieh et al. (2017); Martin (2017); Meleyal (2017) |
| Safety-related behaviours and reducing littering at work (6 studies) | Zetterholm et al. (2022); Dewies et al. (2021); Wu, Paluck (2021); Sterk, Heinemann (2021); Carmichael et al. (2018); Lindhout, Reniers (2017) –literature review |
| promoting pro-environmental behaviours at work<br>(4 studies) | Charlier et al. (2021); De Figueiredo et al. (2020); Chakravarty, Mishra (2019) ; Michaels, Powell (2017) |
| Others (4 studies) | Geng et al. (2022) - encouraging employees to choose delayed but larger wage payment using colour cues; Venema, Van Gestel (2021) –nudging in the workplace in general; Atal et al. (2019) – influencing gender diversity; Kissmer et al. (2018) – susceptibility to digital nudging |

Source: Own elaboration based on the literature review.

The biggest group of studies (27 studies) dealing with nudging in the workplace was targeted at improving employees' health and wellbeing, mainly by increasing employees' healthy food choices in workplace canteens as well as by promoting physical activity and reducing sedentary behaviour in the workplace. The nudging techniques applied in the former case took the form of increasing prominence of healthy options by: food labelling (Meeusen et al., 2023; Rosi et al., 2022; Jia et. al., 2022; Montagni et al., 2020; Montagi et al., 2020; Vasiljevic et al., 2019; McCurley et al., 2019) making up appealing dish names and descriptors emphasizing tasty and enjoyable attributes to boost interest in plant-rich, lower calories dishes (Gavrieli et al ., 2022), priming posters and improved product placement, (Meeusen et al., 2023; Rantala et al., 2022; Immink et al., 2021; Baskin et al., 2017), or altering portion size (Hollands et al., 2018). In the latter case, in order to promote physical activity and reduce sedentary work, in particular among office workers, stair usage and more walking are frequently targeted behaviours of nudge interventions. For that purpose, prompts and signs are located at the "point of choice" between escalators and stairs, footsteps are placed on the floor leading to the staircase, stair-riser banners are added containing a positive feedback message, placed at every top stair riser before reaching the next floor, etc. (Van der Meiden et al., 2019; Avitsland et al., 2017). In the study of Venema et al. (2019) in order to reduce sedentary behaviour at work over time – the default setting of sit-stand desk (SSDs) was changed from sitting to standing height. The placement of such desks was found as an attractive one-off investment for companies, because it allows employees to reduce their sitting time without having to leave their desks. Reminders such as chair sensors, software packages, office clock with reminder function etc., are also frequently used to reduce prolonged sedentary behaviour in offices (Cooley et al., 2022). Interestingly, physical nudges are increasingly more supplemented or substituted by digital nudges. In the research of Mamede et al. (2021) gamification and psychical nudges (such as motivational and point-of-choice prompts) was combined in an App (MoveMore) to promote walking breaks and reduce sedentary behaviour of office workers. In the study of Haile et al. (2020), a nudge-based digital intervention – Welbot was used. This personalised digital intervention sent, at regular intervals, notifications with pictures and motivational messages, encouraging users to engage in a simple 1-3 min activity based on previously set and personalised goals.

The second biggest group of studies dealing with nudging in the workplace (13 studies) contains studies where nudging was used to improve employees communication and performance, in particular knowledge sharing in an organisation. Belle and Cantarelli (2021) tested the effect of descriptive social norms on help-seeking behaviours of public employees in healthcare organisations. Informing what the majority of peers do triggered the conformity and increased the probability of making help requests on the job. Using the same type of cognitive bias, Kretzer and Maedche (2018) demonstrated how enterprise recommendation agents and social nudges can be used to increase information retrieval in an organisation, and more specifically – reuse of existing reports, and thereby prevent redundant reports, data

inconsistencies and, as a consequence – poor-decision making. Enterprise recommendation agents, as an extension of enterprise information system, facilitates users' information searches. However, simply identifying and recommending reports is not sufficient to influence an employee's decision to actually reuse a certain report. Therefore, social influence phenomenon was used to achieve that. Building on three common forms of social influence in organisations: social cohesion (proximity), institutional isomorphism (similarity of positions in terms of business function and location), and hierarchical power, the authors designed four social nudges to steer an employee toward choosing a certain report recommendation from a set of multiple recommendations. The nudges took the form of messages displayed on screens, in which each report recommendation provided additional information about a previous user – their business function, the location and position, as well as whether the recommended report's user is directly connected to the current user or not. In a similar vein, Van Toorn et al. (2022) analysed the applicability of gamification with social notification badges for improving knowledge share and reuse. Query-Driven Knowledge Sharing Systems partially automates knowledge sharing by building the context into data. However, its potential can be limited by analysts' attitudes and behaviours. To overcome these barriers a gamified variant of the platform was designed, which in comparison to the standard platform to create query, content and search previous queries, included two additional design elements (nudges): a search bar with pop-up nudge encouraging users to search for past queries to reuse, and slide-in social notification nudge communicating about other employees who had reused the query. Also Pfeiffer et al., (2022) demonstrate how transfer of know-how between generations in a company can be enhanced through gamification and nudging and how block-chain technologies can play a role in knowledge management. Stieler and Henike (2022) and Dianoux et al. (2019), in turn, consider nudging as a vital tool for fostering organisational innovation. Steiler and Henke (2022) show, on the example of the leading German manufacturing company, how nudging can create innovation engagement of employees in mature companies that struggle with commonly-known innovation management barriers, such as: limited meaning, allowance and capability. The key point made by the authors is that as "the best thinking can come from anywhere" (p. 44), nudging approach can better unlock the prescribed, but often untapped potential in an organisation and digitalisation of the existing processes in a company opens up new avenues for nudges application in corporate context. (For an inventory of nudges used in the workplace – see: Table 3.) Dianoux et al. (2019), on the other hand, point at the potential of nudges to contribute to the agility of an organization, its capacity to remain "continuously in motion", due to the fact that nudging can be based on experimental and iterative processes, are easy and not expensive to put in place. The studies of Martin (2017) and Butle et al. (2021) examined the application of framing nudge to increase organisational performance. Martin (2017) explored different ways in which choice was presented, to overcome status quo bias to commute to the traditional workplace and thereby enhance adoption of telework among employees. Due to limited information people subconsciously evaluate each option within

a specific frame of reference and perceive loss much more than potential gains from the alternative. His findings suggest that a bias for an implicitly perceived status quo can be overruled through an explicitly stated reference point and that embedding the right reference point within communications can frame a decision choice more favourably. Bulte et al. (2021), in turn, explored incentive spillovers, and more specifically – the effect of loss-framed versus gain-framed incentives on the incented task as well as non-incented tasks performed at the same time and subsequently. Consonant with the previous research their field experiments provide evidence that loss aversion incentive induces greater effort on the incented task and they report no harmful spillover effects to subsequent tasks. It has also been found that the growing body of literature is related to the technologies which are currently more common in the work environment, i.e. self-tracking applications that rely on analytics enhanced by machine learning to inform, target and optimise employees' work habits, e. g. Microsoft MyAnalytics (Lomborg, 2022), or AttentivU (Kosmyna, Maes, 2019).

**Table 3.**
*Nudge types used in the workplace*

| Work behaviour | Nudge types |
|---|---|
| **Healthier food options** | increasing prominence of healthy options by making up appealing dish names and descriptors emphasizing tasty and enjoyable attributes, traffic light labelling system (red-unhealthy, green – healthy), priming posters and improved product placement, altering portion size; increasing the prominence of calorie labelling, motivational statements |
| **More psychical activity, reducing sedentary work** | signs located at the "point of choice" between escalators and stairs, footsteps placed on the floor leading to the staircase, stair-riser banners, promotion of walking by self-monitoring (e.g. step counts), goal-setting; reducing sedentary behaviour with help of the default setting of sit-stand desk (SSDs), chair sensors, software packages, office clock with reminder function, welbot - personalised digital intervention sending notifications encouraging a user to engage simple physical activities; combining web-based gamification and physical nudges with an app (MoveMore) to promote walking breaks and reduce sedentary behaviour of office workers; work office design to increase comfort, restoration and social cohesion; social support (nonverbal cues such as kudos or likes) and motivational messaging to increase participation in the corporate wellness programme, etc. |
| **Improving employees' communication and performance** | social norms informing what majority of peers do and building on common forms of social influence in organisations: social cohesion (proximity), institutional isomorphism (similarity of positions in terms of business function and location), and hierarchical power; gamified social badges; digital workflow tool, collective foresight radar, topic campaigns and curation utilising a set of nudges such as: simplification, defaults, salience, commitments, etc.; framing - embedding the right reference point within communications; motivational posters and stickers to encourage alertness to good practice, requirements to confirm the commitment to the professional code of practice when logging-in and wanting to use the data base; self-tracking applications that rely on analytics enhanced by machine learning to inform, target and optimise employees' work habits |
| **Safety-related behaviours and reducing littering at work** | point-of-decision prompts to counteract forgetting, social norms, a wearable proximity-detection technology; priming nudge in the form of decals depicting golden coins placed on the production floors to encourage workers to throw waste in trash bins rather than on the floor |

Cont. table 3.

| | |
|---|---|
| **Promoting pro-environmental behaviours** | "moral appeal" nudges, i.e. messages stressing the responsible use of energy, the "social comparison" nudges which informs employees on the energy consumption of other peer firms, visual prompts in the form of stickers and posters that provide information on everyday actions that might reduce the individual and overall energy consumption of the company; default setting - programming devices to automatically switch off after a period of non-activity, changing the default printer settings to double-sided printing |

Source: Own elaboration based on the literature review.

The third category includes studies of using nudges to promote workplace safety-related behaviours. Frequently they are designed to support users' situational awareness and have a form of just-in-time prompts, i.e. notifications that are timed to be pushed or displayed based on certain activity or inactivity, because peoples' attention is limited and easily distracted. Dewies et al. (2021) tested two nudge techniques to increase compliance of employees of a Dutch local government department with a policy to wear an identifying lanyard with their employee badge for a security reasons. The first nudge was a point-of-decision prompt that served to counteract forgetting to wear the lanyard. It had a form of stickers with an image of a person wearing the lanyard and text saying "You're holding it already, now just wear it". The stickers were placed at all printers and access points to the department's office space as in this places employees needed to scan their badges. The second nudge was meant to raise awareness of security norms. For this purpose, mirrors with a life-size print of the lanyard on it were placed at the department's office space. Observing oneself in a mirror is a typical manipulation to increase awareness of oneself. The study of Zetterholm et al. (2022), in turn, is a good example how technology and digital nudges can counteract human attentional deficits. They tested a wearable proximity-detection technology to nudge employees to maintain physical distance from others during the COVID-19 Pandemic. A dual nudge was used that involves vibration followed by sound to encourage immediate action when the distance to others is not maintained. However, proximity-based warning systems can be used in the workplace for other purposes as well, in particular, in dangerous working environments such as construction sites, or manufacturing plants. On the different note, Wu and Paluck (2021) conducted a field experiment in a Chinese workplace to test the effectiveness of the priming nudge in the form of decals depicting golden coins placed on the production floors to encourage workers to throw waste in trash bins rather than on the floor.

Finally, nudges in the workplace are used to promote pro-environmental behaviour, in particular to promote employees' energy conservation and reduction of paper waste. Charlier et al. (2021) tested three types of nudges to lower energy consumption: the "moral appeal" nudge – e-mail messages stressing the responsible use of energy, the "social comparison" nudge which informs employees on the energy consumption of other peer firms, and visual prompts in the form of stickers that, in a funny way, provided information on several everyday actions that might reduce the individual and overall energy consumption of the company. Their research provides insights into complementarity of different nudges applied to lower energy use in the

workplace. When nudges were implemented alone, there was no significant effect on employees' behaviour. However, when the moral appeal and social comparison nudges were combined with visual prompts, they became effective. The reason for it lies presumable in it that the first two nudges rise employee's awareness, while the third one – provides information necessary to act and plays a role of a reminder to improve energy conservation. There is also evidence to attest the fact that default settings and relying on peoples' inertia are effective strategies in environmental conservation programmes. Programming devices to automatically switch off after a period of non-activity can lead to significant energy reduction (Staddon et al., 2016, as cited in Venema, Van Gestel, 2021). Reducing paper waste – is another pro-environmental behaviour targeted in the workplace. Egebark and Ekström, (2016, as cited in Venema, Van Gestel, 2021), compared the effects of two nudges to influence paper use among university employees. Contrary to initial expectations moral appeal nudge - a message asking university employees to cut back on printing and to use double-sided printing whenever possible had no effect while reduction in paper waste has been achieved thanks to changing the default printer settings to double-sided printing. Comparing the two conservation programmes, the injunctive social norm and default – they pointed at the latter alternative as the most promising in resource conservation initiatives. However, Chakravarty and Mishra (2019) examined effects of injunctive social norms on paper use in two information technology firms in India. In this field experiment posters asking individuals to use less paper were placed on printers and in office cubicles. They found out that during the intervention, employees spent a significantly lower number of sheets per day as compared to the pre-intervention period, measured both in terms of paper used and paper wasted. Moreover, the positive effect lasted over several weeks after the nudge had been removed. De Figueiredo et al. (2021, p. 206) take a somewhat broader perspective on sustainable consumption in the workplace, where individual behaviour is a result of a situated learning – human interactions and intentional material arrangements introduced in the work environment that nudge sustainable energy consumption. As they report: 'the material elements' content became part of the employees' routine over time, changing from simple reminders to become incorporated into practices".

### 4.2. Factors influencing the effectiveness of nudging in the workplace

In most of the studies under review positive effects of nudging in the workplace are reported, although their effectiveness varies. There were also instances of null effects and even backfiring, i.e. where nudges generated behavioural changes in the opposite direction of what was intended (e.g. Dewies 2021; Avitsland et al., 2017; Willson et al., 2015). This begs the question on factors that influence the effectiveness of nudging. Based on the conducted literature review three main factors influencing effectiveness of nudging in the workplace can be identified: (1) starting dispositions of individuals whose behaviour is aimed to be changed, (their attitudes, habits and intentions) (2) situational factors which may interact with the selected nudges, and (3) cultural differences.

Few empirical studies found that individual factors such as strong attitudes, habits and intentions affect the effectiveness of nudging interventions. There is evidence that unsupportive attitudes towards a given policy can cause nudges to be ineffective when applied alone. Nudging strategy used to increase compliance with a security policy requiring employees to wear a lanyard with their employee badge attached to it turned out to be ineffective because of the negative attitude of Dutch local government employees towards nudges which were considered as unnecessary and paternalistic. A substantial group of employees believed that wearing an identifying lanyard separated them from peers working for other departments who did not need to wear it and that this security measure was unnecessary. First, because they can recognize all employees even without the lanyard and secondly, the requirement to scan one's badge to get access to the department's office area was deemed as sufficient protection. Adding to it a lack of personal consequences (sanctions) for not complying the lanyard policy led to the nudging strategy failure (Dewies et al, 2021). It is argued that nudges are particularly effective when there are no clear preferences for a particular choice option or there are conflicting preferences. Then environmental cues can tip the scale in favour of one of the options and thereby reduce the conflict (Venema, Van Gestel, 2021; Venema et al., 2020). Intervention promoting workplace stair-climbing with stair leading footprints and stair-riser banners in the study of Avitsland et al (2017) resulted in significant decreases in stair climbing. It is assumed that the intervention failure was due to a pre-existing high amount of stair climbing and irritation among some employees. The authors point out: "In this case, the influence was telling people to do something they were already doing, which seems to have been interpreted as nagging, and resulted in spiteful behaviour" (p. 8). Kissmer et al. (2018) proposed a model to analyse digital nudging acceptance by employees. Next to intervention factors, such as the perceived nudge intensity and tailoring (personalisation), they incorporated into the model the following individual factors that influence the success or failure of digital nudges: consensus (how far an individual does as other people do), authority (how far an individual value the opinion of experts, superiors), autonomy (the degree of self-congruence, interest-taking and susceptibility of control) and technological commitment (how an individual experiences and is confident with technology).

Secondly, it is claimed in the literature (Belimi, Schroeder, 2021; Wilson et al., 2011), that people might behave differently in the workplace than in their domestic environment. Hence, the effectiveness of the nudges that are targeted at individual decision-making can be affected by situational factors. In the corporate context we tackle the problem of identity and diffused responsibility. For example, while at work employees may not translate their pro-environmental behaviours, in terms of energy use, recycling practices etc. at home to the office. McDonalds (2011, cited in Michaels, Powell, 2017) while comparing the recycling rates at home and in the workplace found out that people tend to recycle more at home than at work because they do not feel to blame for not recycling and shift the responsibility for recycling to the employer. They are also not the ones that pay energy bills and typically are not directly

responsible for the company's environmental impact. Being only a part of a bigger whole employees do not see the consequences of their own actions. Moreover, there are situational moderating variables that may interact with the selected nudges. For example in the study of Cooley et al. (2022, pp. 574-575) office-based workers were interviewed to gain an understanding of their experiences of being exposed to nudges suggesting alternative behaviours of prolong sitting and taking movements breaks during work periods. The participants felt uneasy because their increased self- and others- monitoring of their alternative behaviour and cited many "maladaptive feelings because of a perception of incongruency with the established work normative behaviour". Social nature of offices and many workplaces requires an approach at the level of social practices and organisational routines, that take into account social influence and interdependency of actions carried out by multiple actors. For example, the study of de Figueiredo et al. (2020) focuses on the workplace as a rich environment where social learning is not limited to individuals but is also rooted in the community of practitioners at an organizational level. On a related note, Walker and Flanney (2019) and Baskin et al. (2016) addressed in their study the so-called office cake culture and providing by employers free snacks at the office to bolster employee satisfaction. As it undeniable can negatively affect employees health and contribute to weight gain, it plays also a positive role in the workplace by bringing people together, integrating teams and is generally considered to have morale-boosting characteristics. Their findings suggest that nudge-based initiatives such as reducing salience of snacks and creating new social norm to gain acceptance that the snacks' access will be restricted to limited occasions to which employees can look forward (Walker, Flanney, 2019), or simply increasing the relative distance between snacks and beverages (Baskin et al., 2016) can help employees make healthier food choices while retaining social benefits and employees' satisfaction.

Finally, these are cultural differences that influence effectiveness of nudges when implemented in a particular setting. In China, for example, far greater importance is attached to items that evoke a sense of honour and prestige. While implementing nudge interventions this cultural trait should be taking into account, for instance in food labelling to increase salience of healthy food options (Gavrieli et al., 2022). In the study of Wu and Paluck (2021) Chinese belief in golden coins as protecting fortune and luck was used to design nudge intervention in the form of decals depicting golden coins which were placed on the production floor to encourage Chinese workers to throw waste in trash bins rather than on the floor. Given the existing cultural differences the nudge presumably would not be that effective in different settings.

## 5. Conclusions and directions for further research

Conducted literature review confirms the fact that nudging inside companies is still an emerging research topic in business management that deserves further attention. The problems with establishing the state of research on nudging in the workplace arise from differences in how nudges are defined, as well as the lack of established method for systematical validation and evaluation of their effectiveness in the corporate context. In particular, long-term studies that analyse habituation and behavioural changes beyond the intervention period are missing, as well as the potential of digital and mixed approaches is not yet fully exploited.

With regard to the three research questions that guided our literature review, the following conclusions can be drawn. First, when nudges are implemented in the corporate context they are most frequently used to influence the following workplace behaviours: (1) improving employees' health and wellbeing, in particular by increasing employees' healthy food choices in workplace canteens as well as by promoting physical activity and reducing sedentary behaviour in the workplace; (2) improving employees' communication and performance, in particular to promote knowledge sharing in an organisation; (3) ensuring safety culture at work, in particular to support users' situational awareness; as well as (4) promoting pro-environmental behaviours, in particular to encourage employees' energy conservation and reduction of paper waste. Secondly, as for the nudge types used to influence the above mentioned workplace behaviour the following key nudges are worth mentioning as the most promising for managerial applications: descriptive social norms to encourage employees to knowledge sharing and re-use, reminders - to reduce sedentary behaviour in the workplace or ensure safety culture at work, and defaults in corporate conservation programmes. Descriptive social norms encourage desired behaviours by indicating what others (peers) do and capitalising on peoples' desire to fit in with others. Finding the right reference group is crucial for the effectiveness of social norms. In the corporate context – these can be those similar in terms of business function, position, or location (e.g. Kretzer, Maedche, 2018). Reminders are nudges that counteract peoples' attentional limitations and simply cause someone to remember something using different modes of communications, e.g. e-mails, text messages, making sounds. The timing and the message of a reminder are two crucial factors for its effectiveness. Finally, defaults – play on the peoples' tendency to status quo and have many various applications in the workplace. Default options are pre-set courses of action that come into being as long as the decision-maker actively decides otherwise. Defaults are effective in influencing behaviour when there is inertia or uncertainty in decision making. In this latter case, they may be perceived as a recommended course of action. The third question that guided our research pertains the overall factors that affect effectiveness of nudging approach in the workplace. Based on the conducted literature review the following three factors can be identified. First, these are starting dispositions of individuals whose behaviour is aimed to be changed,

i.e. their attitudes, habits and intentions. Preferably, when there are no clear preferences for a particular choice option or there are conflicting preferences. Therefore, researchers and practitioners are advised to survey and reflect on target group's attitudes and preferences before implementing nudge interventions. Secondly, these are situational factors which may interact with the selected nudges. Nudging in the workplace is different than nudging people's domestic and private lives and experiences gained in these settings cannot be simply transposed to workplace setting. This is because of the identity problem and diffused responsibility. As a consequence, employees need to have a sense of ownership of organisational changes. Just providing them information or incentives may not be enough. Moreover, social nature of many workplaces requires an approach at the level of social practices and organisational routines, which take into account social influence and interdependency of actions carried out by multiple actors. Thirdly, these are cultural variances that affect the effectiveness of nudges. It is argued that cognitive biases which are exploited in nudging approach interact with culturally variable features. Cultures may be more or less susceptible to certain biases. Moreover, biases may conflict with one another and how the conflict is resolved may be culturally dependent (Bovens, 2010). For example, people are driven by the desire for conformity as well as to stand out. Some cultures may value the former at the expense of the latter (the so-called collectivist cultures, such as Mexico or Turkey), and vice versa (individualistic cultures, such as the US or the UK). Hence, nudging requires a keen awareness of the culture .

On a final note, technology advancement opens up new avenues for nudging application in the workplace. Extending the concept of nudging to the digital environment and research on the behavioural effects of interface-design decisions on user' behaviour is a very promising agenda for future research. The technology-mediated nudges allow for a more personalised, well-timed approach. It is also worth mentioning that digital nudging is one out of five key trends recognised by the Communications Trend Radar 2021 - the study which every year identifies key trends in the areas of management, technology and society, i.e. trends that will change corporate communications. Nevertheless, these developments are not free from legal and ethical concerns that should be addressed in the context of self-tracking applications, automated decision-support systems and economy increasingly dominated by artificial intelligence. Nudges that are transparent and promoting reflective (versus automatic) thinking are considered to be the least objectionable.

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# FINANCIAL AND NON-FINANCIAL MOTIVATION OF MANAGERS

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**Purpose:** Appropriate motivation of managers is an important element in achieving the intended financial results of the organization and the implementation of its strategy. The aim of the study was to assess the existing financial and non-financial system of managers employed in the chemical industry and their expectations.
**Design/methodology/approach**: The research was aimed at finding out which elements of motivation are best perceived by managers and what additional elements are worth applying to achieve better efficiency in their work. The study used purposive sampling, the respondents were representatives of the management staff at both the chief executive level as well as directors and managers. The research tool was a questionnaire.
**Findings:** Managers pointed out that the most common component of variable remuneration is the bonus (95%), which depends on the results of their work. In terms of salary supplements, medical care is the most valued. However, the factor that most motivates most to work is a stable income and job security.
**Research limitations/implications:** The analysis is based on respondents' subjective declarations.
**Practical implications:** Those in charge in the organization should be aware of the needs and expectations of managers in terms of financial and non-financial elements of remuneration that affect the level of their motivation to work.
**Social implications:** An analysis of managers' needs and expectations regarding financial and non-financial motivators especially in the chemical industry can be the basis for building or optimizing these systems in the organization.
**Originality/value:** the research results presented are related to the motivation of managers in the chemical industry – there are only very few publications on this topic.

**Keywords:** motivating**,** financial elements of motivating, non-financial elements of motivating, motivating managers.

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

## 1. Introduction

Motivation in the organization is an impact on employees, including managers, focused on creating higher work efficiency and shaping such attitudes and behaviors that the employer and managers care about on his behalf (Oleksyn, 2014). It is particularly important to motivate managers to achieve higher results thanks to their work related to team management. Various incentives are used to motivate. Their role is not only to evoke interest in the desired behavior, but to serve as an instrument for modifying and shaping desired behaviors and their patterns by controlling the environment, not by directly changing employees' attitudes and value systems. According to the theory of reinforcement, rewarding such behaviors increases the likelihood of their repetition in the future (Borkowska, 2006). There is a variety of these stimuli, external and internal, which can be material and immaterial. They can also be agreed individually or prepared for individual professional groups, including managers. Therefore, an effective system for motivating managers should include an appropriate component and remuneration. The aim of the study was to assess the existing financial and non-financial system of managers employed in the chemical industry and their expectations.

## 2. The essence of motivation for managers

Motivation is a human desire, and it is impossible to separate the two states. They are always strongly intertwined (Kopertyńska, 2009, pp. 17-18). Through this, three levels of motivation can be distinguished (Sroka, 2017):

- subordination – employees carry out the orders of the supervisor, as if they themselves did not have enough knowledge in a given topic and could not do something themselves,
- goal identification: the desire for a goal arises and in order to achieve it, employees must clearly define the benefits of their actions,
- commitment: at this level, the employee also has a specific goal and must understand that they themselves are primarily responsible for achieving it and, as a result, must perform their work properly.

At the same time, there are rules of employee behavior modeling, which are reflected in motivational systems (Kazuś, Firek, 2019):

- do not reward everyone equally, use rewards for above-average performance; equal rewards for all reinforce poor or mediocre performance and ignore outstanding ones,
- remember that failure to respond can modify both inappropriate and appropriate behaviors from the organization's point of view; For example, not recognizing successes and above-average results can lead to significantly weaker performance from that individual in the future,
- equip employees with knowledge of what they can do to increase their effectiveness, provide clear and concise criteria and measures of effectiveness that enable them to understand what they need to do to be well evaluated and receive a "reward",
- inform employees about what they are doing wrong,
- Do not punish in the presence of others – publicly admonishing an employee is humiliating and can cause resentment towards the management from the punished individual and other group members.

On the other hand, the effectiveness of remuneration can be assessed in terms of (Juchnowicz, 2011):

- the extent to which key objectives of remuneration systems in the organization are met, including the acquisition and retention of key employees and their effective engagement in work and the organization,
- the fulfilment of traditional remuneration functions: income, cost, motivational and social,
- contributing to the achievement of the company's strategic goals.

The indications outlined above also apply to managers at various levels of management. The importance of the motivating function was pointed out by L. Iacocca, who stated that management is nothing more than the ability to motivate people, emphasizing the fact that managers should be not only decision-makers, but also inspirers capable of motivating subordinates (Zelga, 2018). Understanding motivation — what triggers, directs, and sustains human behavior — has always been important to organizational leaders because they work with and through people (Kazuś, Firek, 2019). In this context, when designing motivation systems, it is important to recognize the needs of the managers, their leadership qualities and to match these elements with specific theories of motivation that will allow for a better alignment of financial and non-financial packages for each manager (Stańczyk, 2018). Therefore, there are many factors that affect the shape of the remuneration system for managers. They can be divided into three basic categories (Pocztowski, 2018):

- characteristics of managers, particularly their competencies and motivation, as well as the values they uphold,
- characteristics of the organization, including its size, industry, the technology used, strategy, structure, and organizational culture,
- characteristics of the environment, created by economic, political, legal, technological, socio-cultural conditions.

In the era of Industry 4.0, competences are of particular importance for the organization because they are built on the basis of the competences of the managerial staff, especially through teamwork based on creativity, imagination, and creative output of managers, which requires an appropriate level of motivation (Kuźniarska, 2022).

According to Pocztowski (2018), the components of managers' compensation include fixed remuneration (financial and benefits), variable remuneration (bonuses, rewards, profit sharing), and deferred remuneration (shares, stock options, pension plans, insurance, savings) (Pocztowski, 2018). Salary incentives are mainly aimed at satisfying the basic needs of employees and their families. On the other hand, non-wage elements make work a source of satisfaction and an opportunity for personality development (Kopertyńska, 2011). The attractiveness of financial incentives is determined by the correlation between effort and wage and the purchasing power of that wage. Financial incentives are divided into two subgroups (Sekuła, 2008, pp. 186-187):

- fixed – there are relatively stable remuneration rules that provide the employee with a fairly equal level of income in each period (months); they are characterized by a high degree of certainty of receiving the reward,
- variable – they depend on the variability of conditions and the reasons for which the employee may be entitled to such remuneration.

Fixed remuneration is most important as a stabilizing element, and variable remuneration primarily serves as a motivating factor to achieve current goals and indirectly generate profits. Non-financial remuneration, on the other hand, is a kind of indicator of a manager's importance in the organization, satisfying their need for recognition and strengthening their sense of self-worth, which plays a significant role in this professional group (Pocztowski, 2018). However, as emphasized by K. Raźniewski, a director in the Human Capital team of EY Poland, a manager needs a considerable amount of self-motivation, perseverance, and a sense of mission to be effective (Koc, 2015). Interesting examples of non-financial remuneration for managers include (Beck-Krala, 2010):

- competence development programs, which are designed to help develop professional skills - mainly hard skills,
- talent management programs, which are designed for employees who demonstrate leadership qualities - known as Talent Management,
- individual development programs – managerial coaching, which focuses on the individual development of a manager's competences,
- Business Academy, which are designed to prepare managers to achieve the company's goals and strategies,
- language training, which is offered to a larger scale for managers.

According to a study by Bigram, Legg Mason and Wolters Kluwer, the biggest motivator for managers is money. As many as 69% of respondents put the basic salary in the first place. Flexible employment and monetary bonuses and incentives tied for second place. The third most popular motivating factor for managers is non-financial benefits (Koc, 2015). According to information provided by Bigram, "unlike managers in the West, Polish executives approach bonuses and commissions with caution, they value stability and "certainty" of remuneration much more" (Bigram, 2022).

## 3. Research methodology

The aim of the study was to assess the existing financial and non-financial system of managers employed in the chemical industry and their expectations. The study used purposive sampling, with the respondents being representatives of the managerial staff, including top-level executives, directors, and managers. When analyzing the respondent profile, the main criterion considered was seniority, and some of the results were presented in correlation to it. This allowed for the evaluation of the substantive assessment of the responses. It was assumed that seniority may affect the expectations and assessment of the incentive system. The research was conducted between 2021-2022.

The research tool used was a survey questionnaire consisting of 5 scaled questions (Taherdoost, 2019) and one metric question related to seniority. The tool was prepared based on a questionnaire used by M. Armstrong and A. Cummins (Armstrong, Cummins, 2015). The survey is considered to be the basic tool for assessing knowledge, attitudes and practices in a specific topic, and it comprises a set of predefined questions based on the research objective (Sharma, 2022).

## 4. Analysis of research results

The study involved 39 managers with varying lengths of service as described below:

1. 0-10 years – 14 managers (36%),
2. 11 -20 years – 12 managers (31%),
3. over20 years – 13 managers (33%).

Before evaluating the incentive system, respondents were asked to indicate the frequency of receiving selected components of remuneration (see fig. 1).

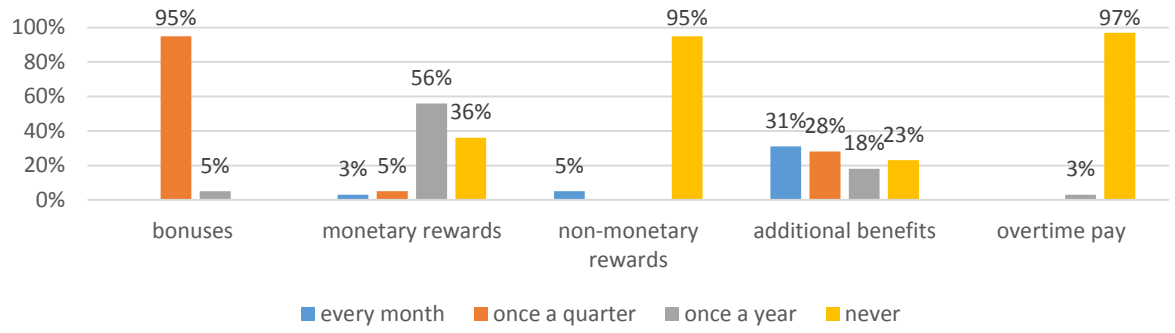


**Figure 1.** Frequency of occurrence of remuneration components.

Source: own elaboration based on research results.

Respondents indicated that only a few receive additional benefits every month (31%), material rewards (5%) and cash rewards (3%). The most commonly used motivational element for executives in the organization is the quarterly bonus (95%), while material rewards (95%) and overtime pay (97%) are not typically offered.

Subsequently, the respondents were asked to comment on claims regarding the company's current bonus system. Figure 2 presents the structure of their responses calculated as an average, where: 1 means – Strongly disagree; 2 – Disagree; 3 – No opinion; 4 - Agree; 5 – Strongly agree.

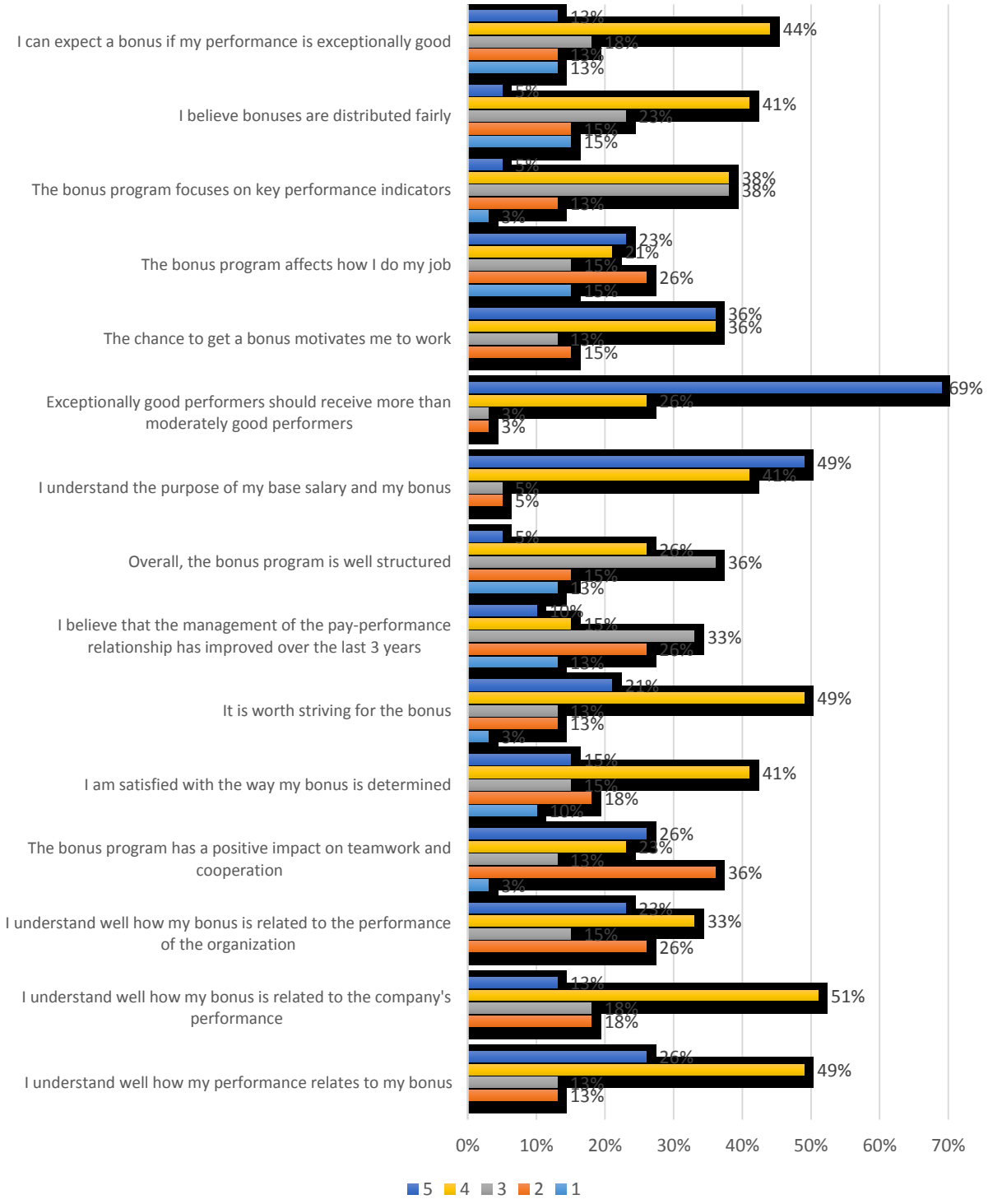


**Figure 2.** Evaluation of the current bonus system.

Source: own elaboration based on research results.

In the current bonus system, respondents rated the distribution of performance-based bonuses highest (69% of respondents) and declared they understood this type of activities (49%). Half of them declared they understood the functions performed by fixed and variable remuneration (49%). The linking of the bonus amount to the company's results (51%) as well as the need to make efforts to obtain it (49%) were positively evaluated. The bonus was

a motivating factor for 72% of respondents, and 46% believed that the distribution of the bonus is fair. Interestingly, in total, only 31% of them positively assessed the bonus program, and 39% believed that it did not have a positive impact on teamwork and cooperation.

Subsequently, the results were subjected to a correlation analysis with respect to seniority.

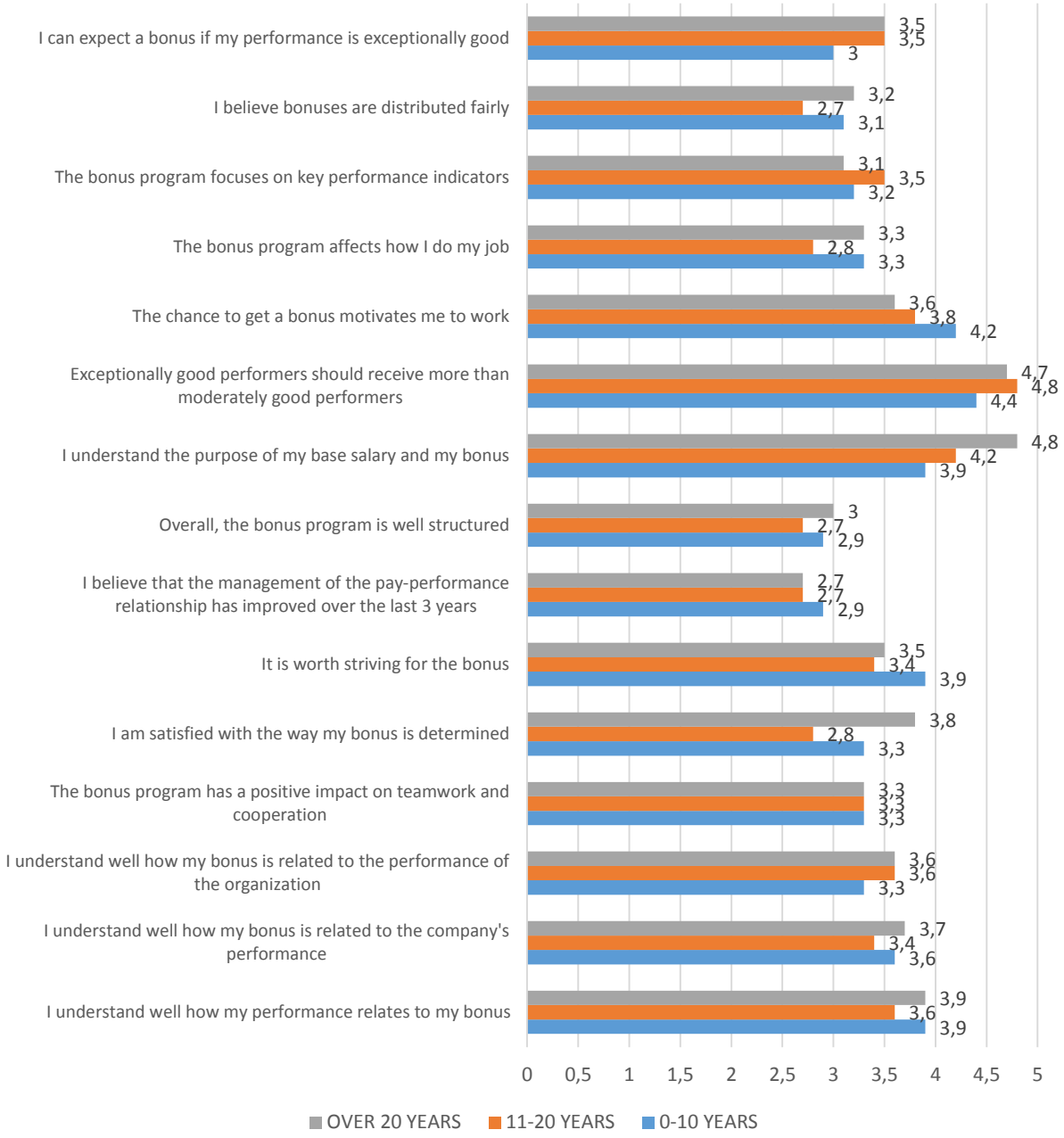


**Figure 3.** Assessment of the current bonus system in correlation to seniority.

Source: own elaboration based on research results.

To compare the expectations of managers depending on seniority, the Kruskal-Wallis ANOVA test was used. In all tests performed, a significance level of $p < 0.05$ was assumed (Kruskal, Wallis, 1952).

On the basis of the test, one important difference was found – regarding the understanding of what the basic salary is for, and what the bonus is for, depending on seniority. People with more than 20 years of experience show significantly greater understanding than people with 0-10 years of experience. In other cases, no significant differences were observed.

In the next stage, respondents were asked to compare the importance of the salary supplements they received. To this end, they were asked to assign a score up to a maximum of 100 points to be distributed among the benefits. The average number of points for each benefit is shown in Figure 4.

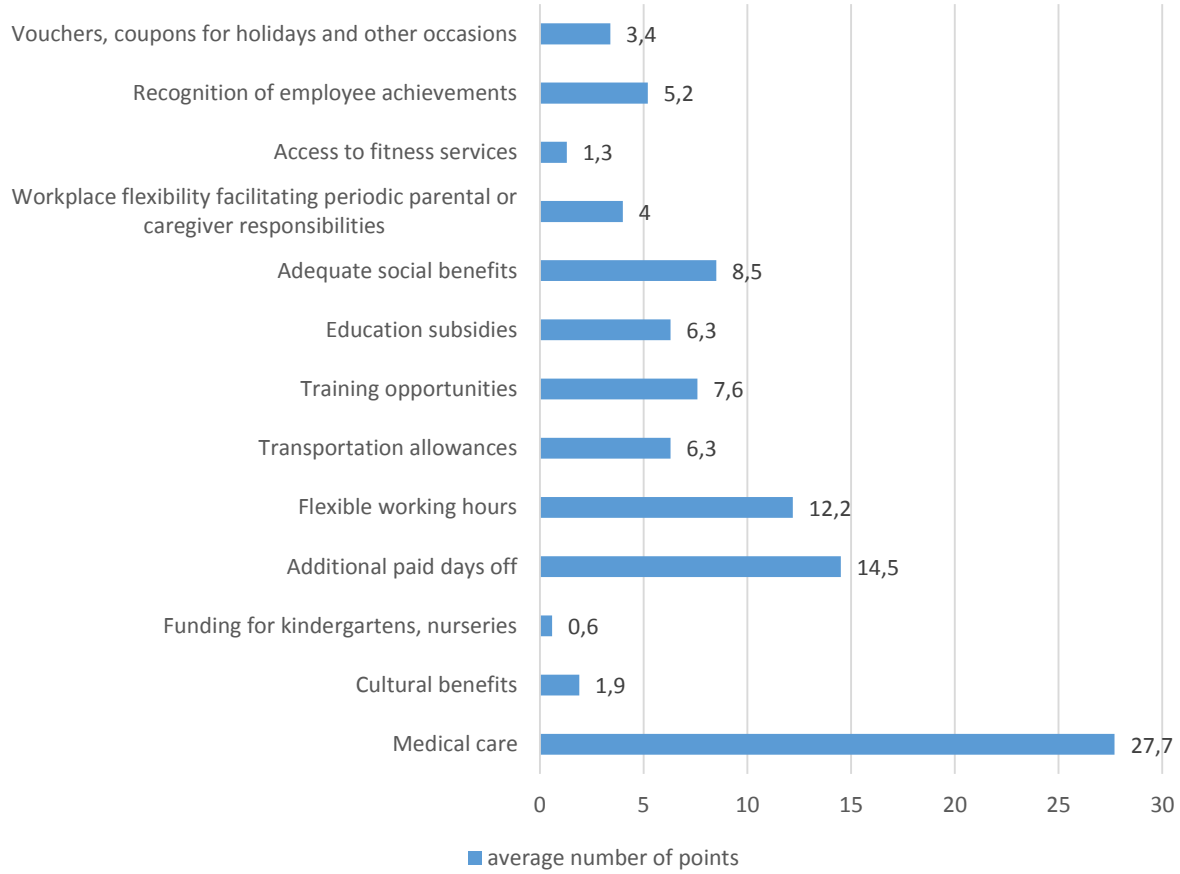


**Figure 4.** Assessment of the importance of salary supplements.

Source: own elaboration based on research results.

Managers rated the importance of medical care the highest (an average of 27.7 points out of 100), followed by additional paid days off (14.5 points) and flexible working hours (12.2 points). Subsequently, the importance of benefits was assessed based on seniority.

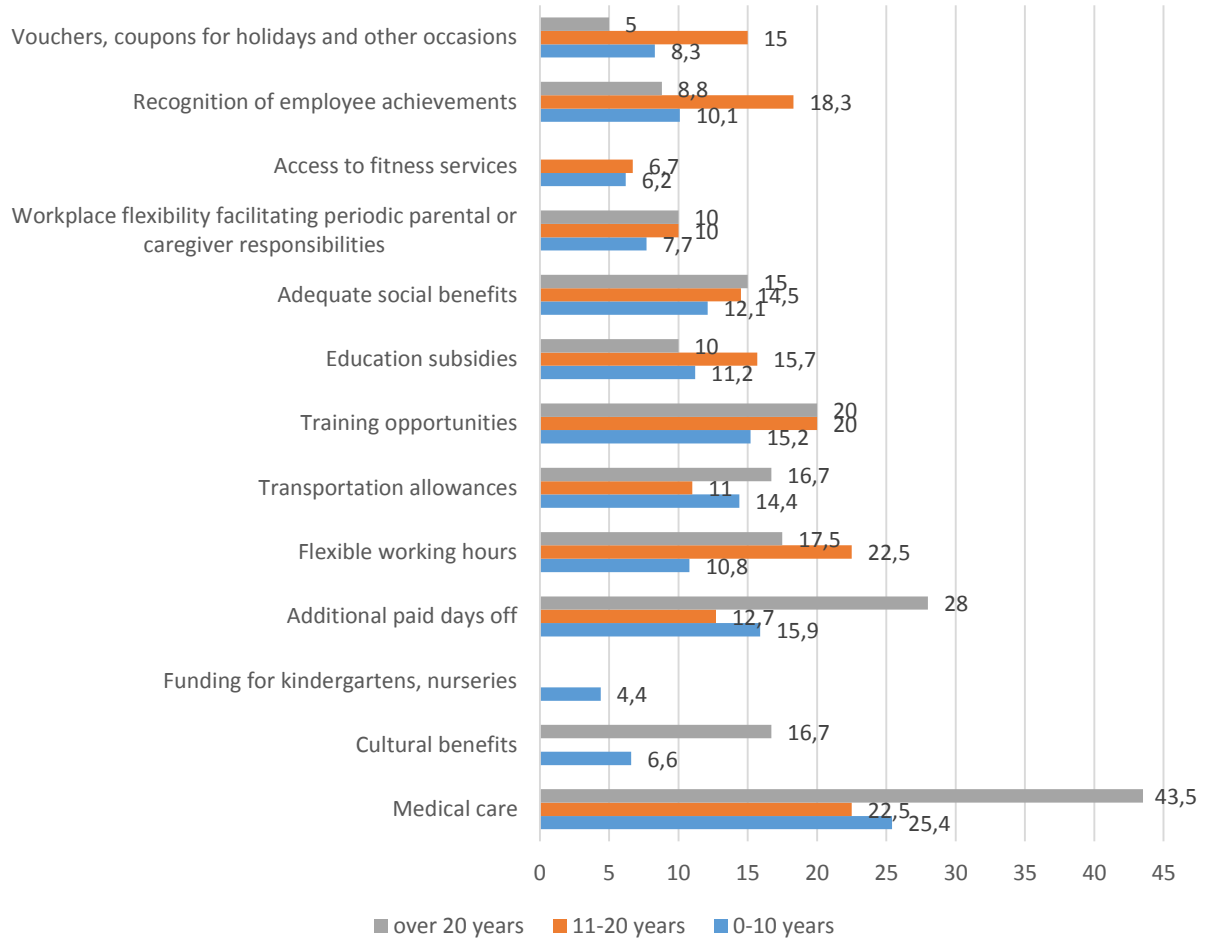


**Figure 5.** Assessment of salary supplements in correlation to seniority.

Source: own elaboration based on research results.

On the basis of the test carried out, the following significant differences were found depending on the length of service:

1. Managers with more than 20 years of service significantly rated medical care (43 points compared to 25.4 points for those with up to 10 years of work experience and 22.5 points for those with 11-20 years of work experience).
2. Financing of kindergartens, nurseries - only managers with 0-10 years of work experience selected this option.
3. Additional paid days off - managers with work experience of over 20 years significantly rated this benefit higher than those 11-20 years of work experience.
4. There was a significant difference in the assessment of the importance of flexible working hours depending on seniority. Individuals with work experience over 11-20 years significantly rated this benefit higher than those with a work experience of 0-10 years.

In the next stage, managers were asked what motivates them to work. The rating was made on a scale of 1 to 5, with 1 being the least important and 5 being the most important. The results are presented in Figure 6.

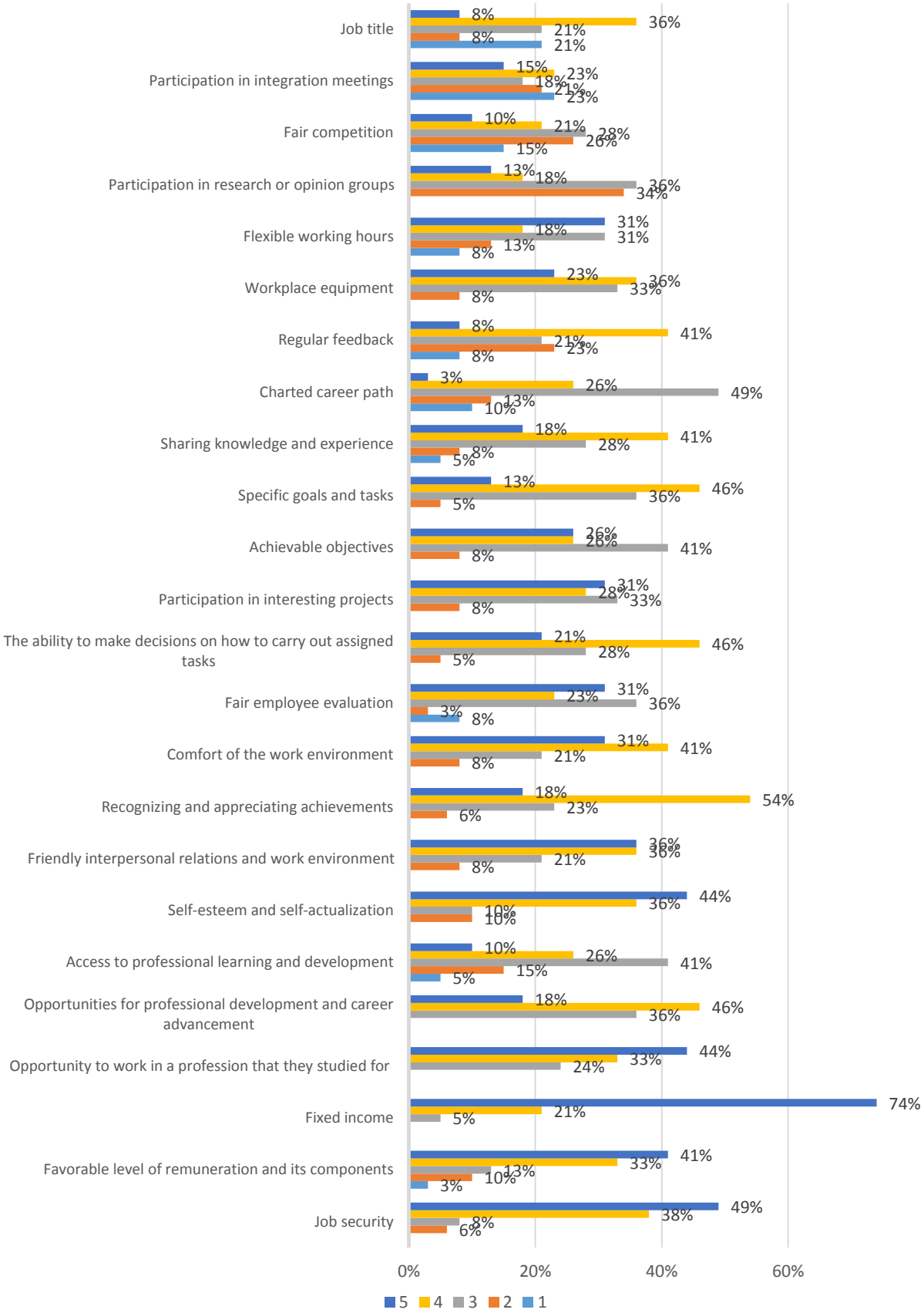


**Figure 6.** Assessment of the elements of motivation of managers.

Source: own elaboration based on research results.

Among surveyed managers, fixed income (74%), job security (49%), opportunity for self-fulfillment and working in a profession that they studied for (44% each), and a favorable level of remuneration (41%) were rated the highest (rated 5 on the scale) as elements of their motivation. Interestingly, integration trips (44%), fair competition (41%), and participation in research or opinion groups (34%) received relatively low ratings (i.e., level 1 or 2 overall). In the opinion of 49% of respondents, career paths were not considered to be a significantly important element of motivation.

The results indicate the importance of monetary factors in motivating this professional group.

Respondents were also asked about the elements of work that should be taken into account when awarding bonuses to managers. Figure 7 presents the structure of their responses calculated as an average, where 1 is the least important, 5 is the most important.

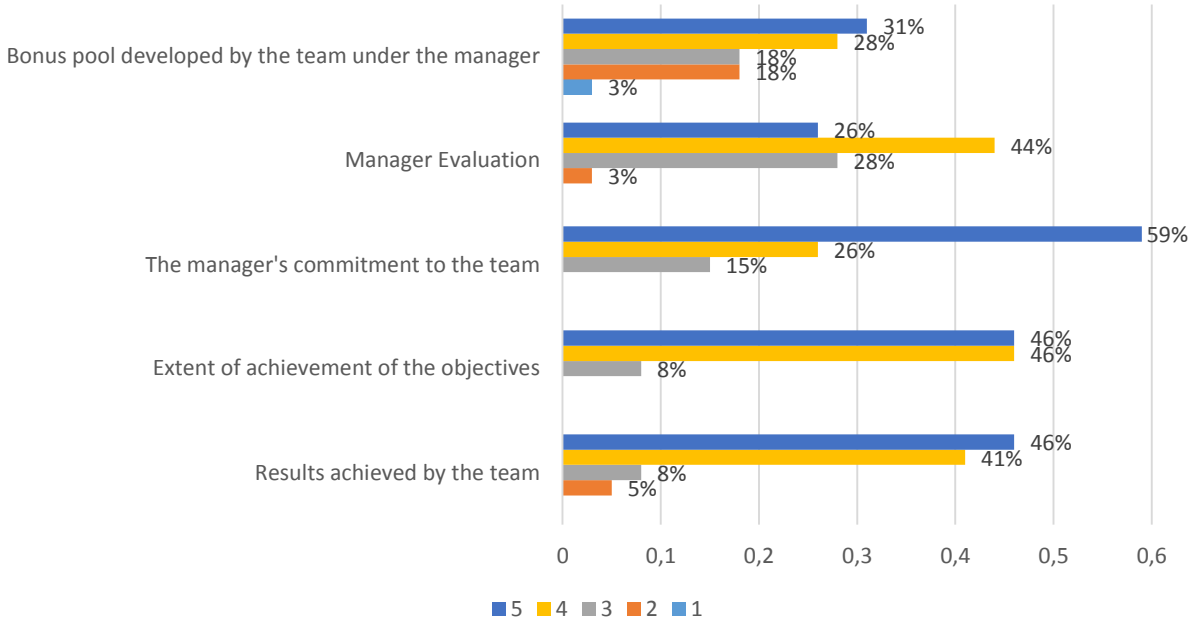


**Figure 7.** Assessment of factors influencing the awarding of the manager's bonus.
Source: own elaboration based on research results.

59% of respondents indicated that commitment to the team should be the most important factor in awarding a bonus to a manager, while slightly fewer respondents, 46% each, considered results achieved and the degree to which goals were met, to be important.

## 5. Summary

The use of both financial and non-financial elements in motivating managers is crucial for the organization to achieve their intended goals. The presented research demonstrates a clear

specificity of the components used for organizations in the chemical industry. It is worth noting the timing of the conducted research, which was during the COVID-19 pandemic. This was an important aspect and contributed to the the results of the research. Managers who provided responses highly value the level of remuneration they receive regularly, which is also related to maintaining their job security. Having access to additional medical care, especially during the turbulent pandemic period, was also found to be significant. One of the important findings of the research is the need to obtain information regarding the factors that influence the allocation of bonuses for managers. Respondents pointed out that the reward should reflect their own contribution to the team's work. As for the limitations of the presented research, a shortcoming that should be pointed out is that the questionnaire used as a tool presents a subjective declaration of the respondents. In identifying directions for further research, attention should be paid to the size of the studied group. The results presented here relate to a single company in the chemical industry. This may serve as a benchmark for other organizations, but it is worthwhile to extend the research to other industries and then compare the conditions of financial and non-financial motivation in different types of organizations.

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# ARTIFICIAL INTELLIGENCE IN THE CHEMICAL INDUSTRY – RISKS AND OPPORTUNITIES

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**Purpose:** The aim of the article is to review the literature on the risks and opportunities of implementing Industry 4.0 - Artificial Intelligence solutions in the chemical industry.
**Design/methodology/approach:** The review was carried out using available scientific articles, popular science publications, and media reports from the world's largest companies in the chemical industry.
**Findings:** The analysis indicates that there are more benefits than risks arising from the implementation of Artificial Intelligence solutions in the chemical industry.
**Research limitations/implications:** The frequent lack of specific economic indicators makes it difficult to clearly indicate the implementation potential of a specific solution in other companies in the chemical industry.
**Social implications:** The implementation of AI in chemical industry companies can reduce environmental pollution, raw material consumption, and optimize production processes.
**Originality/value:** The article, based on real data, is aimed at middle and senior management of companies in the chemical industry, presenting the advantages and disadvantages of implementing AI solutions in the chemical industry.

**Keywords:** AI, Chemical Industry, Machine Learning, Risks, Opportunities.

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

## 1. Introduction

Over 80% of managers in the chemical industry surveyed by IBM admit that artificial intelligence (AI) is going to have a huge impact on their business within the next three years. The areas in which AI is most commonly implemented in this sector are research and development (74%), production (61%), forecasting and planning (47%), and risk management (58%) (Lin et al., 2020). According to a survey conducted by Accenture (Accenture, 2014), 94% of managerial staff in the chemical and advanced materials industry expect the digitization

of the entire industry, and AI plays a crucial role in enabling the digital revolution (World Economic Forum, 2017). The latest technologies allow chemical companies to reduce operating costs, increase profits, and improve product quality. The chemical industry is increasingly interested in using AI to solve problems related to process modelling, optimization, control, as well as fault detection and diagnosis (Hajjar et al., 2016). This article reviews the methods of applying AI in the chemical industry and examines its potential for the sector.

## 2. AI applications in the chemical industry

The industrial sector has a significant impact on the global economy in the long term. In 2022, the size of the global chemicals market was valued at USD 616 billion. It is forecasted that this value will achieve an annual growth rate of 5.1% by 2030. However, recent events such as the outbreak of the Covid-19 pandemic and geopolitical tensions have had a negative impact on the development of this sector. Unstable energy prices, higher production costs, temporary closure of production plants, and numerous disruptions in the value chain of specialized chemicals have resulted in a periodic decline in production and demand (Market Analysis Report, 2022). The significance of the manufacturing sector for economic growth goes beyond direct production. The development of the industry translates into growth in other sectors of the economy, including job creation. A stable industry plays a crucial role, especially in situations of international trade downturns. Indeed, having a robust industrial sector helps to maintain economic security during crises (Development and Technology Ministry statement).

The recent climate, economic, and social changes have had an impact on the future of the global economy. Companies are focusing on efficient innovation acquisition and implementation to achieve defined goals in response to emerging challenges. In a report prepared by Innogy (2019), the authors identified three main megatrends that they believe will shape the future of the industrial sector. These include digital, climate, and organizational transformations. These areas have been singled out due to their relevance, universality, and multifaceted nature. One of the biggest challenges facing contemporary chemical companies is digital transformation. The current socio-economic situation makes it a sort of a business ultimatum, determining the survival of organizations in the market (Matt, Hess, Benlian, 2015). Due to its specificity, the chemical industry is characterized by a high degree of process automation.

Continuous investment in the development of innovative technologies is essential for companies to grow. One of the most rapidly developing fields is the artificial intelligence system and its application in production processes. According to the OECD, artificial intelligence is a machine-based system that influences the environment by formulating recommendations and predictions using input data from machines and humans (OECD, 2018).

In reports prepared by the European Commission, AI is defined as software systems designed and improved by humans, operating in a physical or digital dimension, collecting and analysing data to predict actions necessary to achieve a set goal. Analysing the concept of AI from the perspective of scientific disciplines, it covers areas such as machine learning (including deep and reinforcement learning), machine reasoning (referring to planning processes, knowledge implementation, search, optimization), as well as robotics (including control, perception, sensors, actuators, and the integration of other techniques used into cyber-physical systems). In practice, building an AI system is mainly done through machine learning. Intelligent devices, based on conclusions drawn from previous experiences, using a neural network composed of algorithmic networks, search for connections between variables and process accumulated data in a way that is similar to the human brain. Given the multitude of AI applications and the enormous potential associated with its widespread use, it is impossible not to appreciate the role it plays in the chemical industry. Figure 1 presents the main areas of chemical production where AI has found its application.

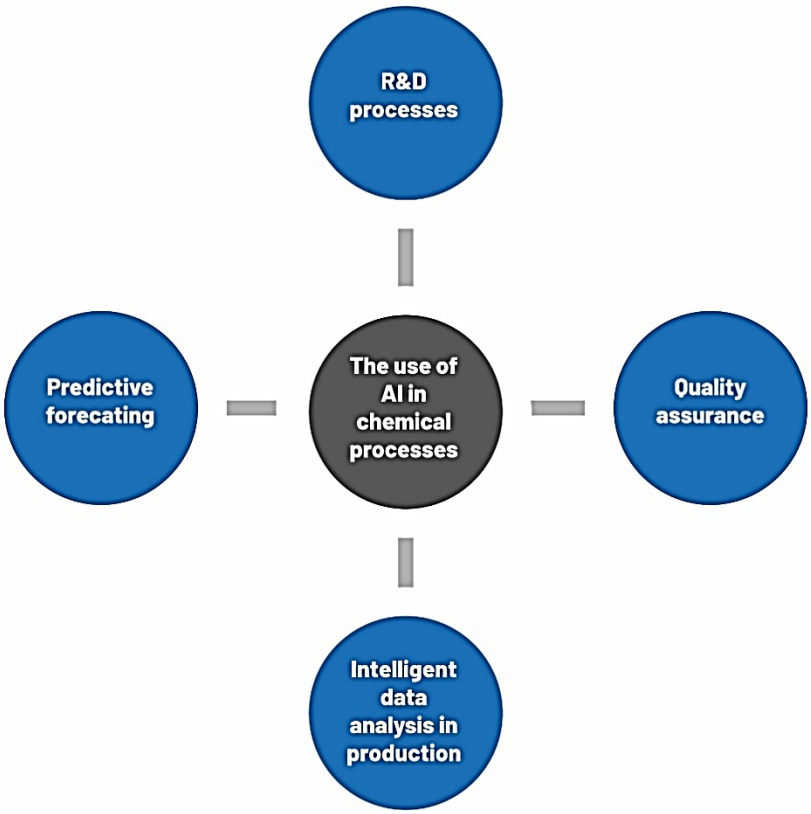


**Figure 1.** Examples of AI utilization in chemical processes.

Source: Own elaboration.

### 2.1. Solutions using artificial intelligence for research and development processes

Research and development play a fundamental role in industrial innovation, especially for companies related to sustainable development (Hájek, Stejskal, 2018). Artificial intelligence is used to predict and optimize chemical reactions (Marcou et al., 2015; Mohammadi, Penlidis, 2018; Zhou et al., 2017) and to improve the design of chemical synthesis (Segler et al., 2018). Machine learning has been investigated for screening research and catalyst design (Li et al., 2017; Li et al., 2017; Zahrt et al., 2019). Several studies have highlighted the potential of artificial intelligence in supporting the development of sustainable chemicals and materials (Doan et al., 2020; Gu et al., 2019). In addition to these technical aspects, one study examined the use of artificial neural networks to assess and improve job satisfaction in research laboratories (Azadeh et al., 2015).

### 2.2. Predictive Forecasting

Machine learning and artificial intelligence models, along with advanced analytics, help to predict the amount of raw materials needed to ensure continuity in chemical production and to determine future demand. AI forecasting leaves room for changes at every stage of the molecule's development. Artificial intelligence also helps to predict the prices of materials and raw materials. This allows for faster adjustment of the production process to market conditions and significantly reduces the company's losses. Artificial intelligence used in the chemical industry can reduce forecasting error by 50% compared to human predictions. Companies can streamline their supply chain and avoid excess inventory by forecasting demand using artificial intelligence (McKinsey, 2017).

### 2.3. Intelligent data analysis in production

Companies operating on the market are obliged to comply with a number of regulatory standards. Exceeding the permissible values of carbon dioxide emissions, water consumption, or the level of pollution in production facilities results in a significant increase in costs. Manual control of indicators responsible for their regulation is very labour-intensive. For this reason, thanks to data analysis based on artificial intelligence, companies can easily track and adjust their production to standards introduced by state authorities. Moreover, with the progress of technology and the use of intelligent sensors, data analysis makes it possible to identify defects and inform employees about inconsistencies that have occurred. Knowing the source of the problem, experts can intervene in the production process and quickly solve the problem.

### 2.4. Quality Assurance in Production

In the chemical industry, timely quality assurance is of great importance. If an improper substance gets into the product line, it can cause irreparable damage, resulting in huge financial losses. With the help of artificial intelligence, it is possible to continuously monitor plant

operation and detect such cases, which ultimately helps to prevent equipment failures and production line downtime. Moreover, AI tools can learn from such incidents and use this knowledge to solve similar problems more effectively in the future. Quality assurance in chemical production is mainly ensured by computer vision. Using deep learning algorithms, computers scan substances on production lines, evaluate them, and classify them based on their properties.

## 3. AI Applications in the Chemical Industry

AI technologies are not a novelty in the chemical industry. For many years, they have been used by chemical companies around the world to develop products, forecast demand, and test quality. Here are some of the most popular examples of using artificial intelligence in the chemical industry.

### 3.1. AI-based production robots, cooperating and context-aware

Chemical companies use robots to clean production areas, minimizing human contact with toxic substances. Context-aware robots can also improve logistics efficiency and shorten travel time for raw materials or finished products between different parts of the production line.

Companies such as Novartis use robots to distribute chemicals on multi-well plates. They help the company test substances and products 24/7, accelerating the process of discovering new drugs.

### 3.2. AI in visual quality and safety control

Optical systems supporting artificial intelligence are used to detect defects such as mechanical inclusions, colour differences, or damaged packaging. AI platforms, such as SG Vision AI, provide advanced monitoring tools that help companies improve data collection accuracy and accelerate the model validation process (Pace, 2021).

Multi-billion-dollar companies such as Dow use AI monitoring to detect and eliminate safety threats associated with entries into enclosed spaces (Andulkar, 2021).

### 3.3. Algorithmic predictive forecasting in supply chain management using AI

Traditional forecasting systems are overwhelmed by the amount of data available on the internet. AI algorithms analyse huge amounts of data and predict demand for a specific product. Companies can adjust production planning and increase cost efficiency based on AI analysis results. In addition, they can implement artificial intelligence to collect data at sales points to predict customer demand and reduce waste associated with items that are not in demand.

Organizations such as Blue Yonder promote AI and machine learning techniques to optimize forecasting and inventory replenishment, while also having the ability to adjust prices simultaneously.

The supply chain is an integrated network in which different entities such as suppliers, manufacturers, and distributors work together to transform raw materials into finished products and deliver them to customers (Beamon, 1998). Artificial intelligence has been used to support the design, planning, and optimization of chemical supply chains, taking into account various environmental and economic aspects, for example: genetic algorithm (Berning et al., 2004; Guillén et al., 2006), heuristic algorithm (Pozo et al., 2012)). Some studies focused on supplier selection - for example, case-based reasoning (Zhao and Yu, 2011), while others used artificial intelligence techniques to predict and manage disruptive events, such as agent-based modelling (Behdani et al., 2009, 2012, 2019; Ehlen et al., 2014). Earlier research also included artificial intelligence in traditional modelling techniques for renewable materials supply chains, such as biomass (Castillo-Villar, 2014; Ghaderi et al., 2016; Lan et al., 2019).

### 3.4. Product property prediction

Japanese company Mitsui Chemicals has implemented technology for predicting the quality of reaction gases. It performs a real-time analysis of 51 different factors, including reactor conditions and process parameters. The new technology has enabled the company to improve the accuracy of reaction signals, resulting in safer and more stable operation of chemical plants. In the future, plant managers will be able to use deep machine learning to analyse huge amounts of data in real time, improving the accuracy of forecasts and control in operational processes, especially during start-up processes and modifications to increase production. It is also going to provide greater transparency in assessing the actual condition of machines and installation components and improve risk management effectiveness. AI-based tools enable production continuity, among other things, because machine learning more accurately predicts failures or the need for maintenance (Mitsui Chemicals, 2021)

BASF has applied a similar solution. In August 2019, they signed a cooperation agreement with Technische Universität Berlin to develop appropriate new mathematical models and algorithms for basic issues related to process chemistry and quantum chemistry.

Kebotix, an American technology platform that optimizes the production of new chemicals and materials using AI and robotics, has announced a strategic collaboration with Dutch company SCM, which specializes in precise methods for predicting properties through atomic modelling.

AI can be used in the area of creating new products. The goal set by Pfizer is to identify new and more precise treatment options by combining AI and data analysis with actual data. The company uses AI to redefine and accelerate the time it takes to complete chemical research (Kantify, 2023).

Given that AI development technologies are still in the research phase, it can be assumed that in the coming years there will be a number of new benefits and applications arising from its implementation in the chemical industry.

## 4. How chemical companies use AI – threats and opportunities

The use of artificial intelligence (AI) by chemical companies is a natural consequence of their pursuit of Industry 4.0. It is undeniable that highly digitized companies can easily access a broad customer base worldwide, which translates into increased opportunities for scaling their business. The increase in the level of automation of production processes, digitalization, and modern machine and equipment stocks are key to increasing the resilience of enterprises to crises and changes in markets. The use of AI solutions in business processes is becoming increasingly common, and the range of applications and benefits arising from their implementation in production processes is generating greater interest among companies. For the vast majority, this is just the beginning of changes that will revolutionize the industry in the near future. On the other hand, the use of AI still raises a number of risks and controversies among employees. Table 1 presents the main advantages and disadvantages of using AI in production processes.

**Table 1.**
*Pros and cons of AI applications in production processes*

| Category | TYPE | |
|---|---|---|
| | **Chances** | **Threats** |
| Economic | ● savings resulting from process optimization<br>● increase in profits from sales,<br>● Preventing the accumulation of excess stocks | ● capital intensity<br>● uncertainty of return on investment, |
| Technical | ● increasing the efficiency of devices,<br>● improving product quality | ● data security,<br>● vulnerability to cyberattacks, |
| Social | ● elimination of human errors,<br>● improving employee safety, | ● fear of losing a job,<br>● protection of privacy,<br>● lack of specialist knowledge,<br>● ethical considerations |
| Environmental | ● reduction of the number of post-production waste,<br>● lower energy consumption,<br>● a tool enabling the achievement of EZŁ objectives, | • increasing the amount of carbon footprint |
| Research & Development | ● accelerating innovation processes<br>● stimulating the development of new products and services | ● Dependence on technology |

Source: own elaboration.

The use of AI algorithms by companies provides higher profits through operational optimization. AI-driven analyses of root causes and test procedures lead to waste reduction and product quality improvement. They stabilize flow and increase device efficiency. Moreover, organizations can adjust to different production variants using AI tools. They can also automatically control manifestation conditions, such as mixing speed, temperature, and process duration. Higher throughput and a 30% decrease in efficiency are possible. Another reason why the production sector is striving for digitization and automation is the profitability of AI solutions. Intelligent tools help companies increase sales and productivity by eliminating the possibility of human error. AI algorithms help analyse changing customer demand and optimize offerings. This is beneficial for achieving maximum profit and preventing excessive inventory. AI solutions can reduce sales and inventory losses by 65% and 50%, respectively.

Another area where AI has found application is environmental protection. In line with the idea of sustainable development, AI enables the creation of global climate models, precision agriculture development, and intelligent power grids to regulate energy consumption. AI also helps reduce waste, which is beneficial from an economic standpoint. According to Nature Communications, AI solutions enable organizations to be 63% more environmentally friendly (Vinuesa et al., 2020).

Artificial intelligence technologies, such as advanced analytics, real-time data collection, and the Industrial Internet of Things (IIoT), can help improve the safety of personnel and physical resources. AI tools prevent potential production-related hazards by eliminating the need for direct human involvement. By collecting data on-site, artificial intelligence significantly facilitates compliance with data collection and documentation requirements.

Currently, only 4 out of 10 chemical companies widely implement artificial intelligence in their operations. Slow progress related to the implementation of AI in production processes is due to several challenges facing this technology. They include, among others:

- underdeveloped tools,
- lack of AI skills among the workforce,
- lack of high-quality data,
- issues of trust and transparency,
- uncertainty regarding return on investment.

To minimize their negative effects, companies should prepare to incorporate AI into their business processes. It is necessary to have a clear understanding of the goals of AI implementation and specific areas where it is intended to be used. As technological progress continues, the benefits of using artificial intelligence in the chemical industry are beginning to outweigh the challenges of its implementation.

One of the main risks associated with artificial intelligence in the chemical industry is the possibility of human error. As artificial intelligence systems become increasingly sophisticated, they can become more difficult to understand and operate, increasing the risk of errors and accidents. In addition, artificial intelligence systems may also malfunction, leading to unexpected results and potential hazards.

Another risk associated with the use of AI in the chemical industry is the possibility of reducing positions and losing jobs for employees. Artificial intelligence systems help automate tasks previously performed by people, which involves the risk of transferring work. In particular, in technologies used by the chemical industry, there are many schematic activities that can easily be automated, leading to significant job losses. However, surveys of employees in chemical companies in Poland indicate a lack of concern about their job security (Kądzielawski, 2022).

In terms of privacy and data security, artificial intelligence systems used in the chemical industry can handle sensitive information and data, such as production processes, chemical formulas, and proprietary information. Ensuring the security and privacy of this data is crucial for protecting a company's intellectual property.

The implementation of artificial intelligence in the chemical industry requires a high level of technical knowledge. Without sufficient specialized knowledge, companies may have difficulty designing, implementing, and maintaining AI systems, leading to suboptimal performance or even failure. Companies that increasingly rely on artificial intelligence systems to optimize their operations may become dependent on the technology. In case of a failure or malfunction of an AI system, companies may not be able to continue their operations, leading to significant financial losses. It is worth noting that with the development of AI systems, there are increasing concerns of ethical nature. For example, AI systems can be used to make decisions that have an impact on human life, such as determining the safety of a chemical product. Without proper supervision and regulation, AI systems can make decisions that are contrary to the interests of society. AI systems rely entirely on data, based on which they are trained. If the data is not sufficiently objective, there is a risk that the AI system will also be biased. Consequently, this situation may lead to unfair decision-making and discrimination.

With the growing integration of AI systems in the chemical industry, there is a risk of cyberattacks. These attacks can disrupt operations, steal confidential information, and cause financial losses.

AI systems in the chemical industry may require integration with other systems, such as enterprise resource planning (ERP) systems, process control systems, and sensor networks. If these systems do not cooperate properly, it may lead to operational inefficiency.

In a study by McKinsey (2019), the implementation phase of AI was divided into 5 stages, and risks were assigned to each of them.

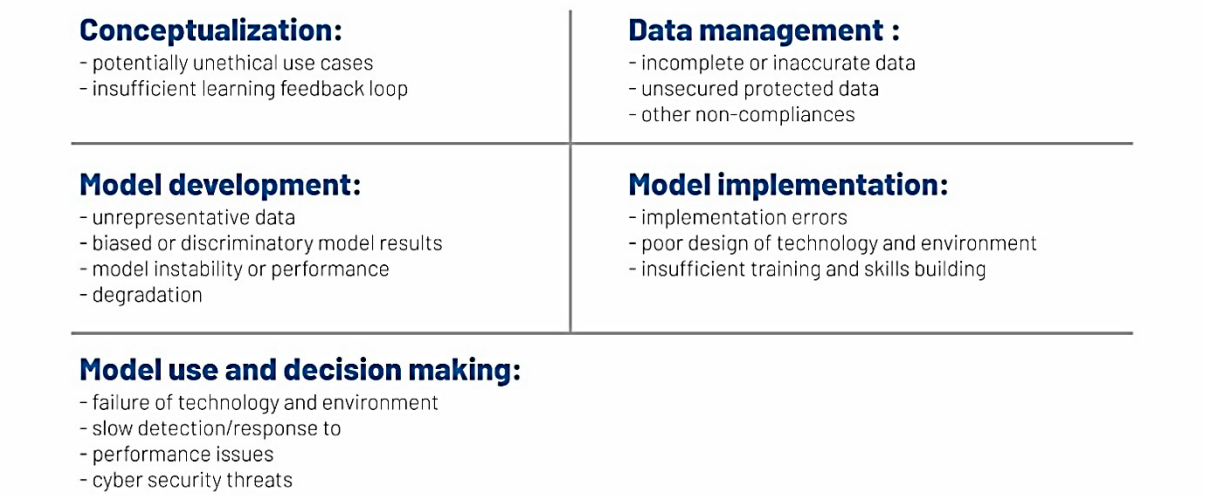


**Figure 2.** Risks of the 5 stages of AI implementation.

Source: own elaboration based on McKinsey, 2019.

Summing up, AI has the potential to revolutionize the chemical industry, but it is important to consider the risks and challenges associated with implementation. These include potential human errors, job loss, data privacy, and security. However, with the proper measures in place, benefits such as increased efficiency, productivity, safety, and sustainable development can be achieved. To maximize benefits and minimize risks, chemical companies should consider a phased approach to AI implementation, starting with pilot projects and gradually increasing scale.

## 5. Summary

AI technologies have tremendous potential in improving chemical production processes. From demand forecasting to quality control, technologies using artificial intelligence are completely redefining the concepts of chemical production.

Significantly reduced costs, increased production speed, and overall business process efficiency are the new standards that AI tools are introducing. Chemical companies that have already implemented artificial intelligence are showing impressive returns on investment, better product quality, and streamlined supply chain processes.

Effective implementation of new solutions plays a crucial role in the development of chemical industry enterprises. These companies, in order to survive and maintain their market position, will have to change their previously used business models and redefine their value chains. With the planned tightening of environmental regulations and standards in the near future, companies should adapt to current trends - including the circular economy - and utilize digital technology opportunities, as well as enhance the qualifications of their employees in this direction.

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# KNOWLEDGE-BASED INTER-ORGANIZATIONAL COOPERATION OF UNIVERSITIES AND BUSINESSES IN THE CHEMICAL SECTOR

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**Purpose:** In this paper, the authors analyze the importance of knowledge in modern socio-economic relations. The main objective of this paper is to show the prospects for development of knowledge-based inter-organizational cooperation between universities and companies in the chemical sector.
**Design/methodology/approach**: The authors recognized that it is reasonable to adopt the research strategy of methodological pluralism. Therefore, the study used an integrated research approach, which included both direct interpretive and positivist research procedures. This required qualitative and quantitative research. Literature studies include Polish and foreign publications.
**Findings:** As a conclusion for the results of the study, it should be stated that the value derived from knowledge positively influences the establishment and subsequent strengthening of the ties between universities and companies. This knowledge (in particular, solutions in the area of digital technologies that focus on monitoring and automation of processes, data integration, and big data analytics, as well as data protection and cybersecurity) can be applied in the process of formation of long-term relationships between universities and companies. In addition, as demonstrated in the article, inter-organizational cooperation between a university and a chemical company requires ensuring symmetry in the partners' structures and management methods, as well as overcoming differences in their organizational cultures. Other conditions that should be taken into account in order to successfully shape long-term relationships are organizational proximity, cognitive proximity, institutional proximity, and social proximity.
**Originality/value:** The added value of the article is to show the prospects for the development of inter-organizational cooperation and to determine the importance of the impact of knowledge on the cooperation of universities and chemical enterprises.

**Keywords:** inter-organizational cooperation, interaction, relations, knowledge.

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

## 1. Introduction

The new economic environment requires a proper interpretation and understanding of social and economic processes that are becoming less predictable and more dynamic. Therefore, learning, which enables the development of available knowledge resources, is becoming one of the key business processes, and knowledge itself is gaining importance as the most desirable resource, a competency, and a value that is essential to growth. The growing interest in acquiring and using knowledge and, at the same time, in the learning process is causing companies to open up to new areas of innovation (Hussain, Haseeb et al., 2021; Ginevičius, Nazarko et al., 2021).

The broad scope of the issues analyzed in this paper leads the authors to ask: How does knowledge foster inter-organizational cooperation between universities and companies in the chemical sector? It also inspires them to identify the main research problem, which is to determine the importance of the impact of knowledge on inter-organizational cooperation between universities and companies in the chemical sector.

The main objective of this paper is to show the prospects for development of knowledge-based inter-organizational cooperation between universities and companies in the chemical sector. The main objective presented in this way encourages the verification of the main research hypothesis: the knowledge of universities has a stimulating (positive) effect on the propensity of companies to establish and maintain multi-dimensional inter-organizational cooperation.

## 2. Knowledge orientation as a requirement of the contemporary times

In the context of constant change and globalization of the economy (Kowalczyk, Nogalski, 2007) building and strengthening a competitive advantage based on knowledge are becoming the only effective way for organizations not only to survive, but also to grow in these difficult conditions. This is one of the premises that explain the growing demand for knowledge. Another important premise is the rapid development of information and communication technologies, which leads to an increasing demand for science, technology, and knowledge (Boguski, 2009), and a search for their sources among modern chemical sector companies.

Although knowledge has always been treated as one of the key factors in economic development (Michalski, 2020), today the increasing turbulence and lability of the environment, the strong market pressures, and the impermanence of competitive advantages make the importance of knowledge even greater (Gąsowska, 2011). This is a special market opportunity for those organizations that build their competitive advantage on knowledge.

Such organizations, but also their environment, including their stakeholders, are increasingly affected by the rapid pace of social, economic, and technological change, and now also by the multi-dimensional consequences of the COVID-19 pandemic that has continued since 2020. Technologies and products are aging faster and faster and are being pushed out of the market by better solutions. The bisociation of digital technology and new communication tools (such as mobile telephony and the Internet) with new economic trends (globalization, privatization, deregulation, trade liberalization, investment in renewable energy sources, and growing social inequalities) is producing consequences that are difficult to predict and require organizational transformations, as well as a complex reconfiguration of economic systems. It is likely that by the end of the 21st century, about 70% of the currently existing jobs will no longer exist due to automation and robotization based on such technologies as artificial intelligence and machine learning. New specialized jobs, new categories of goods and services, and new complex models of economic activity will emerge (Kafel, 2013).

In the future, organizations will take liquidity, volatility, complexity, and multifacetedness for granted (Rajiani, Bačík et al., 2018). Multi-dimensional variability will be widely accepted. The importance of knowledge as a catalyst for innovative technological solutions will increase even more. Innovations will create the need for further, even more innovative solutions, thus triggering an ever-increasing demand for knowledge (Poznańska, 2016). This new reality will require proper interpretation and development of adaptability in organizations. In order to benefit from the changes that will shape the economy of the future, organizations will have to continuously learn and skillfully use their own and external resources of knowledge (Zawiła-Niedźwiecki, 2014).

The phenomenon of knowledge has many definitions and approaches, which are discussed in management and quality sciences. Knowledge should be objective and universal (Sułkowski, 2013). As an intangible resource, it is not easy to capture and measure, which makes it even more difficult to manage in organizations. In the most common approach, knowledge is a combination of data and information, supplemented by expert opinions, skills, and experience (Chaffey, Wood, 2004), which facilitate the decision-making processes in organizations. Data are objective source facts, without a context or an interpretation, that are unprocessed and do not allow drawing conclusions (Gierszewska, 2011). When data is interpreted and given a certain meaning and context, information is created (Jemielniak, 2012), which is used in various spheres of management in organizations. Of particular importance for the development of organizations are those categories that are above knowledge, i.e. wisdom, intelligence, and thinking (Skyrme, 2000), understood as the ability and capacity to acquire, obtain, and create knowledge, and to learn through skillful transformation of data and information (Grudzewski, Hejduk, 2004). Thus, it can be said that knowledge is a form of effective use of information in the activities of an organization (Drucker, 1999) and in solving its problems (Applehans, Globe et al., 1999) that uses the competencies and skills of the organization and its personnel, as well as their creative or imitative abilities. Knowledge is accumulated in people's

minds (Dolińska, 2010), but also in documents, procedures, processes, organizational practices and standards (Davenport, Prusak, 1998), and in repositories and data collections, both traditional or electronic. Knowledge is a liquid combination of formed experience, values, contextual information and inferences that provide a framework for evaluating and absorbing new experiences and information. Awareness of knowledge or access to knowledge can prove to be a source of competitive advantage for an organization.

The dominant vision in the literature is that of knowledge derived from logical behaviorism and a continuum (Jashapara, 2004) extending between tacit knowledge ("I know how"), anchored in people's minds and experiences and manifested in practical actions, and explicit knowledge ("I know what"), imaged in sets of data and facts (Polanyi, 2009; Ryle, 2009). Other important aspects of the perception of knowledge are "knowing why" - with regard to the relations between phenomena and processes, and "knowing who" - with regard to the individuals who know "what," "why," and "how" (Hargreaves, 2000). More and more organizations are choosing to collaborate with other organizations to optimize the process of transformation of tacit knowledge into explicit knowledge (Nonaka, 2000) and enlarging its resources, including through the joint creation of new knowledge.

An organization's approach to knowledge determines how it manages it. A growing number of organizations that are aware of their own limitations with regard to knowledge seek to establish relations that enable them to better leverage external knowledge for competitive advantage (Fox, 2021). P.F. Drucker claims that there are no organizations without knowledge, and instead there are only those that mismanage it (Drucker, 1999). Management of knowledge is an important multi-layered subsystem of organizational management (Zawiła-Niedźwiecki, 2014), but its development requires a certain degree of maturity in organizational and inter-organizational learning, which can be defined as a search for, and use and dissemination of, knowledge. Knowledge management in an organization can develop when it becomes aware of the importance of knowledge as an asset that will allow it to generate wealth (Bukowitz, Williams, 2000) and takes steps in that direction.

Knowledge is now becoming the dominant resource and distinctive competency of many organizations. Some believe that the growth and complexity of knowledge are dangerous, but there is a growing awareness among others that access to expanded knowledge resources can benefit their development (Probst, Raub et al., 2002). Therefore, organizations constantly strive to improve the efficiency of knowledge utilization through learning, which is determined by technological changes and organizational culture, among other factors. Technological advances can inspire changes in market offerings, but also affect the learning process itself, for example by enabling access to electronic knowledge bases and accelerating knowledge transfer. This is particularly important at the time of the emerging new post-pandemic reality and the dynamic development of virtual communication, which also contributes to changes in organizational culture. Organizational culture can be defined as knowledge, shared to a various extent by members of an organization, that is expressed in actions and words. An analysis of

the impact of organizational culture on the effectiveness of management in an organization largely concerns specifically of the organization's approach to knowledge. According to Ł. Sułkowski, the development of knowledge management shifts the focus from the values and norms upheld by an organization to its cognition and knowledge. The cultural approach requires searching for new ways of understanding organizations and business life, which naturally links organizational culture also to knowledge management (Sułkowski, 2008).

Effective knowledge management in an organization is closely linked to the development of human capital, including key competencies and creativity (Poznańska, 2018), which lead to improvements within the organization in such areas as interpersonal communication and research (Zawiła-Niedźwiecki, 2014). With the ability to think creatively and use knowledge, an organization can operate on a higher level, e.g. implement innovations (Fiddler, 2002), and ultimately improve its image in the environment and strengthen its impact on other organizations, such as its competitors. Therefore, many organizations strive to build a competitive advantage based on knowledge, while carefully analyzing signals from the environment so as to avoid and prevent mistakes and losses. Skillful use of knowledge in an organization in response to changes in its environment enables flexible and smooth transformation and rapid adjustments (Penc, 2004).

Change is one of the distinguishing features of the current time and a path for the development of any organization (Osbert-Pociecha, 2011). In order to achieve its survival, which is a natural objective, an organization must respond to, and adapt to, and even anticipate change (Kotelska, Lis, 2022). Change is a disruption to any state of equilibrium an organization is in (Sarayreh, Khudair et al., 2013). A response to change requires demonstrating the ability to adapt quickly, as well as flexibility and innovation (Heckmann, Steger et al., 2016). As a result, the organization reconfigures, integrates, and expands its internal and external resources and competencies. In the past, change occurred quite infrequently in the lives of organizations. Nowadays, the complexity, unpredictability, and turbulence of the environment cause all organizations to be subject to the impact of many factors that trigger changes and contribute to their irreversible transformation in the long term (Czop, 2016). Thus, changes in organizations are the consequence of a realized need to respond to a disturbance that throws the organization out of balance and an opportunity to use the organization’s existing capabilities, e.g. to adapt or act proactively (Klarner, Probst, 2007).

Modern organizations should be able to face the challenges involved in operating in a knowledge-based economy, i.e. to adapt to the objective conditions prevailing nowadays and the changes imposed by the environment, but also to anticipate them and actively shape their environment. The strategic resource that enables such measures is knowledge (Penc-Pietrzak, 2016), which is the basis for the existence, functioning, and development of any organization (Dolińska, 2010,) individuals, and communities (Dahlman, Anderson, 2000), as well as the entire global socio-economic system (Szczepańska-Woszczyna, Muras et al., 2021; Szczepańska-Woszczyna, Dacko-Pikiewicz et al., 2015). In the era of the knowledge-based

economy, all organizations are very dependent on technology and information processing. The rapidly developing new information- and technology-based paradigm requires multi-dimensional creation, condensation, and implementation of knowledge (Brett, 2002), which becomes the root cause of business success or failure. At the same time, the increase in its importance in global processes, not only technological, but also social, has resulted in a change in organizations' approach to resource structure, i.e. placing greater emphasis on the development of intangible resources.

Modern requirements placed on organizations by the knowledge-based economy cause a change in the approach to the structure of resources, which is manifested in the increased importance of intangible resources and the development of inter-organizational links (Mikuła, 2007). This allows the consolidation and complementary use of the available resources, as well as the creation of network organizations that compete with each other (Mikuła, 2007; Moszkowicz, 2002), but are also willing to cooperate in certain areas (e.g. coopetition). The ability to collaborate makes it easier for organizations to respond to today's socio-economic changes and to adapt to the turbulent environment in which they operate.

The ability of organizational learning (Penc-Pietrzak, 2016) and learning from organizational change management (Penc, 2004) is responsible for the proper use, development, or renewal of an organization's resources. Organizational learning not only makes it possible to respond in a flexible manner to changes occurring in the environment (Rutka, 1996), but also facing encourages new challenges, such as innovation. In a knowledge-based economy, where more and more organizations acquire the ability to learn, in addition to the competencies needed to use knowledge appropriately, sourcing valuable and useful knowledge from the best sources is also becoming a strategic skill. One can distinguish sources of knowledge based on four barriers to its creation: the environment, the interior of the organization, the present, and the future. According to this approach, the environment imports knowledge, the interior of an organization implements and integrates that knowledge, the present determines how joint problem-solving is possible, and the future relies on experimentation (Strojny, 2000). To overcome these barriers, organizations need to develop core competencies.

Knowledge creation within an organization is based on the use of relatively easily accessible sources. These include sources of unclassified knowledge, i.e. organizational documents (procedures, regulations, instructions), archives, and data from information systems that contain information on contracts, customers, purchases, etc. Within an organization, it is also very important to use sources of tacit knowledge, which can come from managers and owners, but also - to the greatest extent - from employees. A large role in this case is played by the organizational culture and the value system on which it is founded. However, this value system must not reduce managers, employees, and their creative tasks to a function of resources and means leading to the achievement of the organization's economic and market goals (Sułkowski, 2011), but should treat them as partners in the acquisition and development of knowledge that

supports the achievement of the goals of the organization and its stakeholders. Building so-called experience-sharing communities not only allows employees to exchange knowledge, but also increases their personal happiness and job satisfaction (Chen, Baird et al., 2019).

Sources of external tacit knowledge include external experts and scientists, business partners, customers, and competitors. External sources of explicit knowledge used by organizations include materials available at trade fairs, exhibitions, and conferences, the content of websites and databases, and academic publications. Organizations should have multiple types of knowledge coming from different sources (Michna, 2017), and then should use it in the most appropriate way for themselves, including for defining strategic management elements such as mission, vision, goals, plans, and strategies (Liao, Fei et al., 2008). External knowledge (both explicit and tacit) can be obtained from a variety of stakeholders. Their particular role is to share experiences, transfer knowledge from the outside to the organization, but often also to transfer knowledge from the organization to the outside, especially within consortia, partnerships, and alliances. The most important added value from such collaboration is an expansion of the ability to use different types of knowledge for organizational needs and to equalize knowledge in the intra- and inter-organizational dimensions (Nonaka, Takeuchi, 2000).

The choice of knowledge sources depends on many factors, including their cost. In general, the cost of acquiring knowledge from internal sources is lower than the cost of acquiring knowledge from the outside, so the choice depends on the financial capacity of the organization. Due to the rapid development of information technology, the cost of search for external knowledge has decreased and the efficiency of the process of its absorption has increased. As a result, companies with the same financial capabilities (Poznańska, 2016) can acquire more knowledge in a more efficient manner (Majewska-Bator, Bator, 2011). The search for external knowledge often stems from the development of so-called open innovation. The concept of open innovation, as opposed to the creation of innovations in a closed model, is paradigm of innovation activities of modern enterprises that is rapidly gaining importance (Sopińska, 2017; Michałek, Pachucki, 2020). According to this approach, in order to create innovation, organizations should use both external and internal ideas, inspirations, and technologies (Poznańska, 2012). Intentional inflow and outflow of knowledge, i.e. knowledge transfer in both directions, is the most effective approach to the use of knowledge and accelerates innovation (Chesbrough, Garman, 2010; Lis, Ratajczak, 2014). K. Laursen and A. Salter based their approach to the management of open innovation on a strategy that involves a search for external knowledge. They distinguished two parameters of the knowledge search process: the breadth and the depth of the search for knowledge outside the company's boundaries (Laursen, Salter, 2006). The relationship between these two parameters is explained in Table 1.

**Table 1**.
*The process of search for external knowledge in synthetic terms*

| Dimensions of the knowledge-searching process | Measure | Description of the measure |
|---|---|---|
| The breadth of the search for knowledge | The number of knowledge sources used by an organization | The greater the number of sources of external knowledge, the greater the breadth of the search for knowledge outside the organization's boundaries. |
| The depth of the search for knowledge, i.e. the intensity of the search for knowledge in various sources | The degree of relevance of knowledge from external sources | The greater the relevance of knowledge from external sources, the greater the depth of the search for knowledge outside the organization's boundaries. |

Source: prepared by the authors based on Greco, Grimaldi, Cricelli, 2016, pp. 501-516; Bohdanowicz, Dziurski, 2020, p. 216.

The strategy of a broad search for knowledge outside the company's boundaries is more prevalent than the strategy of a deep search for external knowledge. Most organizations search for knowledge from a wide variety of sources, but they do not do it very intensively. Both the broad and the deep search for external knowledge is costly and, due to the limited nature of resources, requires choices (Bohdanowicz, Dziurski, 2020). There is generally a negative correlation between the breadth of the search for external knowledge and its depth. For this reason, organizations strive to optimize the number of knowledge sources used and the extent to which they are used, as well as the cost of their acquisition. P. Dziurski notes that individual organizations that offer external knowledge compete for the interest of those who express demand for knowledge, especially when knowledge transfer can be a source of revenue (Bohdanowicz, Dziurski, 2020). Such behavior is on the rise in the case of universities and other research units that compete for cooperation with companies.

Studies show that Polish companies that implement open innovation are characterized by a small breadth of search for external knowledge (Sopińska, Dziurski, 2018; Poznańska, Szczepańska-Woszczyna et al., 2022). In 2019, as many as 47.54% of the surveyed companies sought external knowledge from only one type of partner, 38.52% from two, 12.39% from three, and only 1.64% from four. These partners included customers, scientific and research institutions, and suppliers. At the same time, Polish companies were characterized by a small depth of search for external knowledge. A large group of companies (14.75%) did not make intensive use of knowledge available from various sources, i.e. these companies sought external knowledge, but their actions were very superficial (their depth of search for external knowledge was 0). A half of the surveyed companies intensively sought external knowledge from only one source, while 27.05% of the companies sought it from two sources, 7.38% from three sources, and 0.82% from four sources.

The findings of this study confirm that companies only superficially seek external knowledge from customers, while being much more likely to seek it from suppliers and scientific and research institutions (small depth of search for external knowledge). Of particular importance for companies, however, is cooperation with research and development institutions, which gives them access to knowledge characterized by a high degree of novelty. While this

knowledge is also relatively easy to access, it can be difficult to understand, process, and use. Despite the fact that companies cooperate less often with scientific entities than with customers, it is scientific entities that inspire them to search for external knowledge (Bohdanowicz, Dziurski, 2020). Research confirms (De Wit-de Vries, Dolfsma et al., 2019; Kobarg, Stumpf-Wollersheim et al., 2018) that providing companies with access to knowledge is a significant challenge for research entities, as the reported demand for knowledge opens up a wide range of opportunities to offer it in many forms.

## 3. Determinants of the development of companies in the chemical sector in a knowledge-based economy

Nowadays it is difficult to be self-sufficient, (Lynch, 1993) and the ability to assess the environment in terms of its direct or indirect impact is becoming strategically important. The tendency to cooperate with the environment is a natural aspiration of any modern organization that constitutes an open system (Koźmiński, Piotrowski, 2004) that interacts with elements outside it, primarily its stakeholders. These are individuals and groups that are influenced by or significantly influence the organizations (Freeman, 2010), with whom the organization has both unilateral and reciprocal relationships (Koźmiński, Jemielniak, 2009). The key to improving an organization's performance is an understanding of its environment and the relationships it has with its stakeholders. Suppliers that provide the organization with the resources it needs to operate and the customers who purchase its products occupy a strategic place among them (Freeman, Harrison et al., 2018). The exchange between an organization and its stakeholders can involve providing each other with goods or services, as well as resources that are of interest to each party. If such an exchange brings expected benefits and satisfaction to each party, in the long-term it can build mutual trust and attachment (Dacko-Pikiewicz, 2019; Dacko-Pikiewicz, 2022). The value of a specific offering is determined as a result of the relationship that exists between many entities cooperating in different conditions and making resources available to each other.

One of the resources most desired by modern organizations is knowledge. This is fostered by the paradigm of knowledge-based economy whereby many modern organizations are building their competitive advantage by sharing knowledge with each other and jointly using the available external knowledge, as well as through individual, group, organizational, and inter-organizational learning. This is one of the most important reasons for the development of various forms of inter-organizational cooperation.

Inter-organizational cooperation is a relationship between two or more organizations that develops as a result of the evolution of their mutual relations and is beneficial to each party (van Winkelen, 2010; Berlin, Carlström, 2011). This includes both resultant benefits, such as improved access to knowledge, but also inter-organizational cooperation as a value in its own right, requiring each party to provide the capabilities, competencies, and knowledge necessary to create specific interpersonal and inter-organizational relationships (Sitko-Lutek, Pawłowska, 2008; Lis, Kotelska, 2022). Inter-organizational cooperation is based on specific, more or less formal relationships between partners. These organizations, which are independent of each other in terms of their decision-making processes, may or may not follow the recommendations of other partners; however, proper coordination between them is necessary to give their cooperation the right direction.

A key attribute of inter-organizational cooperation is collaboration (Kale, Dyer et al., 2002), whereby partners pursue convergent goals and objectives in the same or different ways. This can take the form of full cooperation or cooperation only in certain areas. Inter-organizational cooperation can develop either as bilateral relationships between two organizations or as network relationships, such as consortia, alliances, networks, or clusters. Collaboration can vary in terms of the scope of activity of the parties (from passive, one-way use of knowledge to active co-creation) and the type of knowledge transferred (explicit or implicit) (Olszewski, 2020). The larger the number of cooperating organizations, the better the results that can be obtained in terms of sharing information, knowledge, and experience, or in terms of synergistic use of joint capabilities and resources (Szczepańska-Woszczyna, 2020). At the same time, the larger the number of cooperating organizations, the harder it is to synchronize the decision-making processes, identify the common interests, reach compromises regarding risk distribution, and share the costs and benefits of activities carried out together (Payan, 2007; Michałek, Pachucki, 2021). Inter-organizational cooperation is justified only if the partners are convinced that its benefits outweigh the costs due to, for example, the time it requires.

Inter-organizational cooperation can develop between organizations with very similar or very different characteristics (Lundberg, Andresen, 2012) in the private, public, as well as non-governmental sectors (Kożuch, Sienkiewicz-Małyjurek, 2015), or between various sectors. Not only the area of cooperation, but also its dynamics, goals, scope, and legal form can vary to a large extent. Asymmetries in the structures and management methods of cooperating organizations, (Kaiser, 2011; Young, Denize, 2008), as well as differences in their organizational cultures have a significant impact on both the course and the results of joint activities. In practice, this can mean that despite each party's efforts, the differences between organizations make it much more difficult for them to work together. Companies that intuitively act in the spirit of rivalry start cooperation only if they are convinced that by doing so they will strengthen their competitiveness, which is a condition for surviving in the market (Kożuch, 2011). NGOs, on the other hand, mostly carry out social missions aimed at specific stakeholder

groups. They seek to obtain the resources they require to achieve their goals or to implement certain values, and view interaction as a mechanism that facilitates achieving the desired outcomes. Compared to organizations in the commercial and non-governmental sectors, public organizations are much more prone to authoritarianism and formalization, while autonomy of action and decision-making in them is limited, and competitive pressures are virtually non-existent (Kearney, Hisrich et al., 2009). Public organizations find it most difficult to engage in cooperation, which by its nature requires a certain amount of flexibility and adaptability.

Cooperation is a riskier form of doing business than operating independently (Czakon, 2007), so inter-organizational cooperation is not easy. A number of factors can be identified that contribute to the high level of uncertainty in such relationships, such as periodicity of operation, divergence of interests, difficulty in comprehending organizational affiliations, dispersion of activities, and lack of competencies for cooperation (Sokołowska, 2005). In extreme cases, involvement in inter-organizational cooperation can result in loss of knowledge due to its overly broad and deep transfer, or to uncontrolled and unwanted knowledge spillover effects. In the case of large asymmetry of tacit knowledge, those who have its largest resources may choose to act independently (Coff, 2010). Another possible problem associated with inter-organizational cooperation is dependence on other partners. Therefore, the price for the uncertainty associated with cooperation must be its high value to the organization, outweighing the benefits of individual action.

Various forms of interaction, such as networks and clusters, can lead to an increase in the knowledge resources in cooperating organizations. They open up new opportunities for collaborative learning and managing the existing knowledge, which ceases to be an individual resource of an organization and, to the extent acceptable to all cooperating organizations, becomes a shared resource. In order to be able to use such accumulated knowledge, it is necessary to implement a process of inter-organizational learning.

A fairly common and flexible form of inter-organizational cooperation is various forms of alliances. These are formalized or informalized inter-organizational relationships of undetermined duration, most often associated with a process of mutual compensation of resources and capabilities of any number of partners. Alliance participants strive to achieve common goals, including by compensating for their own weaknesses with the use of others' resources, including knowledge (Probst, Büchel, 1997). Alliances are most often established to observe, learn, and internationalize the partners' *know-how* (Parise, Sasson, 2002), while the cooperating organizations show a strong commitment to generating core competencies (Harbison, Pekar Jr., 1998), as well as to mutual and collaborative learning. In this cooperation, the similarity and complementarity of the partners, the common skills, and the unique knowledge of each of them play an important role. Alliances can lead to a reduction in uncertainty and an increase in the flexibility of operations (Macias, 2013); among other things, they make it easier to bear the ever-increasing cost of access to knowledge, but also, due to their different learning speeds, the partners may use the shared knowledge available to the alliance

in an unequal manner (Pietruszka-Ortyl, 2007). Certainly, in the process of collaborative learning, awareness of the elusiveness of knowledge and its constant obsolescence is desirable, as is the ability to adapt the activities of the collaborating organizations to the inter-organizational learning model developed jointly. Modern motivations for entering into alliances most often relate to the competitiveness of organizations, i.e. the desire to acquire technology or unique capabilities, share costs and risks in the process of joint research, learn from partners, adapt quickly to new conditions as a result of intensive knowledge transfer (Hamel, Doz, 1989), and benefit from the intellectual capital of partners (Skrzypek, 2015). The knowledge-based alliances defined in the literature (Probst, Raub et al., 2002) involve the cooperation of organizations to achieve the maximum learning effect through the adoption of a specific philosophy of interaction assuming that (Pietruszka-Ortyl, 2007):

- learning is the overarching goal of the alliance and every participant is aware of it,
- the philosophy of human resource management in the cooperating organizations is in line with the assumptions of the process of joint organizational learning of all members of the alliance,
- the cooperating organizations have the financial and material resources necessary for the process of collaborative organizational learning and have appointed to participate in the process their representatives with the appropriate talents, competencies, and skills that make it possible to maximize the learning effect,
- each of the cooperating organizations has thoroughly assessed its learning capabilities and is constantly improving them, e.g. builds an organizational climate conducive to learning, provides its representatives with the best conditions for cooperation with partners, and minimizes barriers to the learning process, such as those arising from cultural differences.

The strategic role of knowledge in the modern world encourages organizations to search for it and develop it in various forms of inter-organizational cooperation. The aforementioned knowledge-based alliance is just one such form. The entities engaged in inter-organizational cooperation are primarily those that are interested in better access to knowledge and its more efficient use, including businesses. It is also an attractive area of activity for organizations that offer knowledge to others as their key product, as well as organizations that use knowledge to self-improve and grow so effectively that others want to learn from them. Such organizations include universities. Many intermediate variants are also possible when organizations with knowledge to offer are themselves simultaneously seeking knowledge and are able to exchange their resources, or learn together, synergistically leveraging the capabilities of all partners.

The activities of universities are commonly associated with the production and release of knowledge (Breznitz, 2014). Accordingly, a modern university pursues three missions: education, scientific and research activities, and the creation of mutual relations with their environment. The third mission is to serve the purpose of greater involvement of academic institutions in social development processes at various levels, including economic and social

(Leja, 2015). In practice, the quality and usefulness of academic knowledge to the environment, as well as the way it is offered, including marketing preparation (Olearnik, Pluta-Olearnik, 2015) and the attractiveness of the university as a partner in various forms of inter-organizational cooperation, can vary to a large extent. It is worth noting that inter-organizational cooperation with regard to universities should mean not only transferring knowledge to the outside, but also drawing knowledge from the outside, which, in practice, means a continuous exchange of knowledge: in the spirit of academic entrepreneurship (on a market basis) (Poznańska, 2014) or through activities related to the social responsibility of science (on a non-profit basis) (Jasiński, 2015). In addition to the typically educational knowledge transfer processes (university teacher - student relationship), universities carry out basic research, but also commercial processes of knowledge exchange, including by jointly conducting research and using its results in relations between universities and companies. Moreover, socially oriented knowledge exchange processes take place there - in relations with local governments or non-governmental organizations.

According to A.H. Jasiński, universities should be seen as modern institutions operating in a market environment, i.e. in a business environment, among other things. The confluence of many factors has forced modern universities to turn to cooperation with their external environment, including, in particular, involvement in activities aimed to modernize the economy and develop cooperation with businesses. Inter-organizational cooperation can thus be developed by universities in many spatial dimensions[1] and in different markets:

- in the market for services (educational, research, consulting and expert, or design services),
- in the market for goods related to the use of so-called science infrastructure (e.g. conference rooms, laboratories, as well as recreational, accommodation, and catering infrastructure),
- in the market for external funds (e.g. participation in competitions for various types of grant funds for projects they perform),
- in the labor market (graduate education[2], activities of academic career offices, human resource processes for teaching, research, and administrative staff of universities engaged on the basis of various employment models),
- in the market for social services (including non-profit activities, charity, and volunteerism).

[1] It can be a local, regional, national, or international dimension.

[2] The role of universities in the development of professional and general competencies is discussed, among others, by: Borowiecki, Kusio, 2016, pp. 71-90; Motoyama, Mayer, 2017, pp. 787-804.

In terms of entities, the supply side in each of the aforementioned markets can be represented not only by universities, but also by all other entities that are able to provide the aforementioned services[3]. This market is becoming increasingly competitive and some forms of inter-organizational cooperation, such as between universities, are also developing there more and more clearly. In general, however, competition for users and buyers of university's offerings representing the demand side (students, businessmen, social partners), but also for resources, e.g. funds for operations, best specialists, and most effective advertising, prevails.

The demand side of the market in which universities operate is made up of diverse stakeholders, whose role in the environment of the academic sector is increasing (Popławski, Forkiewicz et al., 2014) while giving impetus to the creation of new knowledge that is useful to them (Wawak, 2019), as a product to be exchanged with these stakeholders. According to A.H. Jasiński, knowledge should be created not only for the stakeholders, but also with their increasing participation, so that they are not just buyers of the services provided by universities, but also their co-creators (Jasiński, 2015). This is therefore a rationale for the development of inter-organizational cooperation between the demand and supply sides of the higher-education market. The effectiveness of these activities requires the university not only to ensure an appropriate quality and availability of knowledge, and its effective transfer, but also adequate marketing preparation, among other things to create various forms of inter-organizational cooperation with the customers buying the universities' services. As emphasized, the university's entrepreneurial orientation greatly facilitates agreement with stakeholders from the business sector (De Wit-de Vries, Dolfsma, 2019) and minimizes the cultural barriers to such cooperation. According to M. Kwiek, never before have universities faced the changing pressures from their major stakeholders for so long. Therefore, higher education institutions should respond no longer only to the changing expectations of the state, but also to the new needs of students, employers, and businesses operating in the regions where they are located (Kwiek, 2011).

The particular need to intensify the process of collective learning of representatives of science and business in "learning regions" is pointed out, among other publications, by the OECD report (Ischinger, Puukka, 2009). Spatial (geographic) proximity is one of the most important criteria for selecting partners for inter-organizational cooperation. Some studies even indicate that cooperation between universities and companies tends to be local, as knowledge flows make it necessary to establish networks and maintain direct contact. Spatial proximity facilitates the transfer academic knowledge that is complex and difficult to codify (Crescenzi,

[3] While in the market for higher education (educational) services, one can speak of direct competition only between universities (except for the market for training services), in the market for research or expert services, for example, universities have strong and a lot more numerous competitors: experts providing so-called professional services, consulting firms, law firms, commercial laboratories, and research and scientific institutes. According to another approach, the competitive environment of universities also includes, for example, non-profit organizations, among others due to the fact that they compete with universities for funding for social activities (e.g. grants from local governments) - see: Pluta-Olearnik, 2015, pp. 127-135.

Filippetti et al., 2017). Companies with a low capacity to absorb knowledge make greater use of local knowledge, while companies with a high capacity to absorb knowledge and globally connected companies use knowledge from outside their regions. Obtaining knowledge locally also depends on the extent to which local sources are able to provide knowledge that is in line with the information needs of the recipient. Universities whose offerings can meet the needs of companies seeking local knowledge find many potential partners for knowledge exchange in the immediate area. Universities that specialize in narrow areas of research certainly have to take a different path to reach potentially interested companies with their knowledge. Inter-organizational cooperation between universities and companies is also fostered by organizational proximity, i.e. the degree of similarity between their operating conditions, (Boschma, 2005), and cognitive proximity, i.e. access to similar reference knowledge bases and similar knowledge absorption capacity.

Cognitive proximity involves knowledge shared (Cramton, 2001) by the partners, which is particularly important when conducting research together. The more efficiently organizations communicate, the more similar reference knowledge they have. Cognitive proximity has a positive impact on the speed and accuracy of communication, but also determines its scope (Nooteboom, 2000). The cognitive dimension of proximity is correlated with the learning process much more than geographic or organizational proximity (e.g. collaborative learning to ensure the development of smart specialization of the region) (Orlando, Verba et al., 2019). Institutional proximity, understood as the degree of similarity in institutional conditions, can also be an important catalyst for the process of shared learning, but it is not beneficial in every situation. The greater the institutional proximity, the better the conditions for knowledge transfer and interactive learning; however, excessive institutional proximity can create barriers to efficient operation and introduce certain routines (Czakon, 2010). In the case of cooperation between universities and companies, diversity of experience can be a far greater advantage than institutional proximity. Social proximity, on the other hand, is a invariably important factor. Social relations are the natural environment for the development of economic interactions. Social and economic structures influence each other through the interpenetration of human relationships, similarities, and common activities and experiences. The greater the social proximity, the more efficient the learning, as demonstrated, for example, by communities of practice (Molina-Morales, Martínez-Fernández, 2010). However, the literature also points to the dangers of elimination of opportunistic behaviors from cooperation (Karpacz, 2014), and of unchanging functioning in a closed set of relationships, which limits the inclination and ability to go beyond established behavioral patterns (Oerlemans, Meeus, 2005).

A special determinant of inter-organizational cooperation between companies in the chemical sector and universities is the aforementioned ability to absorb knowledge. It is defined as the ability to recognize new external information, assimilate it, and use it for specific purposes, including business ones (Lane, Lubatkin, 1998). From the point of view of an organization that acquires external knowledge, inter-organizational cooperation is

dependent, among other things, on the recognition of the value of the partner's knowledge and the possibilities of its acquisition, assimilation, processing, and use. In an inter-organizational setting, the ability to absorb external knowledge depends on the type of knowledge to be absorbed and the similarities between the cooperating organizations in terms of organizational structures and conditions (Lis, 2017). This view alludes to the importance of organizational proximity in inter-organizational cooperation. In the context of knowledge absorption, it is worth focusing on the partner who shares knowledge. Whether the partner is willing to disclose its knowledge and share it is an important determinant of the effectiveness of the learning process of the recipient of that knowledge. Positive behavior of the provider of knowledge that supports the recipient's learning increases the effectiveness of inter-organizational learning. Therefore, a greater degree of transparency in knowledge transfer promotes improved learning outcomes for the knowledge recipient. An organization that is highly open to learning is more persistent in learning than an organization characterized by limited openness. It is not easy for the former to give up the opportunity to learn even when frustrations and challenges arise (Nogalski, Karpacz et al., 2014). The essence of effective cooperation between companies in the chemical industry and universities is therefore to ensure as much openness to collaborative learning as possible in the organizations.

## 4. Methodology of the research process

The research methodology in general indicates how to build a theory, while in specific terms it defines a detailed research procedure for the objects studied by a specific discipline. Therefore, the areas of interest of methodology include research methods, according to which certain patterns of individual research activities are carried out (Stachak, 2006; Sosenko, 2008; Apanowicz, 2000).

The research process began with an in-depth study of domestic and foreign literature in the science of management and quality. A search of the literature made it possible to identify the research area, recognize the scope of the subject matter, determine the definitions relevant to the topic under consideration, as well as acquire and consolidate information on knowledge management, relationship management, interorganizational cooperation, and collaboration.

Therefore, it would not be possible to achieve the main objective of the study without developing an appropriate research procedure. Accordingly, the authors reviewed methodological approaches, as well as research methods and techniques to help solve the research problem posed. They recognized that in pursuit of in-depth and comprehensive results on how universities in Poland form long-term relationships with businesses, it is reasonable to adopt the research strategy of methodological pluralism. Therefore, the study used an integrated research approach, which included both direct interpretive and positivist research procedures.

This required qualitative and quantitative research, as well as the development of various research tools (IDI, FGI, and CATI interview questionnaires). Also indicated are statistical analysis methods (including the factor method and the structural equation modeling method) and their applications, which can help managers make important decisions on establishing and strengthening ties with other business entities.

## 5. Relationships between universities and companies in the chemical sector in light of the results of quantitative research

According to the authors' earlier findings, the relationship between a university and chemical sector companies should be formed on the basis of value, the sources of which include the knowledge offered by universities. According to F.E. Webster, the basis of the marketing activities of an organization (including a university) is the process of defining, developing, and delivering value to clients (university's stakeholders) (Webster, 2002). Therefore, it is worth taking a closer look at how the respondents perceive the cooperation between companies and universities, what the source of value for companies cooperating with universities is, and how the existing relations between these entities are evaluated.

As part of a CATI interview with representatives of 350 chemical sector companies cooperating with universities, the respondents were asked to evaluate nine statements regarding their perceptions of the activities of universities. The averaged opinions of the respondents divided into those concerning micro (black line), small (red line), medium (blue line), and large companies (green line) are shown in Figure 1. Very importantly for the process of formation of long-term relations between universities and companies, for each of the statements (with one exception, where the average was 4.5), the average on the seven-point scale was between two categories: "I rather agree" (5) and "I agree" (6), which indicates that the level of acceptance of the presented beliefs is high (see Fig. 1).

The information presented in Figure 1 shows that the opinions of respondents representing micro, small, medium, and large companies do not differ significantly. Statements on a broadly defined involvement of universities in activities for the benefit of their environment, as well as the quality of education they offered, were rated the highest. The issue that raised the greatest concern was the causal power of universities, understood as their impact on the socio-economic development of their municipalities, cities, and regions.

| No. | Statement (variable)<br>(To what extent do you agree or disagree with the content of the following statements?) | Averaged ratings on a scale of 1 to 7<br>(Where 1 means "I strongly disagree" and 7 means "I strongly agree") |
|---|---|---|
| 1 | The university has a strong impact on the socio-economic development of the surrounding area | |
| 2 | The university uses modern technology in education and science | |
| 3 | The university educates highly qualified graduates | |
| 4 | The university creates innovative solutions for the society and the economy | |
| 5 | The university disseminates modern technologies | |
| 6 | The university is committed to the digital transformation of the society and the economy | |
| 7 | The university works for the benefit of integration and social cohesion | |
| 8 | The university engages in socially useful activities | |
| 9 | The university engages in activities for the benefit of environmental protection | |

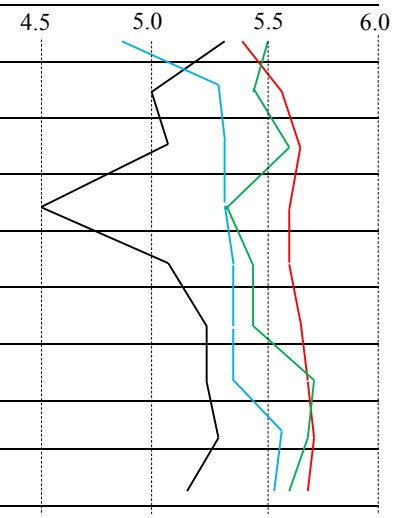


**Figure 1.** Perceptions of universities among the surveyed representatives of companies that cooperate with universities (black line - micro, red line - small, blue line - medium, and green line - large companies)

Source: own research.

On the other hand, Figure 2 shows the average score concerning the strength of the relationships that exist between universities and chemical sector companies on a five-point scale (where 1 means that the relationships between a university(-ies) and companies are very weak, while 5 means that they are very strong). The white bars in Figure 3, on the other hand, indicate the company's desire to further strengthen its relationship with a university(-ies) (based on a specific form of cooperation) in the future (where 1 means that strengthening of the relationship is highly undesirable and 5 means that it is highly desirable).

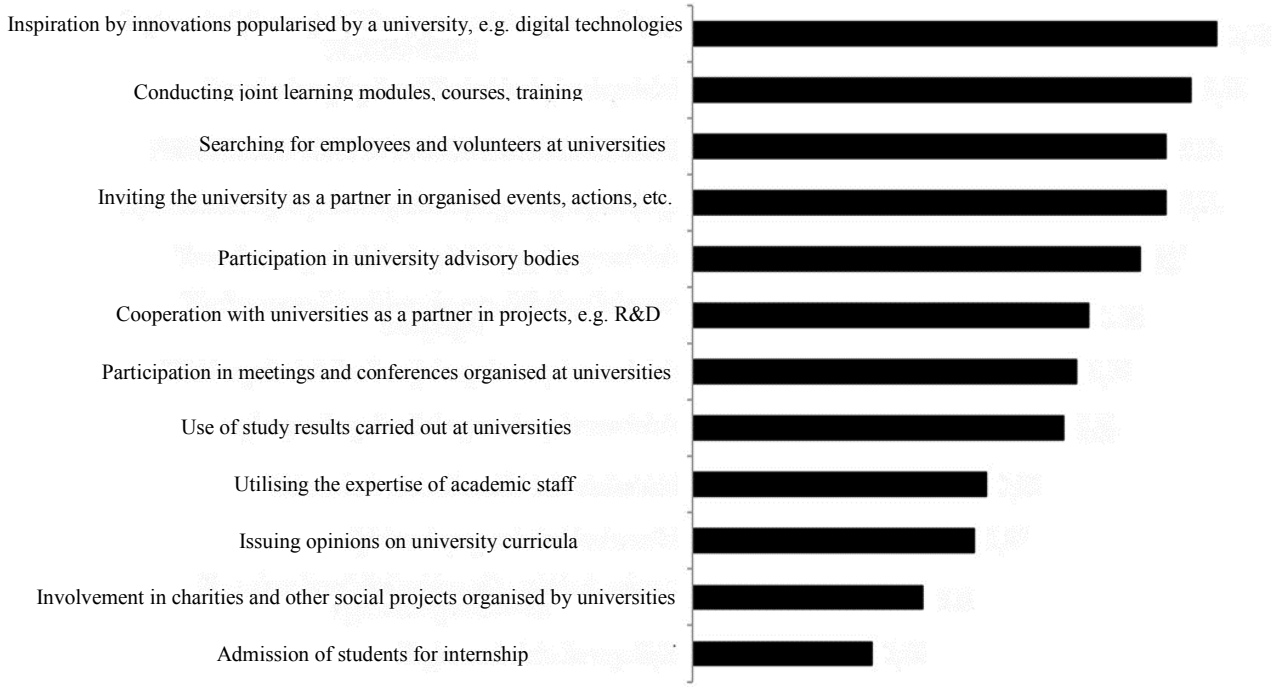


**Figure 2.** Relationships between companies and universities as assessed by the surveyed entities.

Source: own research.

The averaged opinions presented in Fig. 2 indicate that the strongest relationships were observed among those surveyed companies that undertake the following forms of cooperation with universities:

- getting inspired by innovations that are disseminated by the university, such as new digital technologies,
- conducting joint educational modules, courses, and training,
- searching for employees or volunteers at universities,
- inviting a university to be a partner in events, campaigns, etc. organized by the company; and
- participation in advisory bodies operating at universities.

In contrast, the weakest relationships with universities were noted among the companies involved in charitable and other social activities organized by universities, as well as those providing internship programs for students.

An in-depth analysis of the collected material additionally demonstrated that a half of the respondents rated the relationships of their chemical sector companies with universities as strong, a similar group rated them as neutral or ambivalent, while only 3% of the respondents declared weak relationships. The overall average on a scale of 1 to 5 was 3.49, which means that the declared strength of the relationships with universities was between the ambivalent (3) and moderately positive (4) response categories. Of note is the fact that the opinions obtained are slightly polarized, which means a predominance of moderate opinions over extreme ones (positive or negative). Based on the data, it can also be concluded that the strength of the relationships is positively influenced by the size of the organization (the number of employees), the length of the cooperation period, and the number of universities with which the company cooperates.

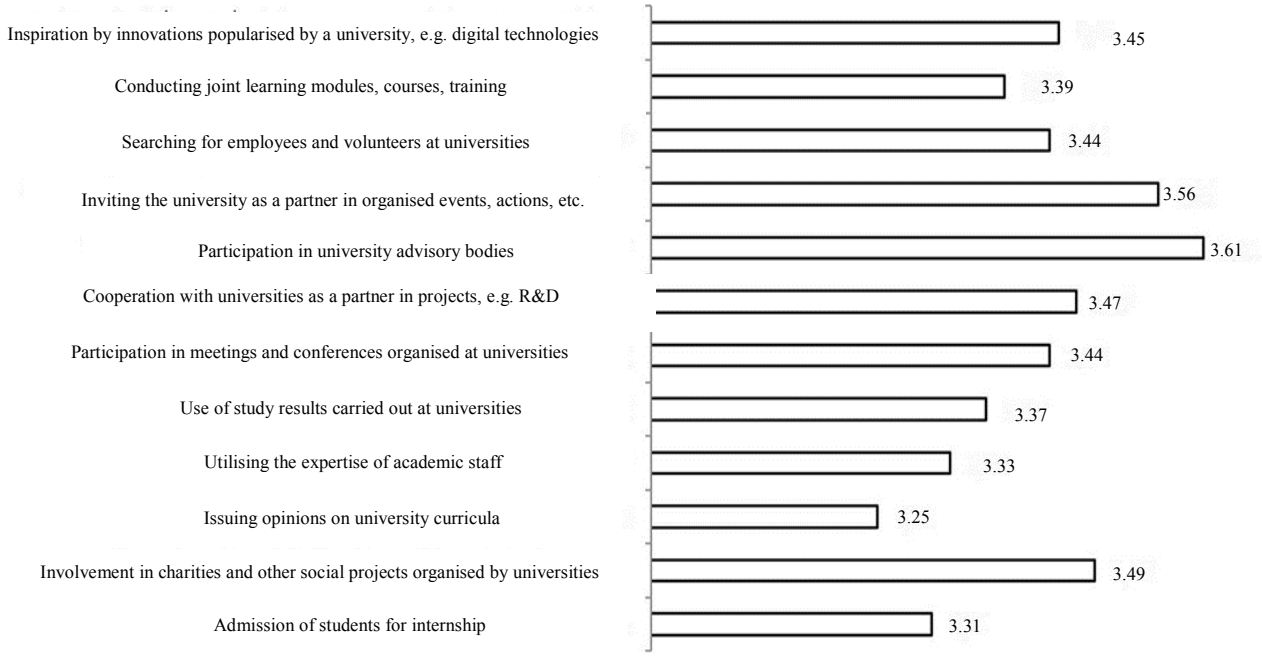


**Figure 3.** Willingness to further strengthen the company's relationship with a university(-ies).

Source: own research.

The data presented in Fig. 3 shows that the entities that are most interested in strengthening their relationships with universities are those that are involved in advanced forms of cooperation with universities: they participate in advisory bodies operating at universities (score of 3.61) and invite universities as partners in projects, campaigns, etc. they organize (3.56). An in-depth analysis of the collected data additionally shows that nearly 66% of the respondents wanted their relationships with universities to be "neither strong nor weak" in the next few years, while 30% expected stronger ties (mostly moderately strong). Increasing the strength of the relationships was primarily expected by those representatives of companies who rated their existing relationships as strong (52% in this group, the average rating was 3.6), cooperate with 2-3 universities (45%), and had maintained relationships with universities for 4-5 years (38%).

The representatives of the surveyed chemical sector companies were also asked whether they were satisfied with their previous cooperation with universities; the distribution of the responses given by representatives of micro, small, medium, and large companies is shown in Table 2.

**Table 2**.
*Degree of satisfaction of the representatives of the surveyed companies with the cooperation with a university(-ies)*

| No. | How satisfied are you with your company's cooperation with a university(-ies)? | Company | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Micro N = 15 | | Small N = 195 | | Medium N = 105 | | Large N = 35 | | Total N = 350 | |
| | | lb | % | lb | % | lb | % | lb | % | lb | % |
| 1 | very satisfied (5) | 5 | 33.3 | 89 | 45.6 | 30 | 28.6 | 19 | 54.3 | 143 | 40.9 |
| 2 | rather satisfied (4) | 8 | 53.3 | 94 | 48.2 | 66 | 62.9 | 15 | 42.9 | 183 | 52.3 |
| 3 | neither satisfied nor dissatisfied (3) | 2 | 13.3 | 11 | 5.6 | 7 | 6.7 | 1 | 2.9 | 21 | 6.0 |
| 4 | rather dissatisfied (2) | 0 | 0.0 | 1 | 0.5 | 1 | 1.0 | 0 | 0.0 | 2 | 0.6 |
| 5 | very dissatisfied (1) | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 | 0 | 0.0 |
| 6 | I don't know/It's hard to tell | 0 | 0.0 | 0 | 0.0 | 1 | 1.0 | 0 | 0.0 | 1 | 0.3 |
| 7 | SATISFIED (4+5) | 13 | 86.7 | 183 | 93.8 | 96 | 91.4 | 34 | 97.1 | 326 | 93.1 |
| 8 | DISSATISFIED (1+2) | 0 | 0.0 | 1 | 0.5 | 1 | 1.0 | 0 | 0.0 | 2 | 0.6 |
| Total | | **15** | **100.0** | **195** | **100.0** | **105** | **100.0** | **35** | **100.0** | **350** | **100.0** |
| Arithmetic average | | **4.2** | | **4.39** | | **4.2** | | **4.51** | | **4.34** | |

Source: own research.

The data compiled in Table 2 shows that the degree of satisfaction of chemical sector companies with cooperation with universities is high (the answer "very satisfied" and "rather satisfied" was selected by a total of 93.2% of the respondents, of which 40.9% indicated the highest possible rating (5 on a scale from 1 to 5, where 1 means "very dissatisfied" and 5 means "very satisfied")). Interestingly, a significantly higher degree of satisfaction (98%) was noted in the group of companies involved in more advanced forms of cooperation with universities, such as conducting joint educational modules, courses, or training. The vast majority of the respondents believed that the benefits of cooperation between their companies and universities were shared by both parties in equal proportions (Table 3). This opinion was most common among the representatives of small companies with 10-49 employees (88.2%). Eight percent of the respondents believed that the beneficiaries of cooperation between companies and

universities were primarily companies; most of those respondents declared maintaining strong relationships with universities (11%) and expected to strengthen these relationships in the next few years (12%).

**Table 3**.

*The party that benefits more from cooperation between universities and companies*

| No. | Who benefits more from cooperation between universities and companies? | Company | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Micro N = 15 | | Small N = 195 | | Medium N = 105 | | Large N = 35 | | Total N = 350 | |
| | | lb | % | lb | % | lb | % | lb | % | lb | % |
| 1 | universities | 0 | 0 | 3 | 1.5 | 4 | 3.8 | 3 | 8.6 | 10 | 2.9 |
| 2 | companies | 1 | 6.7 | 14 | 7.2 | 8 | 7.6 | 5 | 14.3 | 28 | 8.0 |
| 3 | both parties equally | 13 | 86.7 | 172 | 88.2 | 84 | 80.0 | 27 | 77.1 | 296 | 84.6 |
| 4 | I don't know/It's hard to tell | 1 | 6.7 | 6 | 3.1 | 9 | 8.6 | 0 | 0.0 | 16 | 4.6 |
| Total | | **15** | **100.0** | **195** | **100.0** | **105** | **100.0** | **35** | **100.0** | **350** | **100.0** |

Source: own research.

The respondents were then asked about universities' resources that were most desirable to chemical sector companies. The averaged respondents' opinions, expressed on a scale of 1 to 7 (where 1 means "very undesirable resources" and 7 means "very desirable resources") are shown in Figure 4.

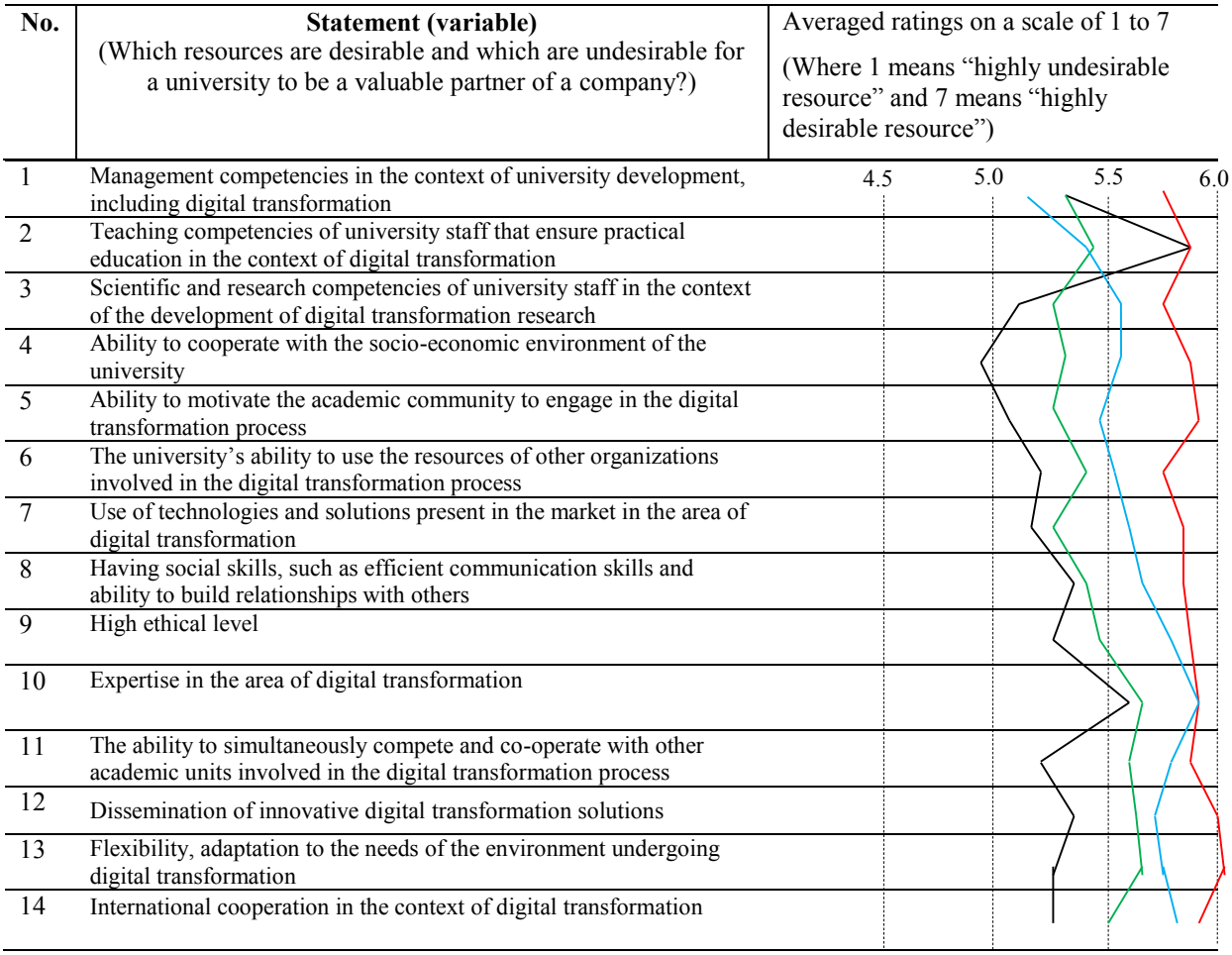


**Figure 4.** The desirable resources of universities (black line - micro, red line - small, blue line - medium, and green line - large companies). Source: own research.

The respondents most often considered as desirable universities' resources related to scientific knowledge and broadly defined social skills, as well as relationship-building skills. The top places in the ranking were occupied by both issues related to the universities' expertise and competencies, as well as certain characteristics of the so-called organizational culture, such as flexibility and openness to change. Once again, the opinions of representatives of micro, small, medium, and large companies did not differ significantly.

## 6. The impact of knowledge on establishing and strengthening the link between universities and chemical sector companies

Before starting to determine the impact that knowledge (of which universities in Poland are a "transmitter") has on the propensity of chemical sector companies to establish and strengthen their ties with universities, it was necessary to define the components of those technologies that are the most important in the process of formation of long-term relationships. These components, in the form of appropriately selected statements, would be used to study the relationships between universities and companies.

**Table 4**.
*Arrangement of the factor loads for the variables concerning the propensity of companies to establish and strengthen their ties with universities*

Method of identifying factors - principal components. Rotation method - Varimax with Kaiser normalization.
a. The rotation reached convergence in 3 iterations.

| Statement (variable) | Factor | |
|---|---|---|
| | 1 Strengthening ties | 2 Establishing ties |
| I would like to create joint international projects with selected universities | **0.810** | |
| I would like to create joint research and development projects with selected universities | **0.781** | 0.398 |
| I would like to have an influence on the educational offer, fields of study, and curricula of selected universities | **0.764** | 0.305 |
| I would like to create joint business projects with selected universities | **0.744** | 0.392 |
| I would like to benefit from the expertise and advice of selected universities | | **0.775** |
| I would like to use the results of research conducted by selected universities for the development of my company | 0.368 | **0.754** |
| I would like to use the modern technologies disseminated by selected universities | 0.409 | **0.728** |

Source: own research.

The data shown in Table 4 indicates that the seven input variables were assigned to two factors, which can be described as follows:

- factor 1: a desire to strengthen ties with universities, focused on more in-depth cooperation and implementation of joint projects, requiring the involvement of both parties, a good understanding of organization and processes, a relationship based on trust and interaction between the two entities (universities and companies),

- factor 2: intention to establish ties with universities, involving simple forms of cooperation and use of the university's expertise, without the need for a high level of commitment on the part of the company or for advanced cooperation.

As a conclusion for the results of the study, it should be stated that the value derived from knowledge positively influences the establishment and subsequent strengthening of the ties between universities and companies. Therefore, it can be assumed that this knowledge (in particular, solutions in the area of digital technologies that focus on monitoring and automation of processes, data integration, and *big data* analytics, as well as data protection and cybersecurity) can be applied in the process of formation of long-term relationships between universities and companies.

As a comment to the final results of the quantitative study, it should be stated that the main research hypothesis that was to be verified, namely that a university's knowledge has a stimulating (positive) effect on the propensity of companies to establish and maintain multidimensional inter-organizational cooperation, has been confirmed**.**

## 7. The main problems in the process of formation of relationships between universities and chemical sector companies based on knowledge in the light of the results of the qualitative research

The qualitative research conducted using the interview method in the form of individual in-depth interviews (IDI) involved 15 experts - representatives of universities who were directly involved in shaping relations between universities and institutional stakeholders (enterprises) (Table 5).

**Table 5.**
*Basic information about the conducted qualitative research (IDI)*

| Specification | Research |
|---|---|
| Research method | Interview |
| Research technique | Individual In-depth Interview (IDI) |
| Research tool | Individual in-depth interview scenario |
| Sampling | Purposeful (representatives of HEIs directly involved in the cooperation of HEIs with institutional stakeholders, in particular in the cooperation between science and business) |
| Sample size | 15 persons |
| The spatial scope of the survey | Silesian voivodship |
| Date of survey | May-June 2020 |

Source: own research.

As part of the qualitative research, four focus group interviews (FGI) were also conducted. The interviews were divided into two thematic sessions carried out in parallel in two groups - with representatives of companies that cooperate (group one) and do not cooperate (group two) with universities. Six experts participated in the interviews (Zoom platform) in each group - managers, employees co-responsible for making decisions regarding the company's development. Only persons representing entities employing at least 10 employees were recruited for the interview, in each group there were persons representing entities employing more than 50 employees, these were representatives of enterprises based in the area of Masovian, Silesian and Świętokrzyskie voivodeships.

Session two (repeated group interviews) (Zoom platform) involved the same people who participated in session one. The basic characteristics of the qualitative FGI study are presented in Table 6.

**Table 6.**
*Basic information about the conducted qualitative research (FGI)*

| Specification | Research |
|---|---|
| Research method | Interview |
| Research technique | Focus Group Interview (FGI) |
| Research tool | Focus group interview scenario |
| Sampling | Target<br>Group 1 (representatives of enterprises which cooperate with universities)<br>Group 2 (representatives of enterprises which do not cooperate with universities) |
| Sample size | 2 FGI x Group 1 (6 people)<br>2 FGI x Group 2 (6 people) |
| The spatial scope of the survey | Masovian, Silesian and Świętokrzyskie Voivodships |
| Date of survey | October 2020 |

Source: own research.

According to the surveyed representatives of universities, cooperation between universities and chemical sector companies arises primarily from the need for a transfer of knowledge and technologies (including digital technologies), which are then developed in companies during the process of commercialization of goods and services. The majority of the respondents felt that the formation of long-term relationships between universities and micro, small, medium, and large companies alike led to the creation of additional value that is important to both the companies and the universities. Importantly, the shaping of relationships between universities and companies was defined by the respondents as the process where universities influence the propensity of companies to establish and strengthen their ties with the universities. At universities, the process most often requires proper management of cooperation agreements (e.g. for the admission of students for internships) and of science-business consortia, as well as the transfer of knowledge and digital technologies.

In the case of chemical sector companies, in the opinion of the respondents, the activities that initiate cooperation with universities mainly involve the performance of tasks that lead to an improved innovation and competitiveness of those companies based on the results of the scientific and research work conducted at the universities. This is because the managers of these companies realize that faster organizational development can be achieved by combining the resources of companies and universities. On the other hand, according to the respondents, universities wishing to conduct groundbreaking research must seek corporate funding. The university employees surveyed also said that universities' initiatives to establish cooperation with chemical sector companies generates a *push* strategy whereby digital technology offerings and research results are "pushed" into the market. Companies, on the other hand, apply the *pull* strategy by seeking partners in the academic sector. They "pull" the results of research, thus raising its importance, which increases the attractiveness of the university in the market for higher education services. At the same time, the surveyed university employees responsible for science-business cooperation considered medium-sized companies to be the best partners. This is because these companies show both great interest in cooperation with scientific centers and have adequate financial, market, structural, personnel, intellectual, and social resources to commission research on new technologies, as well as to implement their results. At the same time, the resources of medium-sized companies are not large enough for them to carry out research and implementation work on their own.

The respondents additionally pointed out that one of the primary ways in which universities cooperate with chemical sector companies involves implementation of educational programs using the actual activities carried out by companies as a complement to, or extension of, the knowledge gained at the university. Through active involvement in the work of these companies, students and young scientists gain practical skills regarding the use of the knowledge they acquired at the university. This knowledge, in turn, is of particular value if it can have a direct effect on a company that accepts students and graduates for work. Cooperation between universities and companies also very often takes the form of so-called academic entrepreneurship. The establishment of technology and entrepreneurship incubators, followed by *start-ups* launched by university students and graduates (based on knowledge and research results obtained in scientific centers), is an important element of cooperation between universities and micro, small, medium, and large companies. According to those surveyed, supporting the so-called *spin-off* companies and thereby disseminating research results through academic entrepreneurship should be a priority activity linking universities to chemical sector companies.

On the other hand, according to the surveyed representatives of universities, the key issue that influences the willingness to establish or strengthen ties between chemical sector companies and universities is the value category, the sense of mutual benefit, which should be measurable and tangible for the partners. However, some of the surveyed representatives of companies that do not cooperate with universities had negative experiences with cooperation

with universities: “the university sends students for an internship, they come to do the internship, and the company does not create any lasting value in this way [...], the benefits are only for the other party...” A similar argument is used by those representing business entities that cooperate with universities. Meanwhile, it is a relationship based on mutual benefits that is the source of satisfaction derived from this kind of cooperation. In other words, the one-way benefit model discourages companies from establishing relationships with universities, negatively affects the satisfaction levels, and discourages strengthening these relationships. Another important aspect is the constancy and longer-term perspective of the cooperation, which, in the opinion of those surveyed, should not be action-oriented or ad hoc, and the desirable model is to build cooperation in a systemic way (through process-based phased activities aimed at forming long-term relationships). According to the surveyed representatives of companies, university graduates are an important link between companies and universities. The respondents recognized that it is the relationships between graduates (employed at companies) and universities that is very often the starting point in the process of formation of relationships between chemical sector companies and universities.

With reference to the qualitative research and the posed research question of how knowledge fosters inter-organizational cooperation between universities and chemical sector companies, it should be stated that the operation of a university depends on a number of factors that influence the formation of long-term relations between the university and companies. As discussed herein, these factors may be due, among other things, to poor transformation capabilities, including the inability to meet increasing technological requirements, which both universities and the chemical sector companies working with them are aware of. In the authors’ opinion, knowledge-based entrepreneurial universities with a combined economic, market, innovation, and management focus are far better prepared to offer knowledge as an attractive product and the value that comes with it, so they also perform better in the process of formation of long-term relationships with companies. Indeed, knowledge-based entrepreneurial university very often have the organizational capacity to anchor their activities in the market and competitive environment. They can also more quickly identify and develop knowledge-based competitive advantages (related, among other things, to digital education and research activities), which are in turn a magnet attracting potential business partners.

## 8. Conclusion

Although the influence of knowledge as a determinant of organizational development has never been put in question, the increasing turbulence of the environment, the growing demands of the market players, and finally the instability of the needs associated with, among other things, rapid technological advances, make its importance in the third decade of the 21st century take on a whole new dimension.

However, the research conducted for this paper leads to the conclusion that a significant number of higher education institutions in Poland are not very well prepared to transfer knowledge externally to those companies that implement innovations in an open model (in particular, knowledge about digital technologies). In the authors' opinion, it is equally important that the transfer of knowledge from the outside to universities is also far too rare if it is the university that plans to implement innovations. In addition, the research shows that there are still strong habits in the cooperation between universities and companies related to one-way knowledge transfer that do not foster the new approach (discussed herein), i.e. co-creation of value, leading to incremental growth of knowledge for both partners in the relationship. In order for co-creation leading to the growth of knowledge to be possible, it is necessary to draw from various sources of external and internal knowledge. This, in turn, requires both university authorities and business managers to be able to find a proper balance between the depth and breadth of the search for knowledge, which can often involve an adoption of a strategy of market specialization.

As demonstrated in this paper, the distinguishing feature of a university as an entrepreneurial, knowledge-based organization is its interaction with companies in various forms of inter-organizational cooperation, which may involve the achievement of at least one of the three academic missions: education, scientific and research activities, and creation of mutual relations with the environment. Each of these missions may involve other applications of knowledge, including on digital technologies, such as in academic training, research, or performance of application projects. At the same time, the complete achievement of each of these missions also requires reliance on practical knowledge and experience that the university draws from the environment, among others from companies, including those from the chemical sector. In other words, cooperation between a university and a chemical sector company is about transferring knowledge to the outside and drawing knowledge from the outside, which can be done on a market basis or as an activity related to the social responsibility of academia. As demonstrated in the article, inter-organizational cooperation between a university and a chemical company requires ensuring symmetry in the partners' structures and management methods, as well as overcoming differences in their organizational cultures that affect the course and results of their activities. Other conditions that, in the authors' opinion, should be taken into account in order to successfully shape long-term relationships between universities and business entities are organizational proximity, cognitive proximity, institutional proximity, and social proximity.

This scientific argument clearly shows the prospects for the development of inter-organizational knowledge-based cooperation between universities and companies in the chemical sector, which leads to the conclusion that the main objective of the paper has been achieved. On the other hand, a comparison of the results obtained with the solutions presented herein should fully contribute to the clarification of the adopted research problem, which concerns the determination of the importance of the impact of knowledge on the inter-organizational cooperation between universities and chemical sector companies.

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# IDENTIFICATION OF THE NEEDS OF USER EXPERIENCE DESIGNERS IN ORGANIZATIONS

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**Purpose:** The purpose of this article is to identify the needs of User Experience (UX) designers in organizations.
**Design/methodology/approach**: In the theoretical part, the author uses a literature review to analyse the literature in the area of User Experience, requirements engineering, and also refers to selected stages of project management in organizations. The empirical part uses a qualitative method - in-depth interviews. The author developed a scenario and the goals she wants to achieve by interviewing User Experience designers.
**Findings:** The needs of User Experience designers have been identified in four areas: the division of the UX/UI position, the essence of design system, communication with the client and the design process in the organization. Most respondents value the lack of division of the UX/UI designer position. UX designers need regular meetings with the client and understanding of the individual stages of design by the client. Designers would also like to be able to conduct their own research with users and maintain constant contact with developers. In addition, respondents emphasize the need to develop a design system in the organization.
**Research limitations/implications**: In future research, the author would like to conduct research with User Experience designers from other countries and conduct a comparative analysis of the collected results.
**Practical implications:** The conducted research indicates the needs of User Experience designers in organizations. After reading the article, project managers should consider whether the problems identified can be noted in their companies as well. Finding solutions to these problems may result in improved working conditions and, consequently, in the construction of better end products.
**Originality/value:** The key value of the research carried out as part of the article is the identification of current problems of User Experience designers. Project managers, after getting acquainted with the requirements, problems of UX designers, will be able to make changes in organizations.

**Keywords:** User Experience (UX), requirements elicitation, project management.

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

## 1. Introduction

The changing environment in which contemporary organizations operate requires high adaptability (Sepioło, Olszowy, Kucwaj, 2022; Ławniczak, 2022). Adapting an organization may involve adapting to new ways of managing projects or creative ways of solving problems. Project management itself has become an integral part of the contemporary organization (Puto, 2022).

User experience (UX) design is closely related to the topic of project management. A common reason for project failure is a lack of focus on the user during the design process (St. Peter, 2015). The role of a UX designer in an organization is to maintain the relationship with the user and to ensure that the user has a positive experience in the use of the product. In addition, designers can also assist the organization in selecting the project management methodology (Mara, Jorgenson, 2015). Understanding the relevance of User Experience allows organizations to identify gaps in the business and how to fill them (Furniss, Curzon, Blandford, 2018).

The first task of the User Experience designer is the gathering of user requirements (Łuczak, 2022). However, when considering the requirements elicitation process, people usually unconsciously think about the users' requirements for the product. People in the position of User Experience designers also have their requirements. Meeting these requirements can determine the quality of UX in a given project.

In this context, the following question can be formulated: What are the needs of User experience designers in organizations? The author has also formulated supporting questions:

(RQ1) What are UX designers' preferences in the area of splitting the User Experience/User Interface designer position?

(RQ2) What are the needs of User Experience designers in terms of communication with clients?

(RQ3) What are the needs of User Experience designers regarding the design process in the organization?

(RQ4) How do User Experience designers evaluate the design system concept in the organization?

The aim of the article is to identify the needs of User Experience designers in organizations. In order to achieve the stated aim, the author used a method such as a literature review and in-depth interviews.

## 2. Literature review of the area

The origins of the interest in User Experience can be traced back to the 1950s (Nielsen, 2017). Among the related fields to User Experience over the years, authors distinguish between user-centred design (UCD) and human-centred design (HCD) (Karat, 1997; Gabbard, Hix, Swan, 1999; Kraft, 2012; Lowdermilk, 2013; Rose, Björling, Kim, Alvarez, 2018; Farooqui, Rana, Jafari, 2019). HCD can be defined as an approach to design system in which user interactions are designed with human factors, ergonomics, and usability in mind (International Organization for Standardisation [ISO], 2019).

In contrast, the term UCD is defined as an approach to design system that enables an organization to create a product that meets user requirements (Lowdermilk, 2013). In practice, the terms UCD and HCD are used interchangeably. However, the term human-centred design indicates that it is worth considering not only users but also non-user stakeholders (ISO, 2019).

Defining User Experience in a single way is not possible. Over the years, authors have formulated the definition of UX in a variety of ways (Hassenzahl, Tractinsky, 2006; Krug, 2013; Allam, Razak, Hussin, Dahlan, 2013; Norman, 2013). In the context of IT products, User Experience can be defined as the users' impressions and reactions resulting from using or imagining using a system (ISO, 2019). In contrast, one of the pioneers of User Experience design, Don Norman, defines User Experience as all aspects of the end users' interaction with an organization, its services, and its products (Babich, 2020).

When considering the topic of User Experience design, it is also important to mention User Interface (UI) design. UX/UI designer is often listed in job adverts. However, there is a difference between the two roles. The UI designer is primarily responsible for the User Experience as it relates to visual elements. The UI designer designs the graphical appearance of interfaces and the transitions between them (Lamprecht, 2022). It should be emphasised that in an organization, the UX and UI designers should work together to maintain product integrity.

In relation to maintaining consistency in the UX/UI domain, it is also important to provide a definition of a design system. A design system is defined as an elaborate set of standards used to manage design in a project, creating a common language and visual consistency (Fessenden, 2021). The benefits of using a design system include the aforementioned consistency, improved contact between designers and developers, and the collection of documentation in one place (Fanguy, 2019; Vesselov, Davis, 2019).

The User Experience design process cannot be seen as a separate component without links to other phases in the project. It is primarily linked to the requirements engineering phase. Requirements engineering can be defined as the process of eliciting, analysing, documenting, validating, and managing requirements (Ambreen, Ikram, Usman, Niazi, 2018). Requirements elicitation is one of the first tasks performed by UX designers at the beginning of the design process. There are various methods for requirements elicitation, including surveys, interviews,

workshops, and observations (Mościchowska, Rogoś-Turek, 2019; Chakraborty, Sarker, Sarker, 2010; Curcio, Navarro, Malucelli, Reinehr, 2018; Sutcliffe, Sawyer, 2013; Zowghi, Coulin, 2005; Carrillo De Gea, Nicolás, Fernández Alemán, Toval, Ebert, Vizcaíno, 2012). The collected requirements form the basis for the User Experience designer to design the User Experience. Furthermore, User Experience design has become the basis for different product design methodologies such as lean UX and agile UX (Gothelf, Seiden, 2021; Aarlien, Colomo-Palacios, 2020; Hartson, Pyla, 2018; Schwartz, 2013; Brown, 2012).

As a final step, it is also worth looking at the number of publications in the field of User Experience in the last 10 years (2012-2022). The author constructed the following search TITLE-ABS-KEY ('user experience' OR 'UX' ) and applied it to the Scopus database (Figure 1).

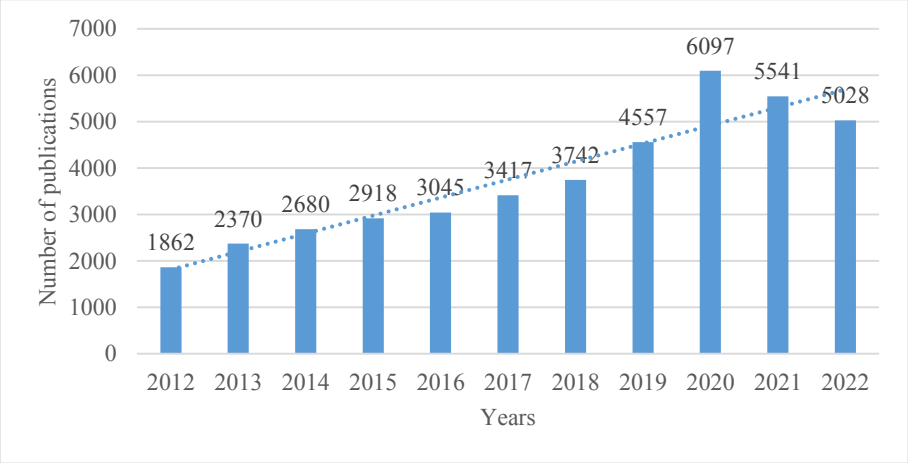


**Figure 1.** Number of publications between 2012 and 2022 in the Scopus database (research as at 31.01.2023).

Source: own elaboration.

An upward trend in the number of publications on User Experience can be observed between 2012 and 2020. From 2020 to 2022, on the other hand, there is a slight decrease in the number of publications; however, in both 2021 and 2022, there are still around 5000 publications on this topic.

In summary, as evidenced by the abundance of academic and industry publications, the topic of User Experience design is highly relevant in today's organizations. By putting the user at the center of the design process, organizations can create products that meet users' needs.

## 3. Research methodology

Using the literature review and in-depth interviews, the author developed the research procedure in the form of a flow chart (Figure 2).

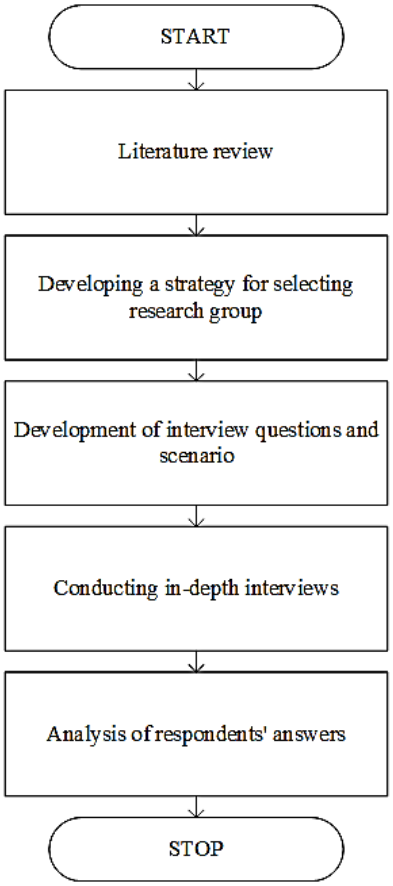


**Figure 2.** Research procedure.

Source: own elaboration based on: (Miński, 2017).

The first stage of the research procedure concerns the theoretical part of this article. The author conducted a literature review focusing on the area of User Experience, requirements engineering and project management in organizations. The systematisation of the main concepts in the chosen topic was the result of this stage.

The second stage of the procedure begins the empirical part of the article and consists in developing a strategy for selecting research group. Purposive selection was chosen by the author. The interviewees fulfil a specific criterion, which is their profession: they are User Experience (UX) designers in IT organizations.

The third stage of the procedure revolves around the development of the thematic blocks and the interview scenario. The author asked the interviewees questions on specific topics related to User Experience design, which will be presented later in the article.

The fourth stage of the research procedure is to conduct in-depth interviews with the respondents. The interviews took place via Microsoft Teams, Zoom and Google Meet platforms, depending on the respondents' preferences.

The final stage of the research procedure is the analysis of the respondents' answers. This is the subject of the next section of this article.

## 4. Analysis of the results of the conducted interviews

When analyzing the answers given by the in-depth interviewees, it is important to start by presenting the key data of the interviews. The in-depth interview was conducted between August and November 2022. A total of 10 people were interviewed. According to the selection strategy of the research group, they were people working as User Experience (UX) Designers in IT companies. The designers had different levels of seniority in the position, ranging from six months to four years (Figure 3).

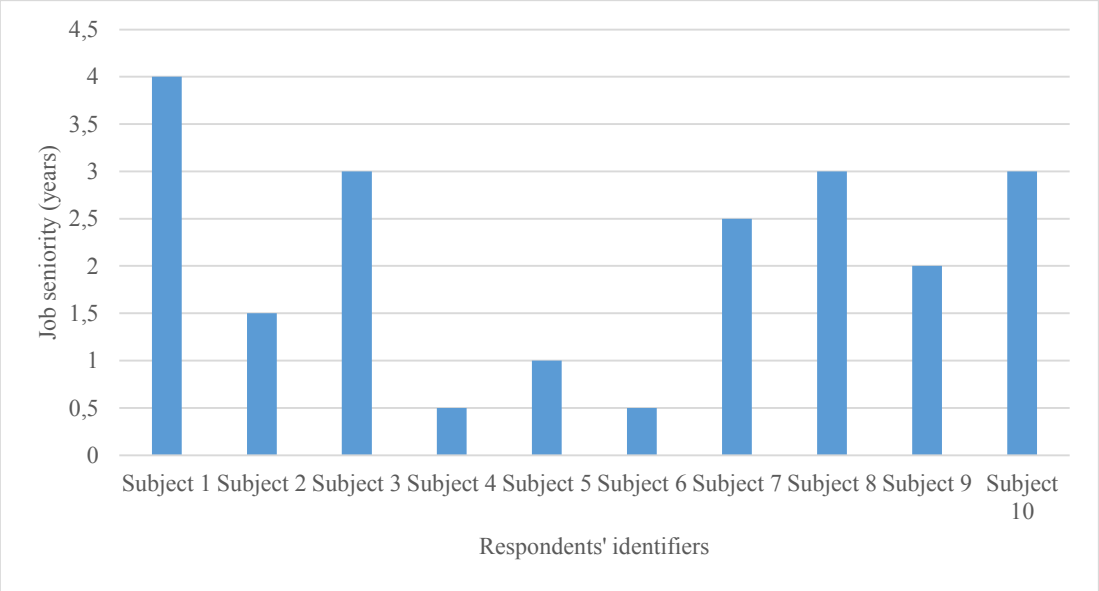


**Figure 3.** Job seniority of User Experience designers (in years).

Source: own elaboration.

The split between UX and UI designers was the first topic the author addressed in the interviews. Six interviewees stated that there is a UX/UI designer position in the companies they work for. Three interviewees answered that these are separate positions in the organization. One respondent working in two companies stated that one company has two separate positions, and the other performs both UX and UI designer tasks (Table 1).

**Table 1.**
*Split of the UX/UI position in the respondents' organization*

| Topic | UX/UI - is it separated in the organization? |
|---|---|
| 1. | It is one person. The UX designer must also have UI skills. |
| 2. | In one company - UX and UI - it is two people. In another company it is one person. |
| 3. | It depends on the project, usually it is one person. |
| 4. | It is one person, but sometimes one person does UX tasks, and one person does UI tasks. |
| 5. | It is two people - UX designer and UI designer. |
| 6. | It is one person. |
| 7. | UX/UI designer is one person. I think it should be separated. |
| 8. | UX/UI is one person. |
| 9. | It is split into two separate positions. |
| 10. | There are two positions - UX designer and UI designer. |
| 11. | |

Source: own elaboration.

The vast majority - eight designers - say that UX/UI positions should not be separated. They claim that a UX designer without UI skills will not do their job properly and vice versa. One respondent also states that the work they do has more to do with User Interface than User Experience. This is because clients do not want to spend money on research. Respondents also emphasize that a designer does not need to be a specialist in both areas. However, they should be familiar with aspects of both UX and UI. The split of the position is appreciated by two respondents. They have research skills and are not necessarily interested in the graphical aspects of interface design.

The second block of topics was the essence of currently popular design system. Respondents were asked for their opinion on design system - does it limit the designer's creativity or is it essential in today's organization. All the respondents were of the same opinion about the validity of having a design system (Table 2).

**Table 2.**
*Evaluation of the design system concept*

| Topic | Design system - kills creativity or is it necessary? |
|---|---|
| 1. | A design system should be created, but the designer should also be able to create his or her own components. |
| 2. | A component database is necessary because it speeds up the designer's work. |
| 3. | Design system allows to maintain integrity in projects. |
| 4. | It is essential - many people work on a project and the application needs to be consistent. |
| 5. | The design system is a big help - the designer is not an artist, but a contractor of a specific product for the client. |
| 6. | Design system is a very good option - the designer has a ready-made set of components; everything is clear to the developer and the designer. |
| 7. | We don't have a design system and I think this should be changed. |
| 8. | Design system can make the UX designer's job easier when he or she uses it correctly. |
| 9. | Design system is essential and definitely helps the designer. I think it will become a standard. |
| 10. | I think it is a necessary element in an organization - it takes time to develop it correctly, but the integrity in the design is worth it. |

Source: own elaboration.

Designers consider the design system to be a great convenience in their work, which allows them to maintain consistency in a project on which more than one person is working. Respondents also pointed out that a good UX designer should not be limited to components from the design system, as this can result in low-quality projects and, ultimately, professional burnout if his or her work is based solely on inserting ready-made components.

The next thematic block dealt with designers' problems in the area of communication with the client. At this stage, designers highlighted various elements of communication that can be problematic (Table 3).

**Table 3.**
*Problems identified in the area of customer communication*

| Topic | Communication with the client |
|---|---|
| 1. | Clients do not understand the mock-up stage. |
| 2. | Problem with time, arranging meetings. |
| 3. | Customer should be aware that once they accept wireframes, it will be difficult to make changes later. |
| 4. | Consultation with the client at the low-fidelity prototyping stage is essential. |
| 5. | The customer adds more work not in line with the contract. |
| 6. | Gathering requirements from the customer is problematic. |
| 7. | Lack of ability to do research outside the client organisation. |
| 8. | Client does not want to invest in research. |
| 9. | Client makes changes to the project after research has been carried out. |
| 10. | Client has very high expectations - I need to get to know them and understand what they really want. |

Source: own elaboration.

Clients' lack of understanding of the mock-up phase is one of the problems identified by designers. UX designers organize a meeting where they present wireframes/low-fidelity prototypes to the client. The result of such a meeting should be client acceptance of the prototypes. During the meeting, the client has the opportunity to ask questions, have suggestions for changes, or talk about their concerns. Some time later, the designers meet again to present the high-fidelity prototypes to the client, incorporating the changes made at the earlier meeting. At this stage, the client often realizes that they had imagined it differently and asks for changes, which can take a lot of time at this stage of the project.

The second problem is gathering requirements from clients. Respondents say that the client can change the requirements within a week after the designers have done some of the design work. Changing requirements leads to design changes. This lengthens the whole project process. There is also the issue of scheduling meetings with clients. Clients often cancel meetings due to lack of time.

Among the problems related to communication with clients, respondents also mention a lack of willingness to allocate funds for research. Usually, clients come to the organization with ready-made research results. Designers note that sometimes these requirements have been written without any research with users. Designers do not know the real cause of the problem, the need for the solution. They are forced to formulate reasons that may not be applicable in practice.

The last block of topics in the interview were the problems encountered during the design process in the organization. As in the case of communication problems with the client, the interviewees distinguished different problem areas (Table 4).

**Table 4.**
*Problems during the design process in an organization*

| Topic | Problems during the design process in an organization |
|---|---|
| 1. | Lack of in-house research. |
| 2. | Implementation process starts during design. |
| 3. | Testing on final prototypes. |
| 4. | Lack of opportunity to test with users. |
| 5. | Lack of clear way of creating documentation; no trainee supervision. |
| 6. | Lack of testing with users. |
| 7. | Lack of precise information about the commissioned task; no contact with developers. |
| 8. | Initial stages perform based on user's own perceptions. |
| 9. | Organization of tests with users. |
| 10. | I think the worst is the beginning and end of the project. |

Source: own elaboration.

Among the problems in this area, respondents point to the lack of opportunities for user testing. Furthermore, testing is often only carried out on final prototypes, and designers would like to be able to test wireframes as well. In addition, respondents again point to the problem of not being able to do their own research, which leads them to carry out part of the design process based on their own ideas.

One interviewee described the beginning and end of a project as the most difficult stages for UX designers. At the beginning a lot of different information must be taken in, the designer must focus on what value the product is going to generate for the customer. The designer then needs to communicate all this information to other team members. The end can also be a challenge when all the work must be handed over to the developers and provide them with carefully described files, mock-ups. Referring to the developers, the respondent also points to the lack of contact with the developers during the design process. Another related problem concerns the start of the implementation process already during the design process. The designer does not know the technical constraints, if a lot of changes occur, the team wastes a lot of time, and the company generates additional costs. Furthermore, the lack of a clarified way of creating documentation can also cause problems within the design team, both between designers and between the designer and developer.

Respondents also pointed out inaccurate information in the tasks assigned by the Product Owner. First, the designer needs information about the cause of the problem, then he or she will know how to solve it. At the stage of describing tasks, the Product Owner should precisely define the problem and its cause before assigning the task to the User Experience designer. UX designers also mention the lack of support in organizing the research from the company. The organization wanted to allocate as little money as possible to the research, so that in the end the research did not take place at all.

A significant problem in the organization indicated by one respondent is the lack of supervision of the intern. The User Experience designer indicated that no one supervised his projects, and the intern was obliged to organize meetings with the client and present designs, having no practice in this area.

The author's in-depth interviews with User Experience designers identified the needs of User Experience designers in organizations.

## 5. Discussion & conclusions

The research conducted for this article allowed the author to answer the main research question: What are the needs of User Experience designers in organizations? During the interviews, most of the designers' needs were identified in the area of the design process in the organization. User Experience designers' needs included the ability to conduct their own research and to improve communication between team members in the organization. In addition, novice User Experience designers should have the opportunity to interact with someone with more experience in this field within the organization. In formulating a detailed answer to this question, the author was helped by the supporting questions developed:

(RQ1) What are UX designers' preferences in the area of splitting the User Experience/User Interface designer position? Most respondents appreciate the lack of split of the UX/UI designer position. Designers believe that a good designer should have knowledge of both UX and UI to perform well.

(RQ2) What are the needs of User Experience designers in terms of communication with clients? Designers need regular meetings with the client. The client should also understand the different stages of the design. Systematic meetings allow designers to review each stage of the design experience and clients to understand the specifics and purpose of these stages.

(RQ3) What are the needs of User Experience designers regarding the design process in the organization? User Experience designers want to be able to do their own research to ensure that the user has a positive experience when using the product. In addition, designers feel the need to be in constant contact with developers to be aware of technical constraints in the designed solution. Among other needs, the author also highlights the need to receive accurate information from the Product Owner, including the cause of the problem the designer needs to solve.

(RQ4) How do User Experience designers evaluate the design system concept in the organization? User Experience designers feel that there is a need for a design system in the organization that ensures consistency in design and makes the work of designers and developers easier.

In future research, the author would like to conduct in-depth interviews with User Experience designers from other countries and make a comparative analysis of the collected results.

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# EVALUATING THE EFFECTIVENESS OF "CUSTOMER JOURNEY" TOOLS FOR SERVICE DESIGN IN ONLINE EDUCATION

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**Purpose:** The main purpose of this article is to describe an assessment of the effectiveness of the methods used in design thinking (DT) for service design. The analysis includes a tool that, due to the range of data used in service planning, is likely to provide reliable information for service optimization, namely the Customer Journey (CJ).
**Design/methodology/approach**: The key source of economic value is now considered innovation and the use of technological facilities to optimise ongoing economic processes. Such an approach enforces the need to develop methods that improve the efficiency of processes related to innovation generation. DT is considered to be one of them, in which, thanks to the methodology used, innovations are developed by design in an optimal way adapted to customers. One of the tools used in DT is CJ, which is a visualised description of the logical sequence of interactions between the customer and the service occurring at each stage of contact, allowing maximum customisation of designed products or services. Methods and tools are powerful insofar as they are subjected to evaluation, so it is important to evaluate the effectiveness of a given tool by those who use it. This article presents research on the evaluation of CJ effectiveness by the online education community, given the economic importance that the industry is increasingly gaining. Survey research was used because this type of research provides tools for analysing attitudes, views, and opinions and can be used for descriptive, explanatory, and exploratory purposes. The main research objective was to determine to what extent the DT and CJ methods were used and to evaluate their effectiveness in designing services in the remote education sector.
**Findings:** The survey showed that the surveyed group makes significant use of DT in the design of their services, in turn, among those who use DT, the vast majority are familiar with and use CJ. This may indicate, and the research confirms it, a high evaluation of CJ's effectiveness as a design tool. In addition, those who do not use CJ mainly cited lack of familiarity or lack of necessity (low complexity of the service being designed) as a reason, rather than a low effectiveness evaluation. These findings may indicate the high design potential of CJ and recommendations for its implementation.
**Research limitations/implications**: Regardless of the results obtained, it should be borne in mind that the high evaluation examined of the effectiveness of DT and CJ remains an opinion on the subject and not an objective fact, but this is a shortcoming that applies to all survey research. It should also be emphasised that the results obtained are limited in scope; as they

apply to a single industry, more general conclusions on the subject require extending the research to other sectors.
**Practical implications:** The research conducted in this article has a very practical dimension due to the subject itself, DT and CJ as a method of action and a concrete design tool are pragmatic in nature, so determining the evaluation of their effectiveness by practitioners, because such a group was surveyed, should be considered a measurable guideline for further implementation. In the present research, the scientific goal is combined with the pragmatic goal.
**Social implications:** Due to the fact that both DT and CJ are, by definition, aimed at maximising the matching of products or services to customers' needs, verification of their effectiveness makes it possible to assess their design potential and, in a broader perspective, to predict how much of the expected difficulties can be eliminated.
**Originality/value:** The most significant thing about the research conducted for this article is its contribution to filling the research gap on evaluating the effectiveness of methods and tools used in the service design process, as while DT is increasingly studied and described, there is still little research on the CJ, this study is a small contribution to changing that trend.

**Keywords:** Design Thinking, Customer Journey, Service Design, Online Education, Online Education Market.

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

## 1. Introduction

Attempting now to identify the most significant transformations characteristic of the business model in the 21st century, attention is drawn to the widespread use of information and communication technologies in economic life and the resulting optimisation every process taking place (Zygmuntowski, 2020; Śledziowska, Włoch, 2020). This is evident in the efforts to implement both the concepts of Industry 4.0 and Industry 5.0. However, we can consider permanent innovation as the real source of these transformations (Prokurat, 2016; Maik, 2016; Osika, 2017; Olko, 2017; Osika, 2019a), because according to the recognition of Paul Romer, the 2018 economic Nobel laureate, the most important among the innovations are those that serve to support the process of creating more ideas of the so-called meta-ideas because they are the ones that place their creators as leaders of economic development (Romer, 2008), thus forcing the need to recognise innovation as a foundation of economic value (Osika, 2019b; Boguszewicz-Kreft, 2021).

The planning of innovations and their effective implementation is associated with the need to develop strategies in which, so to speak, the use of specific methods of operation is inherent. The method of design thinking analysed in these considerations fits this need. Design thinking (DT) should be identified with a comprehensive approach to the design process, in which the needs and behaviour of the customer are placed at the centre of attention (Wojcichowska, 2020). The typical methodical action of DT implies the need to use specific tools that help identify problems, define them, generate ideas to solve them, and create prototypes to help evaluate

proposed solutions up to thorough testing. One such tool is the Customer Journey (CJ); it is used to analyse the customer's current experience during the entire contact with the brand, service, etc., and diagnose any weaknesses in the solution used. Often this analysis takes a visual form, in which case we speak of a customer journey map (Maik, 2017).

Based on the map, we can trace the customer's behaviour, the choices they made, along with the entire spectrum of emotions that accompanied the purchase or service, before, during, and after. What has so far remained in the realm of intuition for those involved in service design, thanks to tools such as CJ, can now be determined quite precisely. Due to the potential effectiveness of a tool like CJ in service design, it is proposed to determine to what extent it is used and how it is judged by those in the online education industry to design services that are maximally customised. This is justified because both in the COVID-19 pandemic and after, due to the educational opportunities uncovered during the massive lockdowns, the sector has been steadily growing its service market (Wasyluk, Kucner, Pacewicz, 2020; Świątek, 2022), projected to reach $585.48 billion worldwide in 2027 (*Online Education Market,* 2022). From this perspective, the search for methods and tools to help ensure quality service appears to be fully justified. The second reason relates to the very limited amount of research that deals with evaluating the use of the CJ tool (Shiratori et al., 2021), the proposed snapshot may help to fill this gap to some extent.

## 2. Methods

The article proposes to conduct a survey due to the fact that this type of research provides excellent tools for analysing attitudes, views, and opinions and can be used for descriptive, explanatory, and exploratory purposes, thus seems the most appropriate method of observation. In addition, the validity of its use applies to such research projects, in which the units of analysis are individual people and their evaluation of specific methods of action (Gonzalez, 2005; Rubin, Babbie, 2009; Bhattacherjee, 2012). The main research problem that was adopted concerns the scope of use of the design thinking (DT) method and its tools, with particular emphasis on the Customer Journey (CJ) in the design of services in the online education sector, as effective instruments for improving the quality of services offered. The study posed the following research questions:

1. Do remote online education service providers use design thinking (DT) in designing their services?
2. Do remote online education service providers use Customer Journey (CJ) as a Design Thinking (DT) tool in designing their services?
3. How do providers of online education services assess the effectiveness of CJ in designing their services?

In relation to the questions formulated, the following hypotheses were adopted.

1. Online education service providers use Design Thinking (DT) in designing their services to a limited extent.
2. Online education service providers use Customer Journey (CJ) as a Design Thinking (DT) tool in designing their services to a limited extent.
3. Online education providers that develop their services using CJ are positive about its effectiveness in designing their services.

To verify the accepted hypotheses, a survey form consisting of five metric questions was constructed to determine age, sex, experience in the profession, form of service, and position held. The number of questions in the survey depended on the configuration chosen by the respondent; they were grouped into three sets allowing, according to the research questions, to determine whether the respondents use the DT method, whether they use the CJ tool and if so, how they evaluate it, and if not, why they never reached for this method and this tool. The sampling in the conducted survey was purposeful, the survey was addressed to the industry of online education. The research was conducted through Google Forms, which were sent in the form of a survey to a Facebook group associating entrepreneurs, trainers, trainers, coaches, and specialists in the education and distance learning sector. The group on the social network has 22,500 members. The research was of a pilot nature, therefore, only a portion of the study group was included, it was carried out in the form of an online survey, with a timeframe of October to December 2022.

## 3. Results

### 3.1. Theoretical framework

According to Jeanne Liedtek, the originator of the term "design thinking" is Peter Rowe, a professor of architecture and urban planning at Harvard's School of Design, who so titled his book published in 1987, but the meaning he gave to the term differs significantly from its current connotations, which focus on the very intellectual process needed to solve a problem, which is the basis of design activities (2015, p. 926). Understood in this way, design thinking (DT) was a response to the problem formulated, in a now-classic article by Richard Buchanan (1992), who pointed to the need to develop methods of thinking that would allow combining different fields and different disciplines from art through science to economy, as he wrote, it is about thinking „directed […] toward new integrations of signs, things, actions, and environments that address the concrete needs and values of human beings in diverse circumstances (Buchanan, 1992, p. 21). Such a method was one of the first to be formulated by David Kelley, a professor at Stanford University, who developed the main tenets of DT in

practise at IDEO, a company he founded in 2005 (Camacho, Kelley, 2016). Initially, the idea of design thinking focused mainly on product development, but over time it has expanded to include all forms of design, from services through strategy building to creating innovations of a social nature (Osika 2019b). Thomas Lockwood equates DT with a human-centred innovation process, emphasising "observation, collaboration, rapid learning, visualisation of ideas, rapid prototyping of concepts combined with concurrent business analysis" (2010, p. xi). Kelley identified five stages in the design thinking process, empathising or carefully identifying needs based on insightful observation of behaviours and the contexts in which those behaviours occur - this is the cognitive stage. The second stage is the definition of the problem or drawing conclusions from observations to determine the essence of the problem. Defining the problem allows the company to move on to the idea generation stage involving the creation of a wide range of potential solutions. The last two stages are prototype building, which is the materialisation of the idea allowing to initially assess its usefulness, and testing, which allows to finally verify the usefulness of the solution in the user environment (Brown, Wyatt 2010; Tichimmel, 2012; Brown, 2013; Sobota, Szewczykowski, 2014; Brodnicki, 2015; Chasanidou et al. 2015; Maik, 2016a; Wolniak, 2017; Jui -Che Tu, Li-Xia Liu, Kuan-Yi Wu, 2018; Pereira, Russo, 2018; Osika, 2019b; Wilkerson, Trellevik, 2021; Belen, 2022).

The Stanford DT model was one of the first nowadays several such models can be distinguished, simplifying the phases of the design process flow (Medina, Bravo, Kamachi, Xavier, 2012) or expanding their scope (Tichimmel, 2012; Brown, 2013) however, a common feature of all models is the structuring of intellectual work according to the psychological conditions of the creativity process. Due to the fact that DT is based on the analysis of the course of the thinking process during problem solving, it can be treated as a "theory" of creativity - because it creates an interpretation for understanding what it is, or as a method, because the described structure of the intellectual process can be used as a design guideline, applying specific steps for developing innovations (Maik, 2015). From this perspective, DT is the conscious application of principles that have been identified as typical of the creativity process and, in this sense, are general in nature, i.e., usable in solving all kinds of problem (Osika, 2019b). Therefore, we can describe design thinking “as solution-oriented, action-oriented, and needs based, and is associated with creative action, designer sensibility, technological feasibility, alternative solutions, emotional satisfaction, and constructive future results” (Barsalou, 2017, p. 102).

The implementation of the DT objectives requires the use of very specific tools, one of them being the Customer Journey (CJ). 'Customer journey (or alternately, customer journey maps) are visual representations of events or touchpoints depicted chronologically, often accompanied by emotional indicators' (Halvorsrud et al., 2016, p. 12; Shiratori et al., 2021, p. 314). CJ is a description of the logical sequence of interactions between the customer and the service that occur at each stage of contact (Kalbach, 2017; Wojciechowska, 2020; Tueanrat et al., 2021), referred to as touchpoint. “These touchpoints are sorted in the customer journey by time

and time, and by types. As a result, the company can map when, where and how interactions between them and the customer are, plus identify possible underestimated/overestimated by the business" (Shiratori et al., 2021, p. 314). Visualised CJ takes into account such categories as: interactions with the customer before, during, and after the service; impressions experienced, motivations, thoughts, and emotions, moments of positive experiences, but also negative ones ("Moments of Truth" and "Pain Points"). Such an analysis makes it possible to predict quite accurately how to design the service in marketing and sales activities, during the provision of the service, and control the impressions that remain after the service. It is these targeted observations that make it possible to optimise the quality of the service and maximise its fit with customers' needs, ensuring the effectiveness of design activities. Importantly, both before providing a service, the main aspects affecting its quality can be comprehensively identified, but CJ is also helpful in corrective actions, in improving existing services, and is therefore a universal tool (Halvorsrud et al., 2016; Kalbach, 2017; Rosenbaum et al., 2017: Wojciechowska, 2020; Shavitt, Barnes, 2020; Shiratori et al., 2021; Tueanrat et al., 2021; Maik, 2016b).

The aforementioned features of the customer journey can significantly contribute to the provision of quality services in the growing online education industry, so it seems important to determine to what extent this tool is currently being used and how its effectiveness is evaluated. The results of the survey on these aspects will be presented later in the article.

### 3.2. Analysis of survey results

86 people participated in the survey, of which 74.4% of the surveyed community were men and 25.6% women. The professional experience in remote teaching of the respondents was at different levels. The largest percentage were people whose experience ranged from 1 to 3 years (67.4%), followed by 20.9% of people who indicated professional experience in the range of 4 to 7 years. Only 11.6% of the respondents have more than 8 years of experience in distance learning. Most of these people (40.7%) provide e-learning services as subcontractors in cooperation with an educational organisation. A lower percentage of respondents (32.6%) provide these services as self-employed, and 26.7% of the respondents provide e-learning services as part of any form of employment in the field of education. The age of the respondents ranged from 19 to 65 years, occupying various positions. The largest number of people (23), which constitutes 31.5% of all respondents, are business owners, 16 people (21.9%) are specialists, 15 people (20.5%) are senior specialists, 8 people (9.6%) are directors, and 7 people are members of the board. The same number of people (7) manage small teams of up to 10 people, 3 people manage teams of more than 10 people, and the remaining respondents (4 people) are trainees or apprentices. The next charts show how the respondents answered, noting that some answers excluded all questions in the survey. Figure 1 shows the answers to the question regarding the design of services by respondents and the use of the operating methodology.

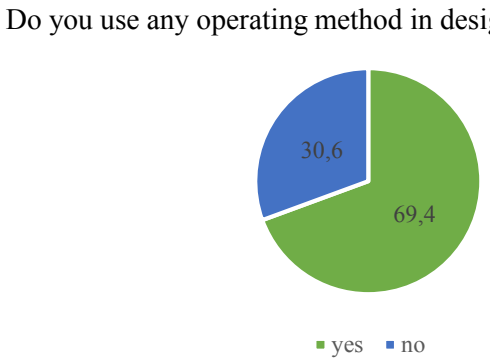


**Figure 1.** Use of the operating methodology in the design of services (%).

Source: Own study based on survey results.

This question was answered positively by 59 respondents, which constituted 69.4% of all respondents. Thus, these people could continue the study by deepening the subject of designing their services. The next question concerned the use of the Design Thinking method in designing their services, and 59 people answered them. The answers received show that 69.5% of respondents use the Design Thinking method in their work (figure 2).

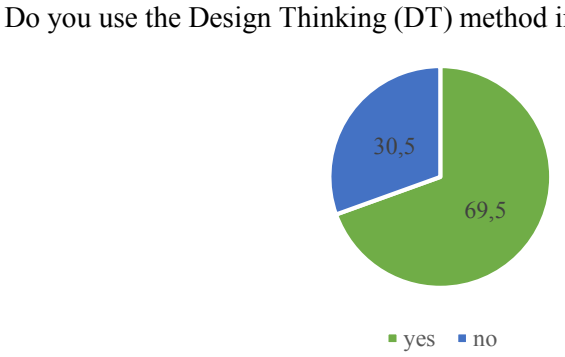


**Figure 2.** Using the Design Thinking (DT) method in designing your services (%).

Source: Own study based on survey results.

Figure 3. shows how the respondents answered the question about their experience in working with the Design Thinking method.

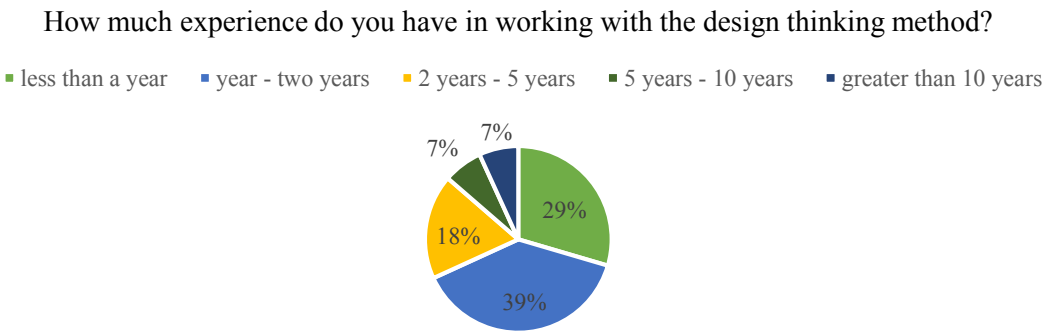


**Figure 3.** Experience in working with the Design Thinking method.

Source: Own study based on survey results.

The largest percentage of respondents were people whose experience in this field ranged from one year to two years. These people accounted for 39% of the respondents. Slightly less - 29.0% are people who have been working with the Design Thinking method for less than a year. Both respondents who indicated experience falling within the time range: 5-10 years and over 10 years account for 7% of all respondents, respectively.

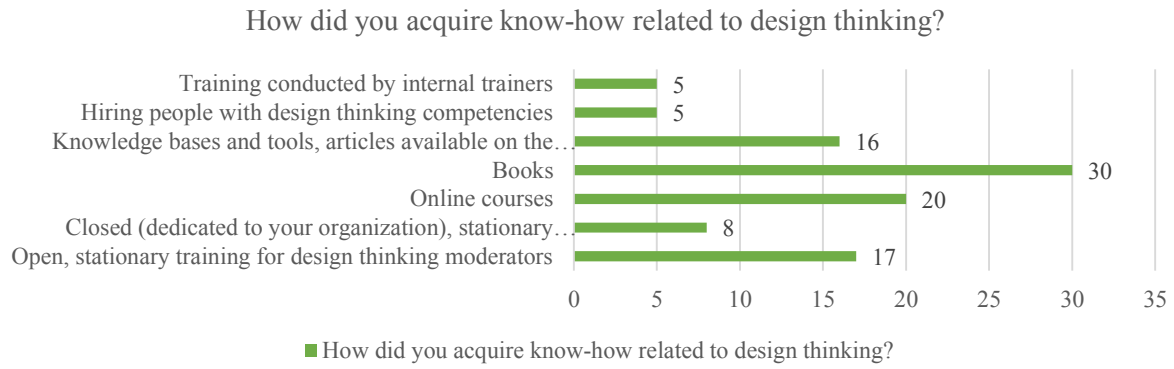


**Figure 4.** Methods of obtaining know-how related to Design Thinking.

Source: Own study based on survey results.

Figure 4. shows the methods of acquiring knowledge about Design Thinking. Respondents could select more than one of the proposed answers. Most of the people answered that they gained their knowledge mainly from books (30 people gave such an answer). Learning online courses was less popular (20 people marked this answer). The least interest in gaining knowledge about the Design Thinking method was training conducted by internal trainers (5 people) and employing people with Design Thinking competences (also 5 respondents). Respondents also indicated that they drew their knowledge from, among others, open, stationary trainings for Design Thinking moderators and knowledge base and tools, articles available on the Internet. The respondents also pointed to closed (dedicated to the organisation) training of the moderators (8 answers).

Respondents in an open question indicated what Design Thinking means to them. The most frequent answers that appeared were:

- a creative problem solving method,
- project management method,
- brainstorm,
- method for managing innovation,
- it is a project management process that is an innovation based on the knowledge and understanding of the client,
- method from Stanford University,
- searching for new services,
- approach to project implementation,
- uses elements in adult education,

- design thinking,
- service design,
- method of implementation of activities,
- the method of finding the right solutions,
- teamwork,
- project management method,
- methodology of managing business ventures.

Design thinking is a method of solving problems focused on innovation, based on teamwork. This method is a combination of mindset, an approach to developing solutions that values openness, continuous improvement, learning from others, researching the needs of recipients, with the structure of the process - these are specific steps and actions that we use to solve the problem.

The most frequently mentioned service design tools as part of the design thinking method are persona, experimenting and testing hypotheses, empathy map, moodboard, customer journey, snake, stakeholder map, prototype, customer experience path, trend map, and quick mission. This proves a great knowledge of tools in the field of service design.

The next questions concerned the Customer Experience Path as an element of the Design Thinking method.

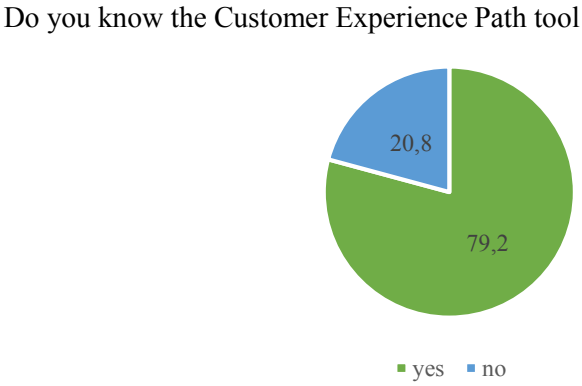


**Figure 5.** Knowledge of the Customer Experience Path tool as an element of the Design Thinking method (%).

Source: Own study based on survey results.

The above graph shows that slightly more than 3 4 of the respondents know the Customer Experience Path tool (79.2% of the respondents) and slightly less, as many as 73.1 respondents, indicate the use of this tool in designing their services (figure 6).

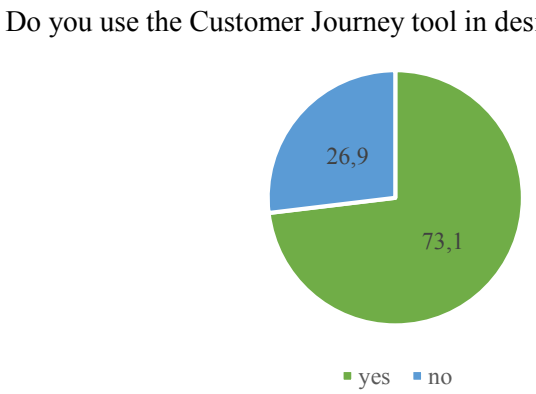


**Figure 6.** Using the Customer Journey (CJ) tool to design your services (%).

Source: Own study based on survey results.

Using the customer journey is a good practise. Organisations focused on working on the customer path and working on customer experience operate more effectively: they observe an increase in company revenues, an increase in customer satisfaction, and they also note cost optimisation. All these benefits are the result of an in-depth knowledge of the needs, problems, and all customer experiences. It is possible to improve the quality and efficiency of the services themselves, but also of service, communication, marketing, sales, and even internal processes in the company.

In the next part of the survey, respondents assessed the usefulness of the Customer Journey (CJ) tools at various stages of the service provision process. The assessment ranged from 1 to 5 o and concerned stages such as awareness of the need for purchase, familiarisation with the offer, selection of a specific product, finalisation of the purchase, and after-sales activities (figure 7).

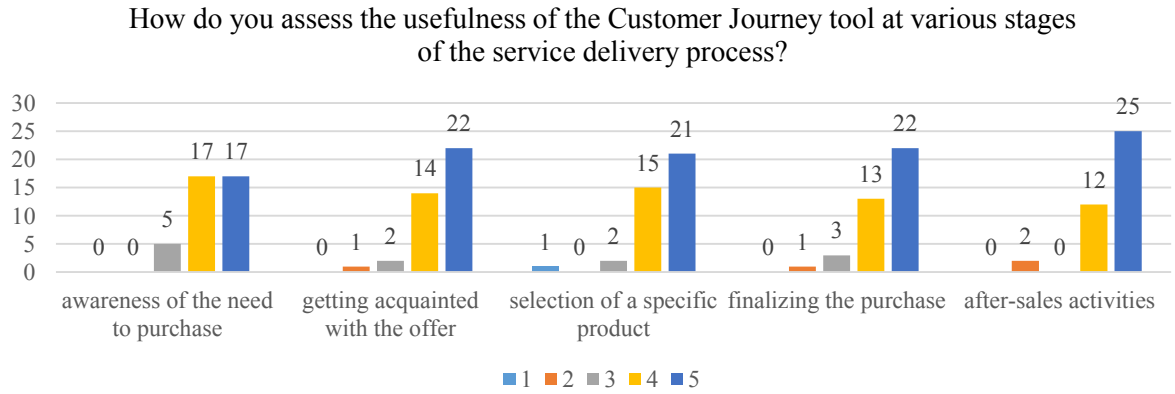


**Figure 7.** Assessment of the usefulness of the Customer Journey (CJ) tool in individual stages of the service provision process.

Source: Own study based on survey results.

The chart above shows that the usefulness of the Customer Journey (CJ) at all stages of the service provision process is rated very well by the respondents. 39 respondents answered this question. In the case of the first stage, awareness of the need to purchase, 17 people gave a very

good rating (score: 5) and the same number of people rated the usefulness of this tool at this stage at the level of 4. Only 5 people gave this tool a 3 rating. offer - up to 22 people gave the highest rating and 14 people indicated the usefulness of this tool at level 4. Two people rated this usefulness at level 3 and one at level 2. In the case of choosing a specific product, 21 people rated the usefulness of using the tool at the highest level. The 4 rating was assigned by 15 respondents. Only at this stage of the service provision process, one of the respondents gave a very poor rating of 1. In the case of the stage, finalising the purchase, 22 people gave a rating of 5, and 13 people gave a rating of 4. The lowest rating is 2 (one respondent). In the last stage, it can be seen that the Customer Journey is rated the best by the respondents (as many as 25 people gave a rating of 5). Two of the respondents rated the tool as 2.

In the chart below, we can see how the respondents answered the question about the purpose of developing the Customer Journey (figure 8). The respondents could select more than one answer to this question.

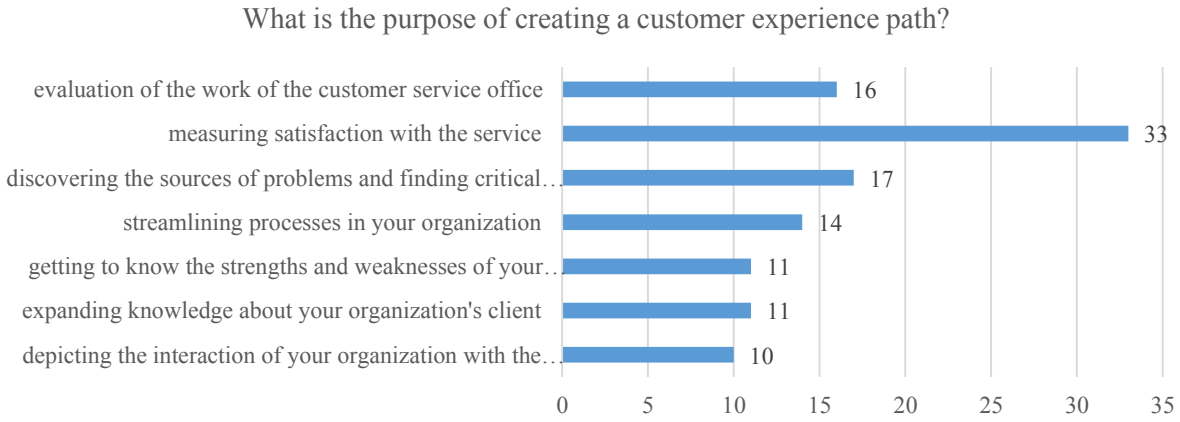


**Figure 8.** Purpose of developing the Customer Journey (%).

Source: Own study based on survey results.

The largest number of respondents indicated that the main purpose of developing the Customer Journey (CJ) is to measure satisfaction with the service (this answer was indicated by 33 people, which is 84.6% of all respondents). Another result - 17 people surveyed - indicated as one of the main goals discovering the sources of problems and finding critical points in the organisation's service path. The most frequently mentioned goals include evaluation of the work of the customer service office (16 people) and improvement of processes in the organisation (14 people). The least indicated goal was to illustrate the interaction of the organisation with the client / use (10 people - 25.6% of all respondents).

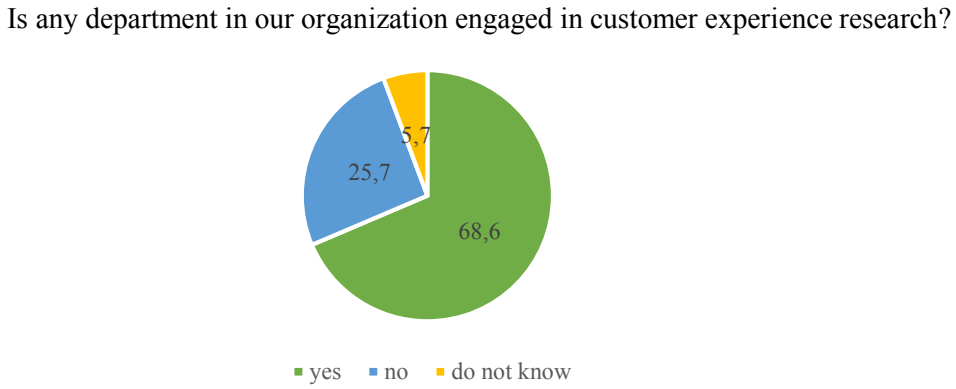


**Figure 9.** Customer experience research in the organisation (%).

Source: Own study based on survey results.

The chart above shows that only 68.6% of the respondents confirm that their organisations have departments that deal with customer experience research. 25.7% of the respondents indicated the lack of such departments, while 5.7% are unable to specify it. The pollsters also pointed to the sense of analysing the customer's behaviour before, during, and after the service is delivered, and they definitely outperform the opponents - 91.5% of the respondents (figure 10).

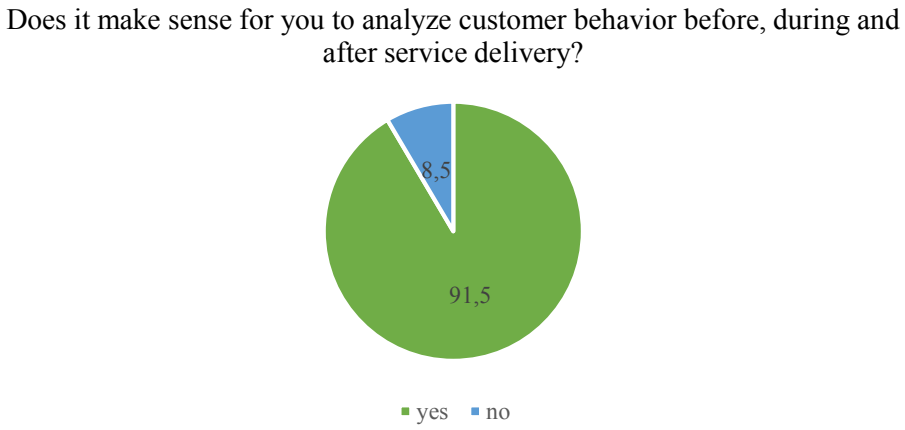


**Figure 10.** The need to analyse customer behaviour before, during, and after service delivery (%).

Source: Own study based on survey results.

Figure 11 shows the sense of analysing possible experiences/emotions that may accompany the client before, during, and after service delivery. 93% of the respondents indicate the sense of performing this type of analysis. Analysing the needs, thoughts, and motivations that may accompany the client before, during, and after the service is reasonable for 91.5% of the respondents (figure 12).

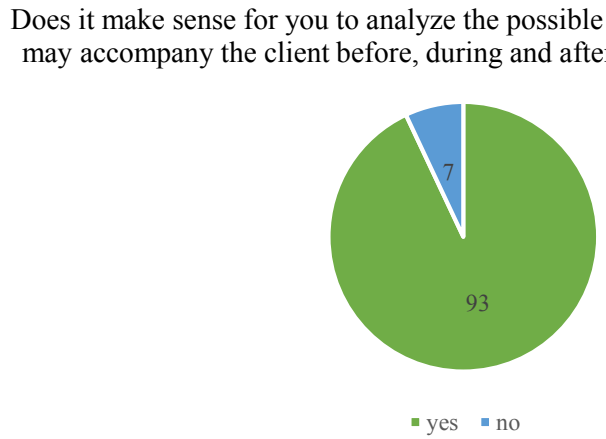


**Figure 11.** The need to analyse possible experiences/emotions that may accompany the client before, during and after service delivery (%).

Source: Own study based on survey results.

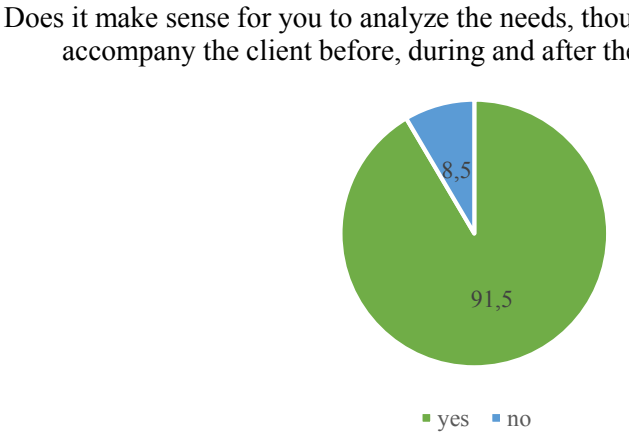


**Figure 12.** Meaningfulness of analysing the needs, thoughts, and motivations that may accompany the client before, during, and after service delivery (%).

Source: Own study based on survey results.

People who did not use the Customer Journey tool in their work to design their services were asked about the reason for their decisions. 7 respondents pointed to the lack of such a need as the scope of their services is limited. The same number of respondents indicated a lack of practise in using these tools. Only two people indicated a low assessment of the effectiveness of these tools (figure 13).

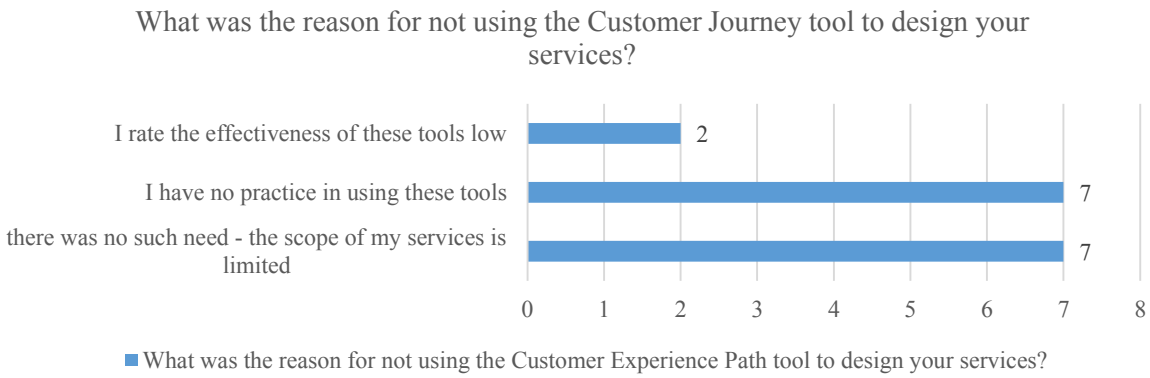


**Figure 13.** Reason for not using the Customer Journey (CJ) tool for designing services.

Source: Own study based on survey results.

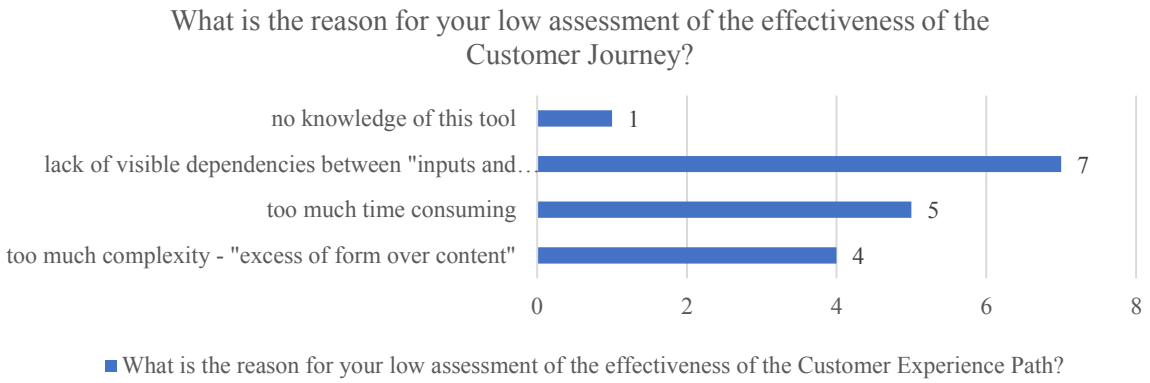


**Figure 14.** Reasons for the low effectiveness of the Customer Journey (CJ).

Source: Own study based on survey results.

The low assessment of the effectiveness of the CJ according to the respondents results from the lack of visible relationships between "inputs and results" based on their own experience (7 people), too much time-consuming (5 people), too complicated "form over substance" (4 respondents) and lack of contact with this tool (1 respondent).

## 4. Discussion

Recognition of innovation as a key source of economic value (Romer, 2008; Prokurat, 2016; Osika 2017; Olko 2017; Osika 2019a; Boguszewicz-Kreft, 2021), coupled with technological facilities to optimize ongoing economic processes (Zygmuntowski, 2020; Śledziowska, Włoch 2020), has necessitated the development of methods to improve the efficiency of processes related to innovation generation. Among such methods, finding increasing acceptance among practitioners, is DT based on a human-centred innovation process, in which observation, collaboration, rapid learning during design, prototyping of concepts combined with simultaneous business analysis are key (Buchanan, 1992; Lockwood, 2010; Brown, Wyatt,

2010; Tichimmel, 2012; Medina, Bravo, Kamachi, Xavier, 2012; Brown 2013; Sobota, Szewczykowski, 2014; Brodnicki, 2015; Chasanidou et al., 2015; Liedtek, 2015; Camacho, Kelley, 2016; Wolniak, 2017; Jui -Che Tu, Li-Xia Liu, Kuan-Yi Wu, 2018; Pereira, Russo, 2018; Osika 2019b; Wilkerson, Trellevik 2021; Belen 2022), all these activities are strongly supported by visualisation techniques. An important DT tool is the customer journey, which is precisely a visualised description of the logical sequence of interactions between the customer and the service occurring at each stage of contact (Kalbach, 2017; Halvorsrud et al., 2016; Rosenbaum et al., 2017; Wojciechowska, 2020; Shavitt, Barnes, 2020; Tueanrat et al., 2021; Shiratori et al., 2021; Tueanrat et al., 2021).

As with any method of operation, it is crucial to evaluate its usefulness, so its effectiveness should be continuously assessed. In the present discussion, opinions on the effectiveness of the DT method and the CJ tool of the online education industry have been studied, due to the fact that it is currently one of the growth industries. However, it seems that from the point of view of evaluating the usefulness of DT and CJ, it is worthwhile to conduct further research in other economic areas in order to be able to ultimately establish a more objective evaluation of both the DT method and the CJ tool.

## 5. Summary

The article describes the results of a survey conducted among on-line education service providers, and it was found to be the most appropriate research method. The main research problem concerned the extent of use of the Design Thinking method and its Customer Journey (CJ) tool in the design of services in the remote education sector, as effective instruments for improving the quality of services offered. The study formulated the following hypotheses:

1. Online education service providers use design thinking (DT) in designing their services to a limited extent.
2. Online education service providers use Customer Journey (CJ) as a Design Thinking (DT) tool to design their services to a limited extent.
3. On-line education service providers evaluate the effectiveness of CJ in designing their services

All three research hypotheses were positively verified, remote learning service providers use DT, 67.5% of respondents answered so, as can be seen, this is a significant percentage of the surveyed group. The respondents also confirmed the use of CJ, as many as 79.1% of them use this tool to design their services. On the basis of this, it can be concluded that CJ is the main design tool among those using DT. This is confirmed, also by the evaluation of the effectiveness of CJ, the usefulness of Customer Journey (CJ) at all stages of the service delivery process is rated very well by respondents, and the range of purposes for which respondents use CJ is also

wide. On the other hand, among those who do not use the tool, the predominant responses are about inexperience, or the lack of need to use complex design methods, so it is not the low efficiency rating that determines the non-use of DT. The final conclusion is that both DT and CJ are used in the service design process in the studied industry, so the positive efficiency rating can be considered reliable. More detailed information is included in the conclusions of the study.

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# INNOVATIVE ENTERPRISES IN THE FACE OF CONTEMPORARY ENVIRONMENTAL CHALLENGES

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**Purpose:** The paper aims to highlight contemporary environmental challenges and to present innovative ways of their mitigation. The study is based on the activities of the Grupa Azoty Capital Group, one of the leaders among European fertilizer and chemical companies. The methods used by the Company are compared with the most important regulations introduced at the national and international levels, allowing for both the problems and their potential solutions to be presented. Simultaeously, the paper emphasizes the importance of undertaking various activities in the interest of the common good.
**Design/methodology/approach:** To prepare this article, the document analysis method and the comparative method were used. The study is a review in nature.
**Findings:** The article identifies the most important environmental problems and innovative ways to limit them.
**Social implications:** Highlighting the most important environmental challenges should increase the awareness of recipients about the importance of taking responsible actions. In turn, the solutions implemented in the Grupa Azoty Capital Group can serve as inspiration for introducing new, innovative ideas.
**Originality/value:** The article presents the growing environmental problems and attempts to counteract them. The discussion of the latest findings and implemented actions is significant not only from the point of view of entrepreneurs but also consumers, who thus gain a more complete picture of reality.

**Keywords:** environmental challenges, European Green Deal, Grupa Azoty Capital Group, Green Nitrogen.

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

## 1. Introduction

As technology advances, humans have an increasing impact on the environment. According to some scientists, the influence of human activity on climate change reaches even 90% (Malucha, 2010). As a result, an observed increase in Earth's surface temperature is accompanied by the extinction of many plant and animal species and changes in surface waters.

Such factors have a direct impact on the quality of life, including access to drinking water and food. The emerging weather extremes and diseases, previously occurring only in selected areas, pose a direct threat to humans (Stochaj 2022). Therefore, it is essential to constantly shape the awareness of both consumers and entrepreneurs.

In response to the strong need for increased environmental protection, numerous legal regulations appear. An appropriate provision is even found in the Constitution of the Republic of Poland, according to which environmental protection should be closely linked to the principle of sustainable development. Various activities, responding to emerging environmental challenges, should inspire the search for innovative solutions and the development of technology, rather than becoming a barrier to further progress (Pilarczyk A., Pilarczyk E., 2022).

The responsibility for introducing and enforcing appropriate regulations lies with public administration bodies (Walas, 2009). The creation of climate protection strategies and counteracting growing environmental problems can be implemented at the national level, as exemplified by the Polish Energy Policy until 2040. However, it should be remembered that local actions are insufficient in this case, which is why a coherent effort to improve the current situation is necessary. In response to this need, numerous regulations, such as the European Green Deal, are created by the European Union (Olech, 2022). Moreover, there significant initiatives are also undertaken by the United Nations and other institutions, both intergovernmental and non-governmental (Prandecki, 2013).

There is no doubt that the way large companies operate has a huge impact on the environment. In their case, meeting the assumptions contained in various regulations often requires the development of an internal strategy. A prime example may be the actions of one of the European leaders in the fertilizer and chemical industry - Grupa Azoty Capital Group. The Grupa Azoty plan for 2021-2030 fits perfectly into the objectives of the European Green Deal and is an idea for meeting contemporary environmental challenges. The company places particular emphasis on issues such as reducing emissions and decarbonization (Grupa Azoty with a strategy..., 2021).

## 2. Contemporary Environmental Challenges

One of the most important environmental challenges in today's world is the rising temperature of our planet. Climate change is a natural process, dependent on solar activity and the Earth's position in orbit. However, it turns out that human activity also has a significant impact on climate change (Malucha, 2010). This problem is inextricably linked to the industrial revolution that began in the 20th century. Since that time, there has been a constant development of human economic activity in a broad sense, which is reflected in the so-called global warming.

Scientists predict that without taking appropriate action, the average temperature of the Earth will rise by as much as 6°C over a century (Mikhaylov et al., 2020).

This type of threat is largely a consequence of the increase in greenhouse gas concentrations. Their increased content in the Earth's atmosphere is related to the combustion of fossil energy resources, deforestation, and industrial activities, among others. The result of the accumulation of greenhouse gases is the increase in the temperature of the lower layers of the atmosphere, and consequently, the increase in the Earth's surface temperature (Mikhaylov et al., 2020; Stochaj, 2022).

One of the main greenhouse gases is carbon dioxide, which is why reducing its emissions is among the basic methods to counteract climate change (Malucha, 2010). The formation of this gas is largely the result of natural processes, such as volcanic eruptions. However, we cannot eliminate such incidents. Therefore, it is particularly important to focus on human activity that contributes to the release of significant amounts of CO2 into the atmosphere, so as not to exacerbate an already serious problem. Highly harmful processes include the extraction of energy from the combustion of brown and hard coal, oil, and natural gas. Deforestation and intensive agriculture are also of great importance (Prandecki, 2013; Gierlotka, 2020).

The presence of certain substances, both gaseous and solid, in the air contributes to climate change on the one hand, and has a negative impact on human health on the other. In the case of Poland, the situation changes depending on the season. In winter, we mainly deal with high concentrations of suspended dust and benzo(a)pyrene. In summer, there is a high content of tropospheric ozone in the air. Occasionally, there is also an exceedance of the standard for permissible nitrogen dioxide concentration, which results directly from the use of internal combustion engine vehicles (Frańczuk, 2022).

Another significant factor with a negative impact on the environment is pollution from solid waste. Improper storage and disposal of waste leads to contamination of water and soil, through the infiltration of heavy metals, and also to the emission of gases such as carbon, sulphur, and nitrogen oxides into the atmosphere. In this regard, there is a strong emphasis on reducing waste generation and finding ways to reuse or process waste. It is also essential to raise public awareness of the importance of this issue (Ferronato, Torretta, 2019).

Both climate change and human activity also contribute to significant changes in access to drinking water. The consequence of irrational management of such valuable resources may be their depletion. The problem is exacerbated by rising temperatures and resulting droughts. This situation poses a direct threat to human health and life. In addition, the lack of water significantly limits or even prevents the procurement of food. The problem of wasting both water and food also adds to the issue. These accumulating threats can lead to a serious crisis, so it is necessary to take appropriate action. Among them, we can distinguish the change in crop models, as well as responsible political decisions, such as regulations governing food export and import (Hashemi et al., 2019; Cattaneo et al., 2021).

All these factors affect not only the climate but also the safety of people. The high probability of exposure to various pollutants does not remain indifferent to health. The presence of undesirable substances in both air and water increases the risk of developing many ailments (Lenzen et al., 2020). There are also many diseases whose occurrence is strongly related to weather conditions, and thus to selected locations. An increase in temperature in one area and a decrease in another can cause infections to spread to an area where this type of threat did not previously exist. This means exposing a large group of people without developed immunity. The changing climate also means an increased risk of extreme weather events. Depending on the region, the frequency and scale of phenomena such as droughts, floods, or hurricanes may increase. Such factors, combined with problems in obtaining clean water, also have a negative impact on crop yields, and consequently, on access to food (Stochaj, 2022).

## 3. Climate change mitigation strategies

In response to the growing environmental issues and related threats, a variety of strategies are being developed to counteract these factors. As mentioned earlier, in Poland, the Constitution itself imposes the obligation to undertake such measures. According to Article 5 thereof, environmental protection should be ensured in accordance with the principle of sustainable development. This means that any adverse impacts on the environment should be minimized, and the benefits resulting from such activities should be greater than the associated damages. The initiatives undertaken must therefore be balanced, ensuring environmental protection on the one hand and serving the social interest on the other. At the same time, they should not conflict with economic freedom (Pilarczyk A., Pilarczyk E., 2022; Frańczuk, 2022).

Environmental protection is, however, such a broad issue that it cannot be considered only at the local level. The consequences of neglecting or even exacerbating the problems discussed earlier are felt on a global scale. There is no doubt that counteracting these adverse changes must also be carried out on a large scale. With this awareness, the European Commission has developed an innovative strategy to help European Union countries meet contemporary environmental challenges. This document, called the European Green Deal, places great emphasis on implementing initiatives such as striving for climate neutrality and ecology. This does not mean that previous environmental objectives have been omitted. On the contrary, they have been not only organized but also expanded (Grzegorczyk, 2022).

The main assumption of the European Green Deal is to create an economy whose development and functioning will be as independent as possible from the use of natural resources. The result of the actions taken is to achieve zero greenhouse gas emissions by 2050. In this way, not only the environment but also human health and well-being are to be protected.

An essential element is also putting people first. The pursuit of the set goals should unite citizens rather than be at their expense. In addition, the European Union should inspire and encourage its neighbours and partners to take action to protect the environment. The global character of the undertaking is also confirmed by the fact that the discussed plan is one of the six key elements of the UN agenda for sustainable development 2030 (European Commission, 2019).

Limiting greenhouse gas emissions is, for obvious reasons, a gradual process. The initial stage of this task is to reduce emissions by 55% compared to 1990. This goal is to be achieved by 2030 as a result of a series of actions described in the Fit for 55 package. The first of these is changes in the emissions trading system, mainly affecting maritime transport and aviation, as well as the construction sector. At the same time, the introduction of a carbon border tax is planned to prevent the undermining of efforts by transferring high-emission productions outside the EU. This approach should also mobilize other countries to undertake pro-environmental actions and, as a result, affect a much larger area. The changes gathered in the discussed document are also to concern land use and forestry, specifically the goal related to carbon dioxide absorption. Emission standards for this gas are also to affect passenger and delivery vehicle drivers. From 2035, the introduction of internal combustion engine vehicles to the market is to be suspended. There is a strong emphasis on the use of alternative fuels. This solution aims to reduce emissions for all types of transport. An important aspect of the actions is also to provide support for companies and citizens who find themselves in particularly difficult situations due to the introduced regulations. This mainly concerns households, micro-enterprises, and transport users. The Fit for 55 package also includes a number of proposals related to energy. Above all, it is about increasing the share of renewable energy sources in the total energy consumption. By 2030, this share should reach at least 40%. Efforts should also be undertaken to increase energy efficiency, as well as to reform the taxation of energy products and electricity (Olech, 2022; Ready for 55…, 2023).

As mentioned earlier, environmental protection requires taking appropriate steps on a large scale. However, the significant diversity of situations in individual countries requires the development of local plans as well. In the case of Poland, the Energy Policy of Poland until 2040 was created to bring about the country's energy transformation. The strategy is based on three main pillars. The first pillar - just transformation - focuses on regions and communities that will find themselves in a difficult situation as a result of the measures taken. To counteract the negative effects of pro-environmental regulations, new development opportunities must be created, such as new jobs and even new industries. The program is primarily aimed at coal regions, but it also foresees benefits for individual energy consumers. The second pillar is a zero-emission energy system. Its main idea is based on the use of nuclear and wind power. However, distributed and citizen energy systems are also an essential element. The third pillar - good air quality - is primarily a strategy to move away from fossil fuels. The implementation of such an extensive plan has been divided into eight specific objectives. The first is the optimal use of domestic resources, the essence of which is to reduce the environmental burden

associated with resource management. The implementation of this task should be carried out without jeopardizing energy security and taking into account the needs and problems of all social groups. The second objective includes the expansion of electricity generation and network infrastructure. This is not only to ensure the stability and security of energy supply but also to fulfil various types of international commitments. According to the assumptions, the planned actions will lead to a reduction in coal's share while simultaneously developing technologies that use renewable energy sources. The next goal concerns the construction of new connections that will enable the supply of natural gas from more than one direction. The measures taken are also intended to improve the reception and storage of crude oil and liquid fuels. Energy markets are also the subject of the fourth specific objective. In the case of electricity, the emphasis was placed on striving to increase the active participation of consumers. The development of the natural gas market is to be related to the establishment of a regional gas transmission and trading centre (hub). In turn, limiting emissions and ensuring fuel security in the crude oil market is to be based on replacing petroleum products with bio-components and alternative fuels, as well as on the development of electromobility. Investment activities related to hydrogen technology are particularly important. Energy production itself is also the subject of two subsequent specific objectives. The first focuses on nuclear power, while the second concerns renewable energy sources, with particular emphasis on offshore wind farms. Additionally, the development of photovoltaics and onshore wind farms is planned, as well as heat pumps and the use of biogas, biomass, and geothermal energy in the heating industry. Meeting heating needs is also the topic of the next specific objective, within which the aim is to use systems with the highest energy efficiency and the lowest possible emissions. The last specific objective, on the other hand, concerns actions aimed at improving energy efficiency, taking into account the entire economy (Ministry of Climate and Environment…, 2021; Olech, 2022).

## 4. Innovative solutions in the industry

Creating new goals and related legal regulations implies the necessity for individual companies to develop detailed plans. The choice of the right strategy depends on the actual situation of a given company and the most significant problems it faces. A huge part of pro-environmental assumptions concerns reducing carbon dioxide emissions, which is closely related to energy production. A great example of consistent pursuit of their implementation is the Grupa Azoty Capital Group, which in response to such expectations prepared an innovative strategy for 2021-2030. This example is not accidental, as one of the leaders in the fertilizer and chemical industry in Europe, it has a significant impact on the energy and raw material situation of our country (Drozdowicz-Tomaszek, 2022; Goranczewski, Kądzielawski, 2022).

The planned actions are primarily aimed at minimizing the emissions of individual installations and implementing modern solutions in the field of renewable energy sources. Focusing on low- or even zero-emission products is a response not only to emerging legal regulations but also to changing customer expectations, who also attach increasing importance to ecology. Another manifestation of concern for the environment is supporting agriculture by striving to increase the efficiency of fertilization and producing the highest quality food (Kwiek, 2021a).

As already mentioned, the key element in combating climate change is minimizing greenhouse gas emissions, the result of which is to achieve climate neutrality. Such an assumption requires modernizing a company's internal energy production. In the case of Grupa Azoty, there is a strong emphasis on replacing coal with renewable energy sources. Implemented projects are to reduce carbon dioxide emissions by over 800,000 tons by 2030 compared to 2020. In addition, as much as 40% of the generated electricity is to come from renewable sources (Kwiek, 2021a).

The basis for the decarbonization process is the production of "green hydrogen" and its use in fuel cells. In connection with this, as part of the "Green Nitrogen" project, work is underway in the Kędzierzyn-based subsidiary of Grupa Azoty to create an Alternative Fuels Laboratory. The main task of its employees will be to assess the purity of the mentioned gas. This parameter is extremely important, especially from the point of view of fuel cells. Hydrogen use is expected to revolutionize transport, primarily rail (Kwiek, 2022a; Świda, 2022). As the largest hydrogen producer in Poland, Grupa Azoty Capital Group is also involved in initiatives aimed at creating Hydrogen Valleys in the country (Kwiek, 2022b; 2022c).

Obtaining energy from renewable sources is essential both from the point of view of environmental protection and for financial reasons. Therefore, one of the solutions used by Grupa Azoty Capital Group are photovoltaic power plants. The benefits of their use include not only reducing the carbon footprint but also the absence of waste resulting from current exploitation and the lack of water consumption. An additional advantage is that such power plants do not generate annoying noise (Kwiek, 2022d; 2022e; 2023). A great example can be a 1 MW installation located in Kędzierzyn-Koźle. On an annual scale, it provides additional energy production of 970 MWh while simultaneously reducing carbon dioxide emissions by as much as 793 tons (Kwiek, 2022f).

Carbon dioxide production is a problem not only in the process of generating electricity but also during the production of chemicals. Also in this area, Grupa Azoty Capital Group shows great commitment and focuses on innovative solutions. The company has been awarded several times in the Decarbonization Initiatives Ranking for its actions. In 2021, the modernization of the nitric acid installation was highlighted. Several years of work in 2020 made it possible to achieve as much as an 83% reduction in carbon dioxide emissions compared to 2018 (Kwiek, 2021b). In 2022, the implementation of a specialized control system was awarded, which led to a reduction in carbon dioxide emissions by over 20 kg per tonne of produced ammonia (Kwiek, 2022g).

As part of the Grupa Azoty Capital Group strategy for 2021-2030, there is also a strong emphasis on research on so-called "green products". By definition, these are products with the smallest possible carbon footprint made from natural raw materials. Examples include varieties of natural polyamide and its derivatives, thermoplastic starch, and modern specialty fertilizers (Kwiek, 2021c, 2022h, 2022i).

## 5. Conclusion

There is no doubt that environmental protection is an extremely important issue. Growing problems such as air and water pollution or climate change pose a direct threat to human health and life. It is no wonder that various organizations around the world have undertaken work to find the best solutions in the fight for the well-being of our planet. As a result, numerous legal regulations have been created that go far beyond the scope of just one country. Such an approach is necessary, as only global actions have a chance to bring about much-needed changes.

In response to the set goals, individual companies have also been forced to develop their own strategies. Grupa Azoty Capital Group is an excellent example of tremendous commitment and the implementation of innovative solutions. The objectives pursued by this company mainly focus on obtaining energy from renewable sources and maximizing the reduction of greenhouse gas emissions, primarily carbon dioxide. An important aspect of Grupa Azoty Capital Group's activities is the modernization of existing production facilities, as well as the search for new biodegradable products with the smallest possible carbon footprint. The efforts described in this study constitute the most significant part of the company's environmental protection activities.

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# INDUSTRIAL PROPERTY PROTECTION AS A CONDITION FOR THE INNOVATIVENESS OF THE POLISH ECONOMY

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**Purpose:** The aim of the paper is to show in detail the quantitative dimension of industrial property protection in the form of indexes of the innovative development of the Polish economy in the first two decades of the 21st century.
**Design/methodology/approach**: A review of the literature on the subject as well as other sources in the form of legal acts and statistical data from the Central Statistical Office.
**Findings:** The conducted research allowed for an analysis of changes in the number of notified solutions in the field of industrial property and their interpretation, leading to, regrettably, not very optimistic conclusions as to the limited effectiveness of Poland's innovation policy.
**Research limitations/implications**: The adopted research method of literature review has many limitations and is not a perfect way to obtain data.
**Practical implications:** The conducted research and analysis make it possible to assess not only the level of innovative activity in terms of the number of applications for the protection of industrial property rights, but also changes in the number of approved solutions. On this basis, the conclusion can be drawn that there has been hardly any improvement in the level of innovativeness of the Polish economy, primarily with regard to the achievement of measurable effects. In possible further research, it seems important to attempt a comparative analysis, based on available data on the amount of expenditures on innovative activities.
**Originality/value:** The value of the paper consists in systematising huge data sets (time series) amassed over a period of more than two decades and using them to perform diachronic analyses.

**Keywords:** industrial property law, intellectual property; innovation, innovativeness of the economy.

**Category of the paper:** Review paper.

## 1. Introduction – innovations, innovativeness and innovation policy

The notion of innovation was introduced into the economic sciences by J.A. Schumpeter[1], who distinguished five cases to which the notion of innovation can be applied: introduction of a new product, introduction of a new production method, opening of a new market, acquisition of a new source of raw materials or semi-finished products, and introduction of a new organisational structure of an industrial sector (Janasz, Kozioł, 2007, p. 12). At the same time he put forward a thesis that innovativeness determines economic development to a greater extent than material (capital) resources (Schumpeter, 1960, p. 128).

A similar approach to innovativeness and its importance for economic development was adopted by P.F. Drucker, who regarded it as a specific tool of entrepreneurship, i.e. an activity that provides resources with new opportunities for wealth creation. In his view, innovations relate more to the social and economic sphere than to the technical sphere (although in fact, for individual enterprises, technical innovations are of primary importance) (Drucker, 1992, p 39).

Thus, innovations should be understood as the practical economic implementation of a new or significantly improved product or process, but also a new marketing or organisational method or organisation of the workplace, or even changes in relations with the environment (Podręcznik Oslo, 2018; 2020, p. 49). The modern definition of innovation goes well beyond the realm of technology, as it occurs when there is an economically successful exploitation of new ideas (Czajkowska-Dąbrowska, 2007, p. 61 et. seq.).

In the broad sense of the term, innovations, constituting an interdisciplinary category described by means of various research methods and techniques (Duraj, Papiernik-Wojdera, 2010, p. 61), can be understood as the introduction of significant changes (Janasz, Kozioł, 2007, p. 15). In a somewhat narrower sense, however, all innovations must contain a distinct element of novelty (Czajkowska-Dąbrowska, 2007, p. 61 et. seq.).

Nowadays, such developments can be seen as indispensable entrepreneurial tools that transform an idea into concrete products or services and thus influence economic development. In the Oslo methodology, innovative solutions are not regarded as an impulse or mechanism that triggers the innovation process, but as its effect (Nowak, 2012, p. 157).

The innovativeness of an economy, on the other hand, should be understood as the propensity of entrepreneurs to constantly search for and use (implement) the results of scientific research and development projects, new ideas, concepts and inventions. Innovativeness comprises also improvements in already known production and operation technologies, the application of new solutions in organisation and management, as well as progress in infrastructure development (Janasz, Kozioł, 2007, p. 45). In fact, only enterprises that are

[1] According to his definition, innovation means the introduction of a new solution into practice (Schumpeter, 1960, p. 104; Janasz, Kozioł-Nadolna, 2011, p. 11 et seq.).

capable of introducing innovative changes have the potential to maintain their positions in the market (Hejduk, 2018, p. 1367).

The ability of a country to generate and implement innovations is so important because it allows for increasing the efficiency of practically all production factors, and thus stimulates growth and socio-economic development (Pangsy-Kania, 2007, p. 95). Modern states, in order to increase the importance of innovation, have started to implement increasingly intensive innovation policies. An innovation policy is a combination of elements of individual policies in the areas of industry, science and technology, i.e. a set of the state's activities that, by means of specialised legal, institutional and economic instruments, influence innovation processes in the economy in order to achieve goals in line with its overall socio-economic policy (Marciniak, 2000, p. 90).

The European Union recognises innovativeness as one of the most important factors determining economic competitiveness (Janasz, Kozioł, 2007, p. 45).

## 2. Challenges to the innovativeness of the Polish economy

For years, Poland has been regarded as a country still at an early stage of the innovativeness development process (Płowiec, 2008, p. 3). There are, of course, many reasons for this state of affairs, but probably of particular importance is the lack of a clearly targeted and properly implemented state policy supporting the development of innovativeness. Meanwhile, it is the increase in the innovativeness of the Polish economy that should already constitute a priority in the state's economic policy.

Innovative activity includes a whole range of scientific, research, technical and organisational measures aimed at the development of new or significantly improved products or processes, as well as their implementation into economic practice.

The development of an innovative economy requires the creation of new values in the sphere constituting the domain of human intellect, involved in the creation of solutions serving the most important civilisational goals understood primarily as raising the level and quality of life of the society, with simultaneous reasonable protection of natural resources (Zadania UPRP).

In order to pursue such objectives in the conditions of intensifying globalisation, what is required includes, on the one hand, highly advanced technologies and, on the other hand, such economic mechanisms that would make it possible to satisfy constantly growing consumption needs and solve complex socio-economic problems (Zadania UPRP).

Poland's relatively fast economic growth in the period of the so-called transformation cannot hide the fact that its economy is not so much innovative as imitative, which has been and will continue to be a great challenge for both the country's economic policy and the

development strategies of Polish enterprises. Consequently, the problem of providing the economy with a strong impulse towards innovation has not been adequately addressed for many years (Cieślik, 2014, p. 140).

It should be borne in mind that solutions adopted and even well tested in countries with a more developed market economy do not always turn out to be sufficiently effective in countries with even a slightly lower level of development, such as Poland, which are unable to create their own internal mechanisms for generating and implementing innovative solutions (Wiśniewska, Janasz, 2016, p. 187). Thus, although the level of innovativeness depends primarily on the capabilities and capacities of economic entities themselves, the mechanisms for creating and supporting innovativeness do not function properly in Poland. It should be noted, however, that the Polish legislator attaches more and more importance to national regulations and the entrepreneur to internal legal acts that are to regulate the matter of intellectual property and its management (Niewęgłowski, 2018, p. 1463).

## 3. Protection of industrial property

The creation of new technical solutions determining sustainable economic development requires ensuring broadly understood protection of intellectual property, which is equally important as the protection of rights relating to tangible property (Sieńczyło-Chlabicz, 2020, p. 1284 et seq.).

The protection of intellectual property, with regard to technology and the economy, is effected by granting inventors, authors and entrepreneurs the rights guaranteed by law to exercise control of their technical solutions, product forms (designs) or trademarks (Sieńczyło-Chlabicz, 2020, p. 1284 et seq.). This area of intellectual property protection is referred to as the protection of industrial property rights.

Traditionally, industrial property rights are understood in the legal doctrine as subjective rights, characterised by their absolute effectiveness and their holder's exclusive use of the object of the right, in a commercial or professional manner (Nowak-Gruca, 2014, p. 303). These rights are therefore very closely related to the possibility of economic exploitation of intangible property.

A feature of industrial property rights is the possibility to determine their object, although the precise determination of the scope of protection of industrial property rights still remains a contentious issue (Nowak-Gruca, 2014, p. 303).

The traditions of industrial property protection date back to the end of the 19th century. The Paris Convention for the Protection of Industrial Property of 20 March 1883 defined industrial property right as a subjective right or a set of provisions regulating the subjective right to patent inventions, industrial designs, utility models, trademarks, service marks, trade

names, designations of origin or names of origin, as well as to combat and prevent unfair competition. Some researchers are of the opinion that industrial property protection was initiated as early as the 15th century, specifically in the Venetian Law of 1474 (Kostański, Żelichowski, 2020, p. 11).

In Poland, the protection of industrial property also has a long-standing tradition, dating back to the beginning of the Second Republic (Nowak-Gruca, 2014, p. 303). At that time such protection was based on two legal acts: the Act on the Protection of Inventions, Designs and Trademarks[2] of 5 February 1924, subsequently replaced by the Regulation of the President of the Republic of Poland on the Protection of Inventions, Designs and Trade Marks[3] of 22 March 1928.

However, it was the changes in Poland's political system initiated in the 1990s, referred to as systemic transformation, that clearly revealed the need to introduce modern regulations, adequate for the new economic conditions, but also to adjust Polish law to the EU and international standards.

The Industrial Property Act (The Industrial Property Act of 30 June 2000, 2001) of 30 June 2000 (effective as of 22 August 2001), comprehensively regulates the issues of industrial property protection and, pursuant to international agreements (Zadania UPRP) ratified by Poland, covers such subject areas as inventions, utility models, industrial designs, trademarks, geographical indications and topographies of integrated circuits, collectively referred to as inventive designs (Nowak-Gruca, 2014, p. 303).

In public statistics, they are treated as important indexes used to assess the effects of innovative activity.

The new statutory regulations abolished the issuance of certificates of protection for decorative designs; previously protection rights for decorative designs had been granted under the Regulation of the Council of Ministers of 29 January1963, which was revoked when the Act came into force. Pursuant to The Industrial Property Act, rights resulting from the registration of industrial designs started to be granted as of its effective date. Applications for decorative designs filed and not considered before the effective date of The Industrial Property Act were classified as applications for industrial designs.

The Act has been amended a few times. In terms of measures for the protection of industrial property rights, the most serious changes were introduced by the Amendment to the Act on Copyrights and Related Rights, and Some Other Acts (The Amendment to the Act on Copyrights, 2007) of 9 May 2007. This amendment was primarily aimed at the implementation of the Directive (2004/48/EC) on the enforcement of intellectual property rights (Directive 2004/48/EC of the European Parliament, 2004).

[2] Journal of Laws, no. 31, item 36, as amended.
[3] Journal of Laws, no. 39, item 384, as amended.

Industrial property rights, i.e. a patent for an invention, a protection right for a utility model, a right resulting from the registration of an industrial design, a protection right for a trademark, a right resulting from the registration of a geographical indication and a right resulting from the registration of topographies of integrated circuits may become (usually are) valuable assets of economic entities, used by them to achieve competitive advantage (Sieńczyło-Chlabicz, 2020, p. 1291). Patent regulations are of particular importance for the chemical industry, as they can affect the profitability of enterprises in this sector (Sieniow, 2018, p. 1545).

The possession of industrial property rights gives their owners the right to the exclusive use of products and services covered by legal protection on the territory of Poland, and thus excludes the possibility of their free use by other competitive entities. This legal arrangement entails the right to prohibit other entities from using, selling, or marketing products and services identical or similar to those covered by legal protection, which significantly increases the market value of an enterprise recognising its industrial property rights as valuable assets (Sieńczyło-Chlabicz, 2020, p. 1292).

This gives such an enterprise an important advantage over its competitors as it becomes the sole provider of an innovative product or service in the market (Sieńczyło-Chlabicz, 2020, p. 1292). Thus, innovation becomes the basis for strengthening its brand, reputation and recognisability.

In Poland, the central body of the state (government) administration responsible for the performance of a wide range of tasks related to the protection of industrial property in Poland is the Patent Office of the Republic of Poland, whose statutory tasks include in particular (Sieńczyło-Chlabicz, 2020, p. 1293 et seq.):

- receiving and examining applications concerning inventions, utility models, industrial designs, trademarks, geographical indications and topographies of integrated circuits, filed for the purpose of acquiring their protection,
- adjudicating on matters concerning the granting of patents and supplementary protection rights for inventions, utility models and trademarks, as well as rights resulting from the registration of industrial designs, geographical indications and topographies of integrated circuits,
- issuing decisions in dispute proceedings,
- maintaining registers for patents, utility models, industrial designs, trademarks, geographical indications and topographies of integrated circuits,
- publishing its official gazette entitled the Patent Office News,
- publishing the Patent Office Bulletin,
- participating in the work of international bodies on natters concerning industrial property, under international agreements entered into by the Republic of Poland, in particular the Paris Convention for the Protection of Industrial Property,
- maintaining a central collection of Polish and foreign patent descriptions.

The main task of the Office is to adjudicate on matters concerning the granting of exclusive rights to objects of industrial property (Kondrat, 2021, p. 55). Adjudications granting exclusive rights are given by independent experts who, within the scope of their decisions, are bound only by the provisions of the Act. Disputes concerning the cancellation or termination of exclusive rights are resolved by the Adjudicating Bodies of the Patent Office (Sieńczyło-Chlabicz, 2020, p. 1296 et seq.).

The representatives of the Patent Office also participate in meetings of the European Commission and the Council of the European Union devoted to the issues concerning the protection of industrial property. Therefore, it is a body that ensures that the Polish economy remains in constant contact with the international system of industrial property protection. Fulfilling its mission in the field of industrial property protection, the Polish Patent Office is one of the most important institutions that influence the shaping of conditions conducive to the development of an innovative economy, characterised by legal security of trade and a high level of competitiveness (Sieńczyło-Chlabicz, 2020, p. 1296 et seq.).

## 4. Forms of industrial property protection

### 4.1. Invention and patent

An invention is a novelty that does not constitute a part of the previous state of the art (Nauka i Technika, 2020). There are four categories of inventions: creations, devices, methods and applications (Nowińska, Promińska, du Vall, 2011, p. 28 et seq.).

Irrespective of the field of technology, a patent is granted for an invention that is new, represents an inventive level (i.e. from an expert's point of view, it does not obviously result from the state of the art (Nauka i Technika, 2020) and can have industrial applications (i.e. if an invention may be the source of a technological creation or method used in any economic activity (Czub, 2016, p. 170).

Inventions do not include in particular (Nauka i Technika, 2020):

- discoveries, scientific theories and mathematical methods,
- products of a purely aesthetic nature,
- plans, principles and methods relating to mental or economic activities and games,
- creations for which the impossibility of use can be demonstrated in light of generally accepted and recognised scientific principles,
- programmes for digital machines,
- presentations of information.

A patent for an invention is granted for a period of 20 years from the date of filing an application with the Polish Patent Office (Czub, 2016, p. 186). However, patents are not granted for inventions whose use would be contrary to public policy or moral standards (Nauka i Technika, 2020).

### 4.2. Utility model

A utility model is a new and useful solution (Nauka i Technika, 2020), capable of industrial applications (if, based on a given utility model, it is possible to obtain a technological creation, in any economic activity), a solution of a technological nature, pertaining to the shape or structure of an object with a durable form or an object composed of functionally connected parts with a durable form (Czub, 2016, p. 202).

A utility model relates to tangible objects with a durable form, which means that solutions relating, for example, to modes of conduct or applications of substances cannot be the subjects of applications for protection (Czub, 2016, p. 202).

The right of protection for a utility model is granted for a period of 10 years from the date of filing a relevant application with the Polish Patent Office (Czub, 2016, p. 202).

### 4.3. Industrial design

An industrial design is a new original (Nauka i Technika, 2020) and individualised form of a product or its part, determined, in particular, by the features of lines, contours, shapes, colours, texture, material and ornamentation of a product (Kępiński, 2010, p. 32). Industrial designs apply to a very wide range of products, from luxurious to everyday ones, as the essence of industrial designs is the protection of their appearance (Czub, 2016, p. 213).

The right resulting from the registration of an industrial design is granted for a maximum period of 25 years (divided into five years' periods), counting from the date of filing a relevant application with the Polish Patent Office (Czub, 2016, p. 226).

### 4.4. Trademark

A trademark may be any sign represented graphically or capable of being expressed graphically, enabling the differentiation of the goods (products) of one enterprise from those provided by other enterprises and capable of being represented in the trademark register in a manner that makes it possible to determine the unambiguous and precise subject of the granted protection (Sieńczyło-Chlabicz, 2020, p. 638 et seq.).

The catalogue of representational forms of trademarks is open, and examples of types of trademarks include: word, word and figurative, figurative, spatial, and sonic (Sieńczyło-Chlabicz, 2020, p. 638 et seq.). The most frequently used representational forms are word marks (words or slogans), as well as word and figurative marks (words with graphic elements) (Żelichowski, 2022, p. 12 et seq.).

The right of protection for a trademark is granted for a period of 10 years from the date of filing a relevant application with the Polish Patent Office. Protection may be renewed for further periods of 10 years upon payment of a fee (Żelichowski, 2022, p. 12 et seq.).

### 4.5. Geographical indication

A geographical indication is a word indication referring directly or indirectly to the name of a place, locality, region or country (area) which identifies goods as originating from that area; it is used to label food and industrial products (Nowińska, Promińska, Szczepanowska-Kozłowska, 2021, p. 491).

The condition for granting the right resulting from the registration of a geographical indication is the association of a product with a given area, if high quality, good reputation or other distinctive features of goods are primarily attributed to their geographical origin (Nowińska, Promińska, Szczepanowska-Kozłowska, 2021, p. 492).

An individual entrepreneur cannot apply for the protection of a geographical indication. Such an application may be filed by an organisation of producers operating in a given area or a central or local governmental administrative body competent for the area to which the geographical indication refers (Sieńczyło-Chlabicz, 2020, p. 1030).

The Patent Office grants the rights resulting from the registration of geographical indications relating to industrial products only, while separate provisions apply to agricultural products and foodstuffs (Sieńczyło-Chlabicz, 2020, p. 1030).

The right resulting from the registration of a geographical indication is granted for an indefinite period of time (Sieńczyło-Chlabicz, 2020, p. 1030).

### 4.6. Topographies of integrated circuits

A topography of integrated circuits is a solution consisting in the spatial arrangement of elements, of which at least one is an active element, and all or some connections of an integrated circuit. Such an arrangement can be expressed in any way. A prerequisite for the registrability of a topography is its originality. Protection can only be granted to topographies that are the result of the intellectual work of a creator and were not generally known at the time of their creation. Both conditions must be met simultaneously (Skubisz, 2014, p. 1206).

## 5. Industrial property protection in the years 2000-2020 – the quantitative dimension

The quantitative dimension of industrial property protection, both submissions of applications and protection rights granted, can constitute an excellent, yet underestimated, picture of the innovativeness of the economy. In the conditions of the systemic transformation

and the building of a market economy in the 21st century, the key issue seems to be very high instability and variability over time of both the number of submitted applications and the number of granted protection rights. It concerned, without exception, all forms of industrial property. Nevertheless, there were considerable differences in the intensity of activity with regard to the particular forms of industrial property, which is shown clearly in the tables below.

**Table 1.**
*Industrial property protection in Poland in the years 2000-2020*

| Year | Objects of industrial property | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Invention | | Utility model | | Industrial design* | | Trademark | |
| | applications | granted patents | applications | granted protection rights | applications | granted rights from registration | applications | granted protection rights |
| 2000 | 2404 | 939 | 1274 | 680 | 1175 | 629 | 14111 | 7118 |
| 2001 | 2202 | 851 | 1057 | 484 | 1223 | 561 | 12434 | 5074 |
| 2002 | 2313 | 834 | 865 | 558 | 1284 | 921 | 12355 | 4803 |
| 2003 | 2268 | 613 | 732 | 666 | 1917 | 1837 | 13281 | 5181 |
| 2004 | 2381 | 778 | 648 | 894 | 1918 | 2026 | 13776 | 5669 |
| 2005 | 2028 | 1054 | 600 | 829 | 1773 | 1973 | 13864 | 8688 |
| 2006 | 2157 | 1122 | 625 | 869 | 1707 | 1437 | 14065 | 10644 |
| 2007 | 2392 | 1575 | 604 | 605 | 1598 | 1431 | 13951 | 14033 |
| 2008 | 2488 | 1451 | 667 | 616 | 1465 | 1207 | 14705 | 13911 |
| 2009 | 2899 | 1536 | 734 | 431 | 1849 | 1299 | 13229 | 8731 |
| 2010 | 3203 | 1385 | 879 | 484 | 1723 | 1231 | 14080 | 10050 |
| 2011 | 3880 | 1989 | 941 | 498 | 1548 | 1294 | 14252 | 8795 |
| 2012 | 4415 | 1851 | 944 | 514 | 1341 | 1532 | 13246 | 7925 |
| 2013 | 4237 | 2339 | 985 | 621 | 1317 | 1268 | 13532 | 9049 |
| 2014 | 3939 | 2497 | 914 | 586 | 1138 | 827 | 13139 | 9386 |
| 2015 | 4679 | 2404 | 994 | 562 | 1022 | 776 | 12613 | 7992 |
| 2016 | 4261 | 3370 | 1084 | 638 | 1063 | 1080 | 13854 | 7902 |
| 2017 | 3924 | 2795 | 953 | 776 | 971 | 815 | 13739 | 13800 |
| 2018 | 4207 | 2906 | 943 | 769 | 1081 | 949 | 12811 | 10470 |
| 2019 | 3887 | 2947 | 855 | 603 | 1004 | 934 | 13294 | 9894 |
| 2020 | 4010 | 2260 | 793 | 533 | 988 | 789 | 13541 | 6556 |

* in 2000 – decorative designs, in 2001 – jointly decorative designs and industrial designs.

Source: the author's own work based on Nauka i technika w 2020 r. [Science and Technology in 2020], compiled by The Central Statistical Office and The Statistical Office in Szczecin, Warszawa - Szczecin 2020, as well as other publications with the same title from previous years.

The above table indicates that over the entire period 2000-2020, the number of patent applications grew quite significantly, although this growth was not continuous and was periodically interrupted by small and short-lived decreases. In total, the number of patent applications during this period increased by as much as 66.8%, giving an average year-on-year increase of 2.59%. The number of granted patents grew at an even faster rate and increased by as much as 140.7% over the entire twenty-one years' period, an average year-on-year increase of 4.49%. This shows a very positive trend, with an increasing share of applications being granted protection.

In the same period, the process of filing applications for the protection of utility models with the Patent Office was quite different, as in the years under examination, i.e. between 2000 and 2020, the number of applications decreased by 37.8%, which constituted an average annual decrease of 2.34%. The number of granted protection rights, on the other hand, decreased in

this period by only 21.6%, or on average by only 1.21% every year. Thus, also in the case of utility models, an increasing percentage of applications were granted legal protection.

The trends in the submission and registration of industrial designs (and in the years 2000-2001 both industrial designs and decorative designs) were different. The number of applications for their protection fell by 15.9%, or by an average of 0.86% on a year-on-year basis, but the number of granted rights resulting from registration decreased by as much as 25.4% over the whole period or on average by 1.14% every year. This indicates that an increasingly smaller percentage of applications were granted legal protection.

The number of applications for the protection of trademarks declined by only 4.0% between 2000 and 2020, an average annual decrease of 0.21%, while the number of granted protection rights granted fell by 7.9%, or on average by 0.41% every year. This means that, also in this case, fewer and fewer applications were being reviewed successfully.

Unfortunately, statistical data on the structure of industrial property protection are only available for patents and industrial designs and cover a slightly shorter period. Nevertheless, they also show quite interesting regularities relating to applications for protection of both patents and utility models.

**Table 2.**
*Patent applications*

| Year | total | including applications filed by | | |
|---|---|---|---|---|
| | | scientific entities of the Polish Academy of Sciences, research institutes, universities | business entities | natural persons |
| 2010 | 3203 | 1577 | 711 | 915 |
| 2011 | 3878 | 1825 | 1335 | 718 |
| 2012 | 4410 | 2102 | 1521 | 787 |
| 2013 | 4237 | 1995 | 1509 | 733 |
| 2014 | 3941 | 1924 | 1511 | 506 |
| 2015 | 4676 | 2015 | 1901 | 760 |
| 2016 | 4261 | 1677 | 2008 | 576 |
| 2017 | 3924 | 1569 | 1763 | 592 |
| 2018 | 4207 | 1798 | 1779 | 630 |
| 2019 | 3887 | 1714 | 1655 | 518 |
| 2020 | 4010 | 1726 | 1709 | 575 |

Source: the author's own work based on Nauka i technika w 2020 r. [Science and Technology in 2020], compiled by The Central Statistical Office and The Statistical Office in Szczecin, Warszawa - Szczecin 2020, as well as other publications with the same title from previous years.

In the years 2010-2020, the structure of patent (invention) applications was dominated by scientific entities of the Polish Academy of Sciences, research institutes and universities (grouped together as one category of entities in Table 2), but with a downward trend in their share of all applications, from 49.2% in 2010 to 43% in 2020. At the same time, the share of applications filed by business entities rose from barely 22.2% to as much as 42.6%, thus almost equalling the share of academic and research organisations. Natural persons submitted the fewest applications; their share fell from 28.6% in 2010 to 14.3% in 2020.

With an overall quite clear, although unstable, growth trend reaching on average 2.3% year-on-year (with an increase of as much as 21.2% in 2011 and a decrease of as much as 8.9% in 2016 in the entire period 2010-2020), the lowest average annual increase (0.9%) was generated by the scientific entities of the Polish Academy of Sciences, research institutes and universities. They were followed by natural persons (4.5%) and business entities (9.2%).

**Table 3.**
*Utility model applications*

| Year | total | including applications filed by | | |
|---|---|---|---|---|
| | | scientific entities of the Polish Academy of Sciences, research institutes, universities | business entities | natural persons |
| 2010 | 879 | 104 | 392 | 383 |
| 2011 | 940 | 109 | 624 | 207 |
| 2012 | 941 | 108 | 562 | 271 |
| 2013 | 986 | 105 | 587 | 294 |
| 2014 | 913 | 126 | 680 | 107 |
| 2015 | 994 | 115 | 673 | 206 |
| 2016 | 1084 | 128 | 811 | 145 |
| 2017 | 953 | 108 | 701 | 144 |
| 2018 | 943 | 115 | 671 | 157 |
| 2019 | 855 | 135 | 599 | 121 |
| 2020 | 793 | 163 | 480 | 150 |

Source: the author's own work based on Nauka i technika w 2020 r. [Science and Technology in 2020], compiled by The Central Statistical Office and The Statistical Office in Szczecin, Warszawa - Szczecin 2020, as well as other publications with the same title from previous years.

In the structure of applications for the protection of utility models (see: Table 3), the trends were fundamentally different. The most applications were submitted by business entities, whose share increased from 44.6% in 2010 to 60.5% in 2020. The share of natural persons declined quite significantly, from 43.6%, to barely 18.9%, while the share of the scientific entities of the Polish Academy of Sciences, research institutes and universities increased from 11.8% to 20.6%.

With an overall quite clear, although unstable, downward trend reaching on average 1.0% year-on-year (with an increase of as much as 9.1% in 2016 and a decrease of as much as 12.1% in 2017 in the entire period 2010-2020), the highest average annual increase of only 4.6% was generated by the scientific entities of the Polish Academy of Sciences, research institutes and universities. The number of applications filed by business entities rose annually on average by 2.0%, while natural persons recorded a decrease of 8.9%.

## 6. Conclusion

In the cognitive and research dimensions, both innovation and innovativeness constitute an interdisciplinary category analysed by many researchers by means of different methods and based on different categories of data or indexes. The lack of a uniform definition of the concept of innovation, and therefore of its objectivised measures, is due to the very specific nature of the subject of research, and consequently the approach to this concept, understood as either a (continuous) process or the effects of this process.

Proving that innovations become a driving force for economic development – a belief shared by the world of science and the general public – is extremely difficult if only fragmentary data are available. In fact, there may not even be conclusive evidence unambiguously confirming their impact on economic development. However, this does not exempt researchers from attempts to study and assess the phenomenon of innovation itself, in both qualitative and quantitative terms. This review does not claim to provide a comprehensive account of the phenomenon, but is intended as a contribution to further research.

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# SAP ERP SOFTWARE AS A TOOL FOR MANAGING THE LOGISTICS SUBSYSTEMS OF AN ENTERPRISE

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**Purpose:** The main purpose of this article is to evaluate the capabilities of SAP ERP software in managing an organization's logistics subsystem, identify the main strengths and weaknesses of SAP ERP software in an organization, and identify the information requirements associated with identifying logistics activities.
**Design/methodology/approach**: In preparing the article, the author used both theoretical and empirical research methods, particularly analysis, synthesis, deduction, induction, comparison, generalization, as well as scientific observation with casual observation technique. The qualitative methods mentioned above were used to analyze the literature on the subject. Analysis was used to deepen knowledge in the area of the issues under study, as well as to identify their interrelationships and the relationships that exist between them. Deduction, for the process of inferring the particular from the general. Induction was used during observation. Comparison was mainly used to identify similarities and differences in the use of SAP ERP software in the various logistics subsystems. Inference was used to develop conclusions, included at the end of this article. Using the aforementioned methods, it was possible to evaluate the functionality of SAP ERP software in the management of the enterprise's logistics subsystems, to identify the main advantages and disadvantages of SAP ERP software in the enterprise, and to identify the information needs related to logistics activities in the enterprise.
**Findings:** Modern enterprises operate in a highly competitive environment, so they need to quickly adapt to changes occurring in their environment: near and far. This is possible thanks to the implementation of modern tools, methods or techniques that enable continuous management of all departments of the enterprise, including logistics system.
**Originality/value:** This article is addressed to theoreticians and practitioners of business management. Theoreticians reading this article will find a sentiment of current data on SAP ERP software and the scale of possibilities for its use. Practitioners, in turn, will find useful tips on where SAP ERP software can be implemented or how to improve the form of its use in an enterprise.

**Keywords:** SAP ERP software, management, enterprise, logistics system, logistics subsystems.

**Category of the paper:** Scientific articles.

## 1. Introduction

Today's businesses, including logistic companies, must deal with large amounts of data provided by various measurement and reporting tools enhanced by international activities. Proper execution of the logistics process must therefore be ensured by dynamically intervening in the event of disruption. Modern businesses are therefore considered dependent on the latest technology, including IT software. There are many software products and platforms available on the global market, offering both basic activities and comprehensive support for all operational areas. It allows you to manage both the entire logistics system and its subsystems and processes. One of the most popular IT software for managing businesses is SAP ERP. It is a comprehensive IT system that enables integrated management, automation and optimization of processes, leading to quality of services provided and reducing costs for companies. The topic of SAP ERP is of interest to modern researchers due to the constant demand from enterprises for effective and efficient business management tools. SAP ERP software is considered one of the most advanced and integrated management systems. It allows you to manage areas of your company's operations. The author of this article focuses on managing his company's logistic subsystem.

Procurement, manufacturing, and sales. One of the most key features of SAP ERP software is the ability to use analytics. It allows businesses to plan, monitor and control activities in real time. In the literature, the researcher works on his SAP ERP software and points to its potential use in various areas of the company, including logistics areas: "Optimizing Supply Chain Management with SAP ERP" (Kilgera, Zimmermański, 2014) . „Implementing SAP ERP in the Logistics Industry " (Gupta A., Kumar Singh R. 2020), "SAP ERP for Better Supply Chain Management" (Liu, Chiu, 2021), "SAP ERP in Logistics and Distribution. Most work bases on the use of SAP ERP software to support resource management, enterprise process management in finance, accounting, human resource management. SAP ERP with the help of data transparency will enable automation of individual processes. In recent years, this software has been enriched with additional functions such as risk management, quality management or project management (www.sap.com). SAP ERP software in logistics processes plays a significant role due to functionality and efficiency, so it is often selected and implemented in both medium-sized and large companies. In addition, SAP ERP software enables the creation of corporate services and the provision of services to end users.

The purpose of this article is to evaluate the capabilities of SAP ERP software in managing an enterprise logistics subsystem, identify the main strengths and weaknesses of SAP ERP software in an enterprise, and assess the information needs of logistics operations.

## 2. SAP ERP software

SAP ERP software is derived from the ERP Enterprise Resource Planning system, a collection of interconnected applications, such as Google's online storage. This system optimizes the company's work in the areas of human resource management and logistics (Rutkowski, 2001). Enterprise Resource Planning was created through the implementation of the LRP module (Logistic Resources Planning System) and similar modules, thus enabling planning, management, and control of all levels of the enterprise. This system uses a single base in its operation, and therefore leads to the integration of enterprise operations (Pegani, 2022). There are several types of ERP systems in the literature, called integrated information systems. Among them are modular systems, consisting of independent but cooperating modules. ERP systems collect scattered data with infinite spreadsheets, then organize this chaos in such a way that the same data can be used, processed, and stored by employees at all levels of the. As P. Lech aptly notes, Enterprise Resource Planning systems streamline, systematize, and optimize the work of the entire enterprise. Which translates into productivity and efficiency of employees. These systems facilitate quality management, affecting the growth of company profits. They provide secure access to collected data, enable real-time online work using the Internet and Intranet. These systems enable automatic and comprehensive use of the financial and accounting program, reducing system maintenance costs, and preparing dependable financial and marketing analyses (Lech, 2003). SAP ERP (Enterprise Resource Planning) software supports enterprise management. Developed by the German company SAP AG in 1972, it was originally known as "Systems, Applications and Products in Data Processing". SAP ERP's first activity was solely concerned with automating financial and accounting processes. The 1980s were a breakthrough time, SAP ERP software expanded into additional areas: procurement, manufacturing, and distribution. Today it is one of the most well-known and widespread software of its kind in the world. It has been constantly evolving and improving over the years. SAP ERP software has constantly introduced new functionalities and integrated with other systems. According to a ranking conducted by Creative Saplings, presenting the world's ten largest IT companies in 2020, SAP ERP was ranked 6$^{th}$ (Grabiński, Piecucha, 2012). In turn, according to statistics, it was the most widely used system in the world. It was used by more than twelve million users in 2020. In Poland, almost 40% of the enterprise business software market used SAP ERP (Lysenko-Ryba, 2017). Well-known international companies have implemented it into their operations: Procter & Gamble (www.basistechnologies.com) a global conglomerate that produces food, cosmetics, and household products. Coca-Cola (https://news.sap.com/france/2004/02/coca-cola) One of the world's best-known beverage brands, Unilever (https://www.unilever.com/news/press-and-media) Global manufacturer of food, cosmetics and home products. Nestle one of the world's largest food manufacturing companies (https://www.nestle.com/news/press-and-media). As well as: Heineken

(https://news.sap.com/netherlands/2022) multinational brewing company, BASF (https://www.basf.com/) one of the world's largest chemical manufacturers, Siemens (https://www.sap.com/poland/products) an international electrical engineering, automation and information technology company, and Daimler AG (https://iot-automotive.news/sap-daimler-ag/) car and commercial vehicle manufacturer.

## 3. Management of logistics subsystems in the enterprise

Enterprises act for their own benefit as business units authorized to trade (produce, trade or provide services) under applicable law. Every business has its own name, brand, books, movable property, real estate, liabilities, liabilities, and ownership. It represents an economic, organizational, legal and production-technical peculiarity whose purpose is the implementation of managerial decisions, one of the elements of management (Krzemińska, 2005).

Management understood as a set of actions, taken by management to implement the various processes of the enterprise (Zalewski, 2005). With the help of management, it becomes possible to achieve the goals of the enterprise (organization) effectively and efficiently, while maintaining rational economy. As well as obtaining maximum benefits with given inputs or using minimum inputs in pursuit of certain goals. Management is planning, organizing, giving orders, coordinating and controlling (Dembińska-Cyran, Jedliński, 2005). A. Zalewski says company managers use the tools available to them to achieve their goals (Zalewski, 2005). The types, methods and means of corporate management depend on the external factors that affect the company. These include increased economic interdependence with globalization, increased economic interdependence between countries, and border ambiguity in the context of international trade. The flow of capital, goods, and services, and the revitalization of SMEs. Intensifying international competition, use of the latest technology. We will provide high-quality products and services and carry out aggressive marketing. External factors also include population aging, lifestyle changes, consumer preferences and expectations. A change in employer and employee orientation that has proven to be an added value for the company. Shifting from an industrial economy to an information economy, building a new distribution network, manufacturing products that meet local needs (Penc, 2002).

Logistics in a company is a very important pillar. Generalizing, we can say that it deals with the management of movement and storage activities designed to facilitate the flow of products from points of origin to places of final consumption, as well as related information. The purpose of this management is to offer customers an adequate level of customer service at a reasonable cost (Beier, Rutkowski, 2004). A logistics system is an organized and interconnected set of elements along with the relationships that exist between them and their properties that determine the flow of streams of material goods, financial resources, and information (Nowakowski, 2011). Management, support, primary and secondary order processes (planning, execution and management of raw materials, production materials, finished goods and related information from origin to point of consumption to meet customer expectations, efficiently and economically The literature further subdivides in-house logistics processes. Transportation, storage, inventory management, customer service, order processing, information flow. Today, logistics activities are given great importance in customer service. D.M. Lambert, J.R. Stock as in (Lambert, Stock, 1993) each of the company's logistics activities affects the product received by the customer, which should be delivered to the right customer, in the right quantity, in the right condition, in the right place, at the right time and at the right cost (Rutkowski, 2006). Customer service should be implemented at the highest possible level, as it translates into the management of logistics processes in the company. F.J. Beier, K. Rutkowski highlight that an efficient and effective logistics system is treated as the same as an asset on the company's books (Beier, Rutkowski, 2000). Moreover, it is difficult for competitors to copy. A high degree of consistency and flexibility are two of the most important characteristics of a logistics system. A change in one subsystem causes changes in other subsystems (Lambert, Stock, 1993). Management of logistics subsystems has been described by: R.H. Ballou, author of Business Logistics/Supply Chain Management, which is considered one of the most important studies on logistics and supply chain management. J.T. Mentzer, author of many articles and books on logistics and supply chain management, wrote, among other things: "Defining Supply Chain Management: A Historical Perspective and Practical Guide". D. Simchi-Levi, author of "Designing and Managing the Supply Chain: Concepts, Strategies, and Case Studies," which is considered one of the most important studies on supply chain design and management.

## 4. Use of SAP ERP software in the management of logistics subsystems

Modern IT software is indispensable for the proper implementation of company processes, including logistics. One of them is SAP ERP software. The scope of its logistical activities is shown in Figure 1. There are few publications in the literature that focus on the management of individual logistics subsystems of an enterprise using a tool such as SAP ERP software.

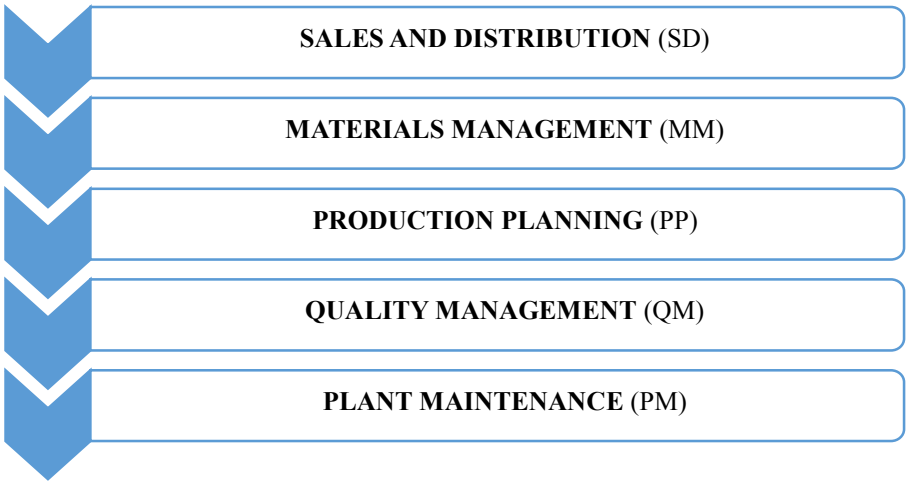


**Figure 1.** SAP ERP software functional modules.

Source: compiled from www.sap-erp.com, 16.11.2023.

SAP ERP makes it possible to manage not only the entire logistics system, but also its individual enterprise logistics subsystems. It automates purchasing processes, including planning needs, negotiating with suppliers, ordering goods and monitoring deliveries. It is also possible to manage the warehouse in real time, i.e. the flow of goods, control of current inventory levels, optimization of warehouse space and tracking of deliveries. Supply management using delivery planning and tracking, monitoring the movement of goods and delivering them to customers on schedule. Production management by planning and optimizing production, monitoring progress and delivering products to customers on schedule. Supply chain management, tracking and controlling the movement of goods from suppliers to customers. Among the most well-known logistics companies that use SAP ERP software to manage their company's logistics subsystems are: Deutsche Post DHL (https://narzedzia.dhl.pl/pl/), one of the world's largest logistics service providers. It uses SAP ERP software to manage purchasing, warehouse, production and delivery processes. Kuehne + Nagel (https://www.appsruntheworld.com), a global provider of logistics services. It uses SAP ERP software to manage purchasing, warehouse, supply and supply chain processes. DB Schenker (https://www.dbschenker.com), the world's leading logistics service provider, has implemented SAP ERP to manage its purchasing, warehouse, production and delivery processes. UPS (https://www.ups.com), one of the world's largest logistics service providers, uses SAP ERP to manage warehouse, delivery and supply chain processes. FedEx (https://psg.office.fedex.com/sap/), SAP ERP implemented to manage purchasing, warehouse, production and delivery processes. The use of SAP ERP software is noted in all subsystems of the company's logistics system. In her study, the author focused on three main subsystems: procurement, production and distribution. In the procurement subsystem, it is used to automatically generate orders for raw materials and supplies, that is, to plan and optimize deliveries. By using this software, it is possible to avoid situations in which a shortage of raw materials can cause production downtime, and an excess of raw materials can generate

unnecessary storage costs. SAP ERP is also used to control the quality of supplies, by setting requirements that relate to the quality of individual raw materials and materials. In addition, it provides an opportunity to monitor whether the conditions of the transaction being carried out have been met. Another application of SAP ERP software in the procurement subsystem is the tracking of deliveries: raw materials and materials from the supplier to the company's warehouse. It is verified whether the deliveries are made in a timely manner, in accordance with the order. Another use of the software is inventory management (checking whether inventory levels are at the right level and whether there is a risk of running out of raw materials during production). SAP ERP enables the generation of various types of reports on raw material and material supplies, costs, quality, deliveries and inventory levels. This allows the company to analyze its procurement processes and make more informed decisions.

In the manufacturing subsystem, SAP ERP software is used to streamline processes related to production planning, execution and control. With the help of monitoring the supply of raw materials and materials needed for production, it becomes possible to detect possible problems early and prevent delays. SAP ERP is also used to manage production processes through production optimization, quality control, working capital management and production cost control. In addition, it can be used to manage inventory.

SAP software is also used in the distribution subsystem, which begins with the establishment of customer relationships and ends with the invoicing of materials delivered or services provided. With SAP ERP, it is possible to automatically generate sales documents and invoices, as well as monitor deliveries and payments. With this software, the company better controls its finances and manages customer relationships. It plans and tracks deliveries, optimizes delivery routes, manages inventory and warehouses, and tracks and analyzes company and employee performance. In addition, it enables integration with suppliers, customers and other parties involved in the distribution process, allowing the company to perform tasks faster and more efficiently. Moreover, with real-time tracking of deliveries and warehouses, the company can react faster to changes in its needs and adjust its operations to distribute products efficiently and reliably. M Chyka’s article describes the use of SAP LES (Logistics Execution System), one type of SAP ERP software used mainly in the distribution subsystem. It allows full control over all activities and over every participant in the process. By interfacing with wireless mobile devices, it provides full control over all movements of goods in the warehouse. It describes how warehousing and transportation work is synchronized, as well as all activities related to external release from the warehouse using SAP ERP (Cywka, 2007).

It is worth noting that SAP ERP software is flexible and can be customized to meet the needs of a specific enterprise, which means that it can be used to manage not only a single subsystem of the company, but also finance, HR and payroll, purchasing and other areas of the business.

## 5. Research on the use of SAP ERP in the management of logistics subsystems

It is important to signify that there is other competing software to SAP ERP, offering similar functions and tools for business management, such as financial, human resources, procurement, and production management. Among the best known are Oracle E-Business Suite, Microsoft Dynamics, Infor CloudSuite, Workday Financials. Choosing the right software depends on a number of factors, such as the size and needs of the company, budget, and function requirements. Research conducted by: IDC in 2019 found that 82% of companies in Europe use SAP software in their business processes (https://news.sap.com). A 2018 Gartner report indicates that SAP software is one of the most popular ERP tools in the world and is used by more than 400,000 customers (https://www.gartner.com). A 2016 Forrester study found that SAP software is one of the best-rated ERP tools on the market and is particularly strong in financial and accounting management (https://www.forbes.com). In turn, the use of SAP ERP software to manage logistics subsystems, among other things, confirms: Logistics IT Company Report of 2018 (https://www.statista.com/topics), which showed that more than 50% of supply chain management. In contrast, a study conducted by A.T. Kearney (https://www.kearney.com) in 2017 showed that using SAP software to manage logistics subsystems allows companies to increase the efficiency and effectiveness of logistics processes by up to 30%. Supply Chain Management Review report (https://www.scmr.com) from 2016 indicated that SAP software is one of the best-rated tools for managing logistics processes, and its use supports more efficient and flexible delivery. The above examples confirm that many studies show the benefits of using SAP software to manage logistics subsystems. What sets SAP ERP software apart is its information integration, which makes it possible to integrate information from different sources, such as production systems, finance and accounting. This allows a full view of the company's logistics, monitoring inventory, goods flow and distribution processes. Using logistics process optimization, the software enables the optimization of logistics processes such as inventory management, demand planning and production planning, leading to increased efficiency and cost reduction. SAP ERP makes it possible to monitor and manage deliveries, making it possible to ensure efficient and effective delivery of goods to customers. The software, thanks to its ability to generate analysis and reports, makes it possible to track performance and improve logistics processes. Using SAP ERP software to manage logistics subsystems, an enterprise has a complete view of its logistics. Therefore, it can improve the efficiency and quality of logistics processes, increase customer satisfaction through efficient delivery of goods. This is all thanks to the many analytical functions that SAP ERP has: Business Intelligence (BI) - which enables the review and analysis of business data, taking into account different perspectives such as volume, costs, margins, etc. Reporting and Visualizations - allows you to create and view reports and data visualizations that make it easier to interpret

and understand information. Planning and forecasting - enables businesses to draw forecasts about future business trends and events, and plan actions based on those forecasts. Cost analysis - enables companies to track and analyze costs across business areas to optimize operations and control expenses. Risk analysis - enables companies to identify and assess risks associated with various business activities, allowing them to better prepare for and respond to potential challenges.

Optimization of SAP ERP software in an enterprise involves tailoring the software to the needs and business processes of a given enterprise, so as to best support its operations and enable effective management. This optimization can include several aspects, such as: configuration of the SAP ERP system, i.e. adapting it to the specifics of the company's operations, so as to best meet its needs. Integration with other systems, for example, warehouse systems, production management systems, etc. Optimization of business processes: purchasing processes, warehouse processes. Implementing SAP ERP software can involve several drawbacks, such as high costs, the implementation process, customization of the software to meet the needs of the company, and difficulties in integrating with other systems. The implementation of this type of software should be preceded by a thorough analysis of cost-effectiveness, as well as a detailed plan for carrying out this operation, considering possible difficulties in the functioning of the organization. It is possible to prepare the software along with data migration, and then successively switch individual departments from the old type of software to software based on new technologies.

## 6. Summary

SAP ERP has undergone a major update in recent years, adding new tools and capabilities such as cloud integration, big data analytics, and machine learning. You can expect SAP to continue developing software to meet the requirements of increasingly complex business processes and market requirements. SAP ERP is used to manage various aspects of a company's operations, such as: B. Finance, Human Resources, Production, Logistics, Sales, etc. SAP ERP integrates data from different parts of the company, giving you better control over your business processes and facilitating more informed decision making. SAP ERP is widely used in many industries such as industrial, retail, service, and public sector. It is software that can adapt to the needs and optimize business processes of different types of businesses, small businesses and large enterprises. The planned innovations of SAP ERP keep pace with the dynamic changes of the modern world and point the way for this type of software transformation. As one of the most important business management tools in many industries, SAP ERP will gradually offer more capabilities than traditional data collection and analysis. A trend affecting the future of SAP ERP is the growing demand for cloud software (cloud computing).

Many companies already use SAP ERP software in the cloud. This saves time and money and makes managing your data and business processes easier and more flexible. Another key trend is the growing demand for software integrated with the Internet of Things (IoT). SAP has already implemented his IoT-based solution in ERP software, enabling companies to track and analyze data from various IoT devices to improve business processes. Therefore, it is safe to assume that many companies in various industries around the world will continue to use this software to better manage their data and business processes. With SAP ERP in managing the logistics subsystems within your enterprise, you can automate and optimize all processes, thus increasing efficiency and profitability. Using SAP ERP software is therefore valuable to your company for several reasons. This enables the automation and optimization of logistics processes, leading to improved quality and reduced operating costs. SAP ERP software is a flexible and scalable system that can be customized to suit the needs of any business. In addition, the system allows better control and management of all aspects of logistics that are critical to a company's success.

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# ESG RISK MANAGEMENT SUPPORTED BY ARTIFICIAL INTELLIGENCE SYSTEMS

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**Purpose:** ESG risk management and adapting to decarbonization requirements are among the key challenges European industrial enterprises will face in the upcoming decade. Addressing this challenge will involve the significant role of new technologies, particularly artificial intelligence. This article discusses research aimed at evaluating the effectiveness of a system utilizing artificial intelligence for risk management in the process of managing ESG goals.
**Design/methodology/approach:** In order to achieve the intended goal, the following research questions were formulated: Does the implemented system support the realization of ESG objectives in the studied organization, and would these objectives be achieved without implementing an AI-supported ESG risk management system? The research was conducted in a petrochemical sector company using qualitative methods (systematic literature review, case study description, self-observation and participant observation, informal interviews with selected system users). Due to the qualitative nature of the research, according to the methodology, no research hypotheses were formulated. Both the purpose of the research and the content of the above-mentioned issues indicate that they fit into the functional-systemic paradigm.
**Findings:** The analysis of research results indicates that the ESG risk management system based on artificial intelligence algorithms contributes significantly to the realization of ESG objectives in the studied organization. Additionally, managing the ESG risk in the organization is possible without implementing a system supporting this process, however, the effectiveness of such actions is limited significantly.
**Research limitations/implications:** Limitations result from the adopted research method. The systematic literature review, despite following the procedure derived from management and quality sciences, may be incomplete. Cited studies were conducted in various organizations and cultures. The case study description does not apply to every organization. Furthermore, self-observation as a method may be burdened with subjectivity, resulting from, among other things, the researcher's experiences.
**Practical implications:** Among technologies with the highest potential for managing risks in the ESG area, particularly in the context of decarbonization, artificial intelligence undoubtedly stands out. AI has the most significant impact on the digitalization of the economy, the implementation of the 2030 Agenda, the Green Deal, and the Paris Agreement. AI integrates most of the Industry 5.0 technologies and has the most crucial impact on supporting the

realization of climate goals – from monitoring trends, predicting weather events, to specific solutions reducing or completely eliminating greenhouse gas emissions.
**Originality/value:** The results of the conducted research demonstrate the significant potential of using artificial intelligence in managing ESG goals, especially in the implementation of decarbonization objectives and the digitalization of production processes in industrial enterprises. Additional value is the possibility of ensuring economic (cost reduction of processes), practical and reliable, high-quality production, as well as accelerating data analytics in the pursuit of identifying risks and achieving ESG goals.

**Keywords:** artificial intelligence, management, ESG, sustainable development.

## 1. Introduction

In publications discussing the role of artificial intelligence in the economy, it is emphasized that we are currently dealing with the fourth revolution, which results from the development and implementation of both artificial intelligence and other technologies (Pouliakas, 2021). In many industries, artificial intelligence reduces the number of repetitive tasks previously performed by employees (cf. Parker, Appel, 2021). Proponents of artificial intelligence have envisioned a scenario in which intelligent machines would perform routine tasks previously reserved for humans, freeing them to engage in creative activities. Nevertheless, there is widespread fear of potential job loss (Jaiswal, Arun, Varma, 2022). Awareness of the advantages and limitations of using artificial intelligence is also growing (Lou, Wu, 2021). There is no doubt that the dynamic development of artificial intelligence systems and automation is rapidly changing employment needs, professional skills, and the structure of work (Chuang, Graham, 2020).

One of the currently dominant areas of artificial intelligence application is management. It is increasingly being implemented, for example, in innovation management processes (Liu, 2022, p. 1). It is the result of an innovation process and influences or is influenced by contextual structures (Navneet et al., 2020; João Correia, Matos, 2021). In the previous decade, a relatively large number of research and implementations concerned the use of artificial intelligence in financial management. This trend continues (Yubo, 2021; Ghandour, 2021). The pandemic has prompted the financial sector and the business world to pay even more attention to the possibilities offered by artificial intelligence. (www; Soon, 2021).

Research continues to focus on improving decision support systems (Gupta et al., 2022; Patalay, Bandlamudi, 2021). Artificial intelligence is used in big data management processes, including the integration of knowledge generated throughout the product life cycle. The aim is to ensure economic, practical, and reliable production and improve product quality (Luo, Li, Yu, 2021).

Artificial intelligence, including affective data processing, is one of the most important and popular technologies currently used by educational institutions for data conversion and big data analysis (Aljarrah et al., 2021). One of the biggest beneficiaries of artificial intelligence is the business sector, especially in the era of Industry 4.0. The main idea of the fourth industrial revolution (4IR or Industry 4.0) is the digitization and integration of all elements and processes in a company (Blazek, 2021; Yu, Liang, Xue, 2022). New technologies characterized by high-performance computing potential enable the creation of complex artificial intelligence systems (Oliveira et al., 2021). Artificial intelligence also supports processes aimed at improving the state of the environment (Kshirsagar et al., 2022), e.g., in the design and operation of water supply systems (Czapczuk, Dawidowicz, Piekarski, 2015). AI solutions are also helpful in measuring, reducing, and mitigating the effects of emissions and greenhouse gases (GHG)[1].

Businesses have been eager to employ various programs and applications, realizing the potential benefits they may enjoy. Scientific publications often point to the possibility of reducing the costs of various processes or accelerating them, for example, in the field of data analytics (Lou, Wu, 2021).

AI also enables the aggregation of ESG-related information, which is currently provided in various reports, allowing comparisons and decision-making by companies, market participants, and rating agencies (https://www.ey.com…).

Existing research focuses mainly on ESG goals and risk management methods. However, the area of key interest in this study is the extent to which there are opportunities for the application of artificial intelligence. Therefore, after reviewing the literature, we have formulated research objectives, which involve evaluating the effectiveness of a system that uses artificial intelligence for risk management in the process of managing ESG goals.

## 2. Review of previous research

Currently, sustainable development management and disclosure of ESG indicators are gaining importance and becoming a significant element in the evaluation of companies in investment processes, seeking financing, or company valuations. Over the past decade, the efficiency of managing ESG factors has become strongly integrated with their investment value, particularly with the perception of risk levels. Measuring ESG performance indicators is already standard for large companies, especially public ones. A challenge for both companies and their stakeholders, such as investors, ESG analysts, financial institutions, and insurance companies, is the strategic management of ESG factors, particularly in data analysis, goal-setting, and risk prediction. ESG data management tools are necessary both for companies that

[1] Report developed in collaboration with Boston Consulting Group (BCG) and BCG GAMMA.

must integrate ESG goals with business objectives and from the perspective of investors or banks, which are obliged to assess the risk of invested funds or insured assets. Artificial intelligence may be the answer to the growing needs in the field of ESG data analytics. The increasing importance of ESG in financial institutions' risk management requires the creation and implementation of innovative evaluation techniques. There are many potential benefits associated with implementing artificial intelligence systems dedicated to ESG risk management. The literature on the subject indicates that these systems:

- can significantly help reduce CO2 emissions (McKane et al., 2017),
- directly support an organization's impact on the environment and improve ESG risk analysis and assessment processes, leading to improved financial results for companies and investors (Bassani, Osorio, 2017),
- contribute to reducing an organization's carbon footprint and improving the implementation of climate goals (Field, 2019),
- are used as a support tool to reduce greenhouse gas emissions (Ginevicius et al., 2021),
- support sustainable organizational activities (Brem et al., 2020).

In the available literature, one can notice that there are many motives for implementing ESG risk management systems. These include:

- drawing stakeholders' attention to the faster and more drastic climate changes, enabling the identification and mitigation of risks related to ESG issues, and improving the company's image while reducing costs associated with ESG risks (Sousa Jabbour et al., 2017),
- aiming to reduce costs associated with production or services (Karcher, Jochem, 2015).

Analysing the research results presented by various authors in the literature, it can be concluded that:

- there is a lack of publications that, on the one hand, would indicate methodological possibilities, and on the other hand, empirical examples of effective ways to assess the potential effects of implementing ESG risk management systems (McKane et al., 2017; Jovanović, Filipović, 2016).

Managing ESG risks and adapting to decarbonization requirements are key challenges for European companies in the coming years. Accenture's research shows that digitalization, particularly technologies such as AI, Cloud, 5G, IoT, and Big Data, will play a crucial role in addressing these challenges.

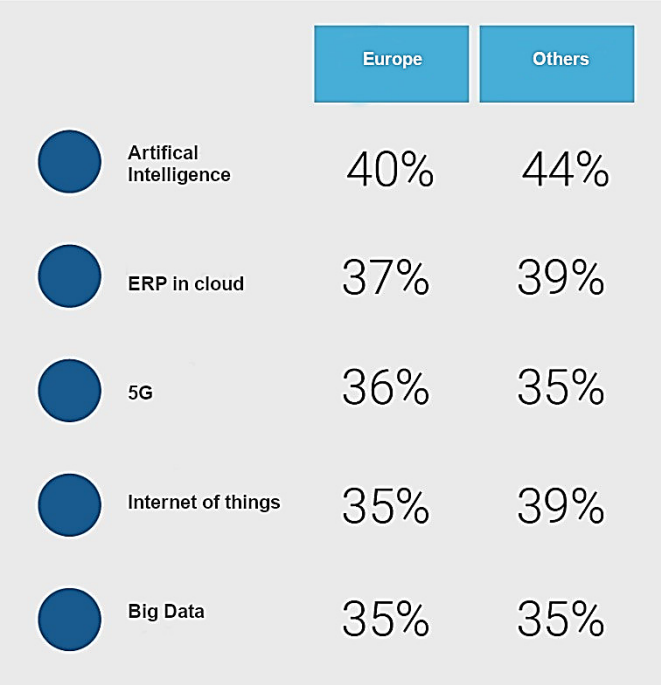


**Figure 1.** European companies plan significant investments in cutting-edge technologies.
Source: Accenture.

Among the technologies with the greatest potential for managing risks in the ESG area, particularly in the context of decarbonization, artificial intelligence stands out. AI has the most significant impact on the digitalization of the economy, the implementation of Agenda 2030, the Green Deal, and the Paris Agreement. AI integrates most of the Industry 5.0 technologies and has the most crucial impact on supporting climate goals – from monitoring trends to predicting weather events and implementing specific solutions that reduce or eliminate greenhouse gas emissions.

Considering the above content, the research goal is to evaluate the effectiveness of a system using artificial intelligence for ESG risk management in the examined company. To achieve the intended goal, the following research questions were formulated:

**P1. Does the implemented system support the achievement of ESG goals in the studied organization?**

**P2. Would these goals be achieved without the implementation of an ESG risk management system using artificial intelligence?**

## 3. Research Method

To address the aforementioned problems, qualitative methods were used. According to the problem classification, these methods have a practical nature (Lisiński, Szarucki, 2020, p. 106; Pszczołowski, 1978, p. 184). Due to the qualitative nature of the research, in accordance with

the methodology, research hypotheses were not formulated. Both the purpose of the conducted research and the content of the problems presented above indicate that they fall within the functional-systemic paradigm (Lisiński, Szarucki, 2020, p. 76). The following methods were used to conduct the research:

- systematic literature review (e.g., Creswell, 2013, p. 49 et seq.),
- case study description (e.g., Stake, 2014, p. 623; Dźwigoł, 2018, p. 72) and within its framework,
- self-observation and participant observation (e.g., Ciesielska, Wolanik Boström, Öhlander, 2012, p. 41 et seq.; Babbie, 2009, p. 325),
- unstructured interviews with selected system users (e.g., Kvale, 2012; Kostera, 2003, p. 121).

The case selection was purposeful, as the study's assumption was to focus on a specific ESG risk management system based on artificial intelligence tools rather than another system functioning within the integrated management system in the enterprise under investigation. The authors were interested in the effectiveness of this system after an initial period of operation (Ryan, Bernard, 2000). The same applies to the selection of respondents and the area of the organization in which the study was conducted (e.g., Flick, 2012, p. 62 et seq.). In the case study, a small group of people collaborates with the AI-based ESG risk management system. Interviews were conducted with respondents to document their opinions on the actual impact of the system on the ability to effectively manage ESG risks. The research was carried out in a petrochemical production company in January-February 2023.

## 4. Results of the conducted research

In the studied company, an ESG risk management system based on artificial intelligence tools operates in the scope of decarbonization modules. The utility billing analysis module uses regression models to normalize energy performance for weather indicators and KPIs, allowing for the measurement and tracking of savings relative to reference periods over time. The interval utility meter analysis module uses rule-based analysis and AI algorithms to automatically detect exceedances of expected demand or media consumption. The sustainable development program tracking module is equipped with a scenario modelling tool and savings tracker, which supports the investment decisions of sustainable development projects.

In relation to the first research question [P1], considering both the content analysis of available documents and self-observation and participant observation, it was found that the ESG risk management system implemented in the organization, based on artificial intelligence algorithms, significantly contributes to the achievement of the ESG goals of the studied organization.

Considering the second research question [P2], it should be noted that ESG risk management in the organization is possible without the implementation of a system supporting this process, but the effectiveness of these actions is significantly limited. Thus, the implementation of the system improves the efficiency of ESG risk management in the organization.

**Limitations**

The limitations stem from the adopted research method. The systematic literature review, despite following the procedures from management and quality sciences, may be incomplete. The cited studies were conducted in various organizations with diverse cultures. The case description does not apply to every organization. Meanwhile, self-observation as a method can be burdened with subjectivity, resulting from, among other things, the researcher's experiences.

## 5. Conclusions

Referring to the assessment of the effectiveness of the ESG risk management system supported by AI tools, which is the subject of the study, the following observations can be formulated based on the presented results.

In recent years, responsible investment in sustainable development has evolved, and today it is referred to as a "megatrend" in the world of finance. Businesses are increasingly building their value based on ESG indicators, whereas investment firms are seen to use ESG results for portfolio management more commonly. The development of ESG has stimulated the creation of methods that enable its quantification. Consequently, the number of provided measures requires standardization and harmonization to support responsible investment and risk assessment. AI-based mechanisms can support the process of building a responsible ESG sector in terms of increasing trust in process management and minimizing potential risks associated with ESG management.

Research on ESG topics, risk management, and artificial intelligence is still relatively rare but seems to be developing and gaining importance. The introduction of artificial intelligence tools in ESG risk management can bring many benefits but also requires attention to potential threats and challenges associated with its implementation. One such challenge is, for example, ensuring the transparency of algorithms, which is particularly important in the context of risk assessment in ESG management.

Thanks to the application of machine learning and the analysis of large datasets, it is possible to conduct a more precise analysis and identification of ESG risks, allowing for more effective management. Additionally, artificial intelligence can help identify positive ESG factors, enabling investors to find companies with high social and environmental value and detect potential sources of profit.

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# CURRENT ACTIVITIES FOR QUALITY AND NATURAL ENVIRONMENT TAKEN BY SELECTED ENTERPRISES BELONGING TO SMES FROM THE ELECTROMECHANICAL INDUSTRY

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**Purpose:** The purpose of the article is to present results of pilot studies from survey research of small and medium enterprises (SMEs) from the electromechanical industry of the countries of the Visegrad Group, i.e.: Poland, the Czech Republic, Slovakia, and Hungary.
**Design/methodology/approach**: As subject of research selected SMEs from electromechanical industry. Survey research was quantitative in nature. They were conducted in a written and electronic way using the MS FORMS platform.
**Findings:** In recent years, issues related to nature protection have become more and more priority for small and medium enterprises from the electromechanical industry of Visegrad countries. This is mainly due to the updated way of managing organisations and the increasing emphasis on the use of sustainable development tools. This pressure is exerted by competition but also by customers. It turned out that today it is not enough to ensure high quality of products, but in order to achieve the basic goals of the organisation, it is also necessary to invest in sustainable development. However, there is resistance in this area, related to awareness and costs.
**Research limitations/implications**: The article included initial research. In the future, the next research is planned in this area.
**Originality/value:** The article presented an analysis of the pilot survey research of approach to quality and environmental issues in SMEs. The article refers to enterprises from one industry, i.e.: the electromechanical industry of Visegrad Group - Poland, the Czech Republic, Slovakia and Hungary. The conclusions from the research are important for national SMEs and organisations that support the development of this sector.

**Keywords:** sustainable development, quality, natural environment, making decisions, SMEs, Visegrad Group.

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

## 1. Introduction

Today, sustainable development becomes more important theme for enterprises and all society (Pimenowa et al., 2023; Rodrigues, Franco, 2023; Saqib et al., 2023). In the face of challenges related to the degradation of natural resources, climate change and environmental pollution, more and more companies from various industries are starting to take action to protect the natural environment (Liu, Liu, Li, 2023; Nulkar, 2014; Pacana, Siwiec, Bednárová, 2020). Sustainable development and essential product quality are closely related to each other (Siwiec, Pacana, 2021; Siwiec, Pacana, Gazda, 2023; Szabó et al., 2023). In the context of production and consumption, sustainable development has requirements production and consumption of goods and services in a manner consistent with social, economic and environmental requirements (Jaiswal, 2014; Olejarz, Siwiec, Pacana, 2022; Yasir et al., 2023). All these factors have an impact on the development of the company. Among these companies, a special role has numerous enterprises from the electromechanical industry, mainly small and medium enterprises (SMEs), which are approximately 98% and which increasingly come into contact with initiatives taken for sustainable development (Pinget, Bocquet, Mothe, 2015; Mishra, Choudhury, Rao, 2019). In this context, it is advisable to look at the activities undertaken by a sample of companies from the electromechanical industry belonging to the Visegrad Group, in order to assess their plans and real contribution to environmental protection.

The Visegrad Group, which consists of four countries: Poland, the Czech Republic, Slovakia, and Hungary (Braun, 2019), is a region in which many enterprises form the electromechanical industry. As part of this group, many enterprises take different initiatives and actions to reduce the negative impact of their activities on the natural environment and ensure the sustainable development of their companies and the region (Kużelewska, Bartnicki, 2017).

In the article, the focus is on enterprises from the electromechanical industry belonging to SMEs, which are operating in the area of Visegrad Group, and promoting or taking concrete initiatives and activities to protect the natural environment. These enterprises were subjected to preliminary surveys. The use of the survey was influenced by the fact that surveys are the most widely used research tool that allows you to collect reliable information from respondents on a specific topic. It is planned to collect questionnaires in both written and electronic form. Thanks to the survey, data on the opinions, behaviour, preferences, and needs of the respondents were obtained, which allows for a more accurate understanding of the studied phenomenon and making the right decisions. On the basis of the collected and analysed data, it was pointed out

what goals were set for these enterprises, what specific actions were taken to achieve these goals, and what benefits for the natural environment and for the companies themselves result from these actions. Such actions may be the *use of modern technologies, the limitation of energy demand, the implementation of an environmental management system, and the promotion of environmental awareness among workers and local society.* A separate issue of the analysis was potential benefits resulting from environmental protection activities and challenges for enterprises in the implementation and maintenance of activities related to sustainable development.

## 2. Methods

In the period from March to April 2023, preliminary surveys were conducted among enterprises belonging to the electromechanical industry from the Visegrad Group countries - Poland, the Czech Republic, Slovakia and Hungary. There were SMEs enterprises. The conducted research was in aim to analyse the current elected activities for the quality and natural environment taking by selected companies belonging to the electromechanical industry. The research was carried out by survey research in an electronic way (MS FORMS) and in a paper version. The survey fragment from MS FORMS is shown in Figure 1.

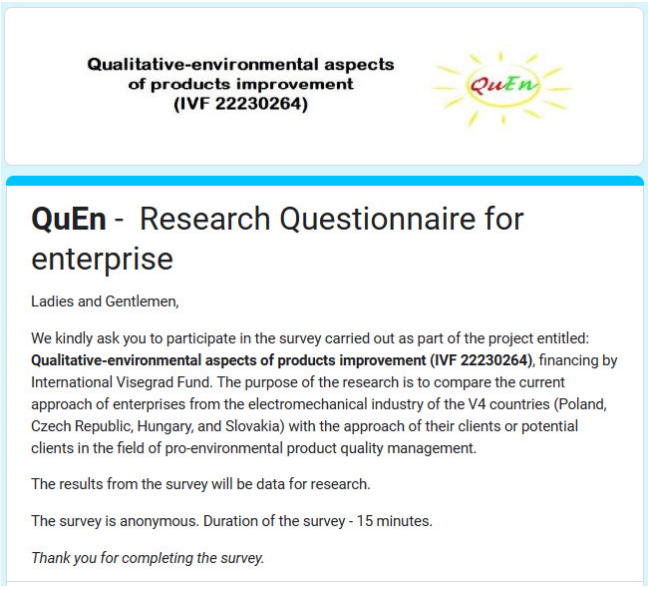


**Figure 1.** Fragment of a research survey in MS FORMS.

The survey included eight questions on the survey data sheet and thirty-six questions in the essential part. The survey was developed based on the literature review, for example (Benito-Hernandez et al., 2023; Bryła, 2020; Jerzyk, 2015; Wysocki, 2018; Saqib et al., 2023), and after initial pilot research (conceptual - verifying conception), which results are shown in the studies,

that is: (Siwiec et al., 2022; Hajduk-Stelmachowicz et al., 2022). The survey questionnaire included single- and multiple-choice questions, including questions with the possibility of indicating other (own) answers. From the conducted surveys 16 out of 36 questions were selected that refer to current activities for the quality and natural environment of SMEs enterprises from the electromechanical industry. The selected questions are shown in Table 1.

**Table 1.**
*Selected questions form questionnaire of research survey*

| | | | | |
|---|---|---|---|---|
| **How often actions to improve products' quality are taken in the enterprise?** | | | | |
| 1 – they are not taken | 2 – less than once every three years | 3 – once every two to three years | 4 – once a year | 5 – more than once year |
| **How often action to improve products' quality, but considering customers' expectations are taken in the enterprise?** | | | | |
| 1 – they are not taken | 2 – less than once every three years | 3 – once every two to three years | 4 – once a year | 5 – more than once year |
| **How often in the enterprise actions to compare the quality of products with the quality of the same types of competitive products are taken?** | | | | |
| 1 – they are not taken | 2 – less than once time year | 3 – once every two to three years | 4 – once a year | 5 – more than once year |
| **How often action to improve products' quality including its impact on the natural environment are taken in the enterprise?** | | | | |
| 1 – they are not taken | 2 – less than once every three years | 3 – once every two to three years | 4 – once a year | 5 – more than once year |
| **What is the degree of customers' expectations which have an impact on the pro-environmental improvement of products?** | | | | |
| 1 – very low | 2 – low | 3 – average | 4 – high | 5 – very high |
| **How often actions to compare competing products in terms of their environmental impact are taken in the enterprise?** | | | | |
| 1 – they are not taken | 2 – less than once every three years | 3 – once every two to three years | 4 – once a year | 5 – more than once year |
| **Is the enterprise planning investment in pro-ecological solutions in the next three years?** | | | | |
| Yes | | | | |
| No (go to the question no. 23) | | | | |
| **What pro-environmental activities does your company implement?** | | | | |
| ❑ adherence to environmental principles as part of the sustainable development<br>❑ applying a dilution or filtering strategy<br>❑ applying preventive environmental strategies (recycling or prevention strategies)<br>❑ participation in Cleaner Production Program<br>❑ implementation of technological eco-innovations (concerning new products or processes)<br>❑ implementation of non-technological eco-innovations (concerning organizational or marketing solutions)<br>❑ use of ecological labels (eco-labels), ecological certificates (FSC, Blue Angel, Ecolabel), environmental declarations on e.g. raw materials, materials, products, packaging<br>❑ use of environmentally friendly additive technologies (“end of pipe”)<br>❑ use IPPC Directives and BAT guidelines<br>❑ eco-design<br>❑ eco-product<br>❑ minimization of waste in production processes<br>❑ recycling<br>❑ creating "green" alliances with other entities with common ecological goals in mind<br>❑ creating green supply chains<br>❑ training, education, raising awareness<br>❑ other, what?.....<br>❑ none | | | | |

Cont. table 1.

| **What principles are used in the process of pro-ecological product design taking into account the product life cycle (LCA)?** |
|---|
| ❑ achieving environmental efficiency |
| ❑ saving resources and using available renewable resources |
| ❑ increased product durability |
| ❑ design for reuse |
| ❑ designing with material recycling in mind |
| ❑ design for disassembly |
| ❑ minimization of harmful substances |
| ❑ environmentally friendly production |
| ❑ reducing the impact of the product on the environment during use |
| ❑ use of environmentally friendly packaging |
| ❑ disposal of non-recyclable materials |
| ❑ use of environmentally friendly logistics |
| ❑ other, what?..... |
| ❑ none |
| **Why do you not intend to invest in pro-ecological solutions?** |
| ❑ lack of funds for investments |
| ❑ lack of knowledge/know how, experience |
| ❑ investment already made |
| ❑ unprofitable investment |
| ❑ the infrastructure (e.g. premises, building) does not belong to the company |
| ❑ the enterprise is too small for pro-ecological activities |
| ❑ there is no place for pro-ecological solutions in our business |
| ❑ hard to say |
| ❑ others that ..... |

| **How often does the company take steps to improve the quality of its products while taking care of the natural environment?** | | | | |
|---|---|---|---|---|
| 1 – not at all | 2 – rarely | 3 – sometimes | 4 – often | 5 – very often |

| **To what extent does the need to care for the natural environment affect the activities undertaken in the company when improving the quality of products?** | | | | |
|---|---|---|---|---|
| 1 – very low | 2 – low | 3 – average | 4 – high | 5 – very high |

| **Define the company's current approach to taking actions aimed at improving the quality of products in terms of quality and the environment** |
|---|
| ❑ improving the quality of products is definitely more focused on achieving the quality of products that satisfy customers than on reducing the negative impact on the natural environment |
| ❑ improving the quality of products is definitely more focused on reducing the negative impact on the natural environment than on achieving the quality of products that satisfy customers |
| ❑ improving the quality of products is aimed at reducing the negative impact on the natural environment as well as at achieving the quality of products that satisfies customers |
| ❑ none of the above statements is true, because in the company improving the quality of products is focused on (please complete the sentence) …… |
| **What quality and environmental measures are taken by the company to improve the quality of its products?** |
| ❑ activities are undertaken separately, taking into account customer requirements as to the quality of products and taking into account the impact of products on the natural environment |
| ❑ activities are undertaken simultaneously taking into account customer requirements as to the quality of products and taking into account the impact of products on the natural environment |
| ❑ other, i.e.: ..... |

Cont. table 1.

| **Indicate only those activities that are implemented in the company as part of improving products in terms of quality and environment** |
|---|
| ❑ specification of products catalogs are being developed |
| ❑ catalogs describing the impact of products on the natural environment are being developed |
| ❑ a catalog of activities aimed at improving the quality of products is kept |
| ❑ surveys of customer satisfaction with the quality of products are conducted |
| ❑ satisfaction surveys of customers and interested parties are conducted regarding the impact of products on the natural environment |
| ❑ computer software is used to support making quality and/or environmental decisions as a part of the product improvement, i.e. …… |
| ❑ other, i.e. …… |
| **Indicate the actions that are the most difficult when improving products and/or reducing their negative impact on the environment** |
| ❑ selection of quantitative criteria (technical, measurable) |
| ❑ selection of quality criteria (subjective, immeasurable) |
| ❑ selection of pro-ecological criteria |
| ❑ determination of changes in products required by customers |
| ❑ determining the rank (catalogue of criteria importance) ensuring an increase in customer satisfaction |
| ❑ determination of the rank (catalogue of importance of criteria) ensuring care for the natural environment |
| ❑ defining a group of criteria that will increase customer satisfaction while having a pro-environmental impact |
| ❑ others, i.e. …… |

Within two months, a relatively small research sample was obtained, consisting of no more than 51 questionnaires from SMEs companies from the electromechanical industry for each partner from the Visegrad Group (Poland, Czech Republic, Slovakia and Hungary). There were 30 surveys from Poland, 12 surveys from Czech Republic, 8 surveys from Slovakia, and 1 survey from Hungary. Despite that, the obtained sample sizes were not comparable and possible to statistical justification, in view of the character of the initial research, there were considered enough to formulate initial conceptions.

Based on the answers provided in the records, it was concluded that most of the enterprises (17) were located in the city of 150 000 to 500 000 residents, then in the city of 20 000 residents (13), and relatively similar in the rural area (11). These were mainly medium-type companies (18) and had an international range of activities (38). They operated in the electromechanical industry area belonging to the electrotechnical and electronic area (12), means of transport (11), and also, for example, metal, machine, or precise industry. The vast majority of enterprises (28) declared that they have implemented the ISO 9001:2015 system. In case of ISO 14001:2015, answers were relatively similar, and shown on implemented this system (18), and simultaneously no implementation (18), where slightly fewer respondents from these enterprises (12) pointed out that does not know whether the system has been implemented. However, in the case of the organisational and legal form, these were general partnerships (18) and partnerships (18), mostly limited liability companies (27). The analysis of survey research conducted on selected questions from the essential part has been shown in the next part of the study.

## 3. Results

The results of the survey research obtained in enterprises in the electromechanical industry of the countries of the Visegrad Group (Poland, Czech Republic, Slovakia and Hungary). Initially, questions related to the frequency of actions as part of products were analysed and their impact on the natural environment. The summary number of answers obtained to analyse companies from the Visegrad Group countries and the percentage of these answers are shown in Table 2.

**Table 2.**
*Selected results of initial survey research from enterprises of electromechanical industry from Visegrad Group countries (Poland, Czech Republic, Slovakia and Hungary)*

| No. | Question | Number of all responses on the Likert scale | | | | | Percentage of total Likert responses [%] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 1 | How often actions to improve products' quality are taken in the enterprise? | 1 | 2 | 6 | 7 | 34 | 2 | 4 | 12 | 14 | 68 |
| 2 | How often action to improve products' quality, but considering customers' expectations are taken in the enterprise? | 1 | 3 | 5 | 12 | 29 | 2 | 6 | 10 | 24 | 58 |
| 3 | How often in the enterprise actions to compare the quality of products with the quality of the same types of competitive products are taken? | 5 | 9 | 6 | 10 | 20 | 10 | 18 | 12 | 20 | 40 |
| 4 | How often action to improve products' quality including its impact on the natural environment are taken in the enterprise? | 5 | 7 | 7 | 13 | 19 | 10 | 14 | 14 | 25 | 37 |
| 5 | What is the degree of customers' expectations which have an impact on the pro-environmental improvement of products? | 3 | 8 | 18 | 15 | 7 | 6 | 16 | 35 | 29 | 14 |
| 6 | How often actions to compare competing products in terms of their environmental impact are taken in the enterprise? | 11 | 5 | 11 | 15 | 9 | 22 | 10 | 22 | 29 | 18 |

Firstly, answers refer to frequency making actions to product quality improvement were analysed. Most of the companies in these countries (68%) reported that their actions are made more than once a year. Simultaneously, more than half of the countries of the Visegrad Group (58%) confirmed that these actions include the expectations of customers. Then, the frequency of actions to compare the quality of products with the quality of the same types of competitive products were analysed. Analysing summarical all responses of companies from researched countries of Visegrad Group, it was found that these actions take place more than once a year (58%). The largest number of these answers provided by enterprises from Czech Republic (7 from 12) and Poland (11 from 30).

Then, it was analysed how often actions to improve product quality, including its impact on the natural environment, are taken in the enterprises. Most of the electromechanical industry companies surveyed (37%) indicated that they did it more than once a year. Slightly fewer responses (25%) indicated that this is done once a year. The enterprises from Czech Republic declared that it is more than once a year (7 from 12), enterprises from Slovakia and Hungary relatively similar that more than once a year, once a year, or once every two/three years. In turn, the highest number of responses from Polish enterprises related that it is once or more often a year (9-10 out of 30). The next analysed issue was the degree of customer expectations, which has an impact on the pro-environmental improvement of products in enterprises from the electromechanical industry from selected countries of the Visegrad Group. The largest number of all responses from researched enterprises show that this impact is average (35%), where little less answers show high impact (29%). The responses of the enterprises from the individual countries of the Visegrad Group surveyed could also be determined in a similar way. Referring to the next question, most of these enterprises (29%) declared that once a year making actions to compare competing products in terms of their environmental impact are taken in the enterprise. Except that, slightly less responses (22%) indicated that these actions are taken once every two to three years or at all. In individual countries, the number of responses was distributed similarly between these responses, with the vast majority of Poland companies (9 out of 30) indicating that they do not engage in such activities at all.

Later, pro-environmental activities undertaken by the Visegrad Group countries (Poland, Slovakia, Czech Republic, Hungary) were analysed. The cumulative number of responses is shown in Figure 2.

It was shown, that the most frequently undertaken pro-ecological activities by researched enterprises were: recycling (12%), minimization of waste in production processes (11%), and training, education, raising awareness (10%), the same percentage of responses (8%) were given for:

- use of ecological labels (eco-labels), ecological certificates (FSC, Blue Angel, Ecolabel), environmental declarations on e.g. raw materials, materials, products, packaging,
- creating "green" alliances with other entities with common ecological goals in mind,
- implementation of technological eco-innovations (concerning new products or processes).

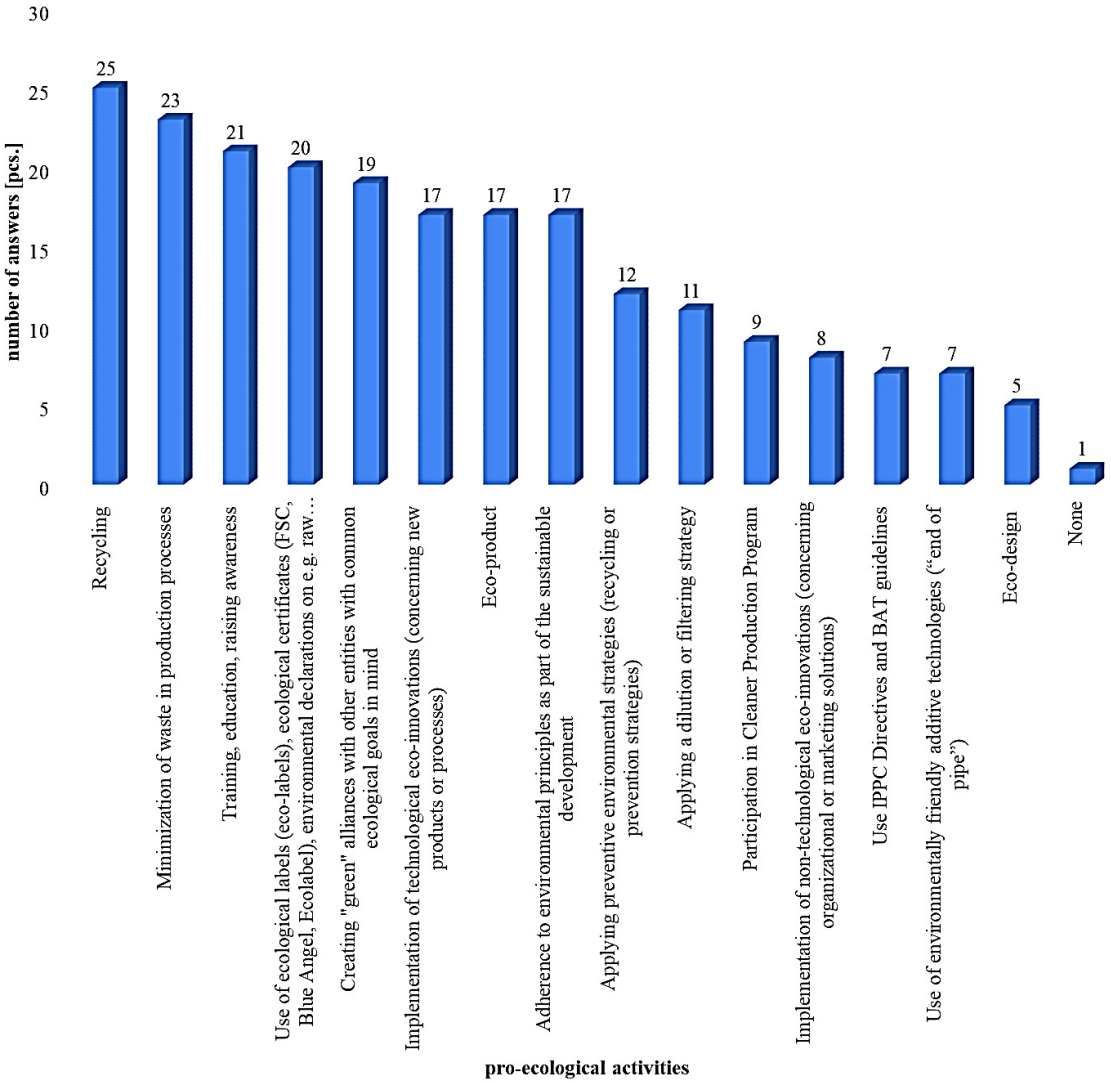


**Figure 2.** Pro-environmental activities implemented by companies from electromechanical industry in Visegrad Group countries (Poland, Czech Republic, Slovakia and Hungary).

Other indicated pro-ecological actions were for example: eco-product, adherence to environmental principles as part of the sustainable development, applying preventive environmental strategies (recycling or prevention strategies), or applying a dilution or filtering strategy.

Then, the answers regarding the rules applied by the surveyed enterprises in the electromechanical industry of selected countries in the Visegrad Group were verified. These principles refer to the process of pro-ecological product design taking into account the product life cycle (LCA). The cumulative results of the research companies from the Visegrad Group countries (Poland, Czech Republic, Slovakia and Hungary) are shown in Figure 3.

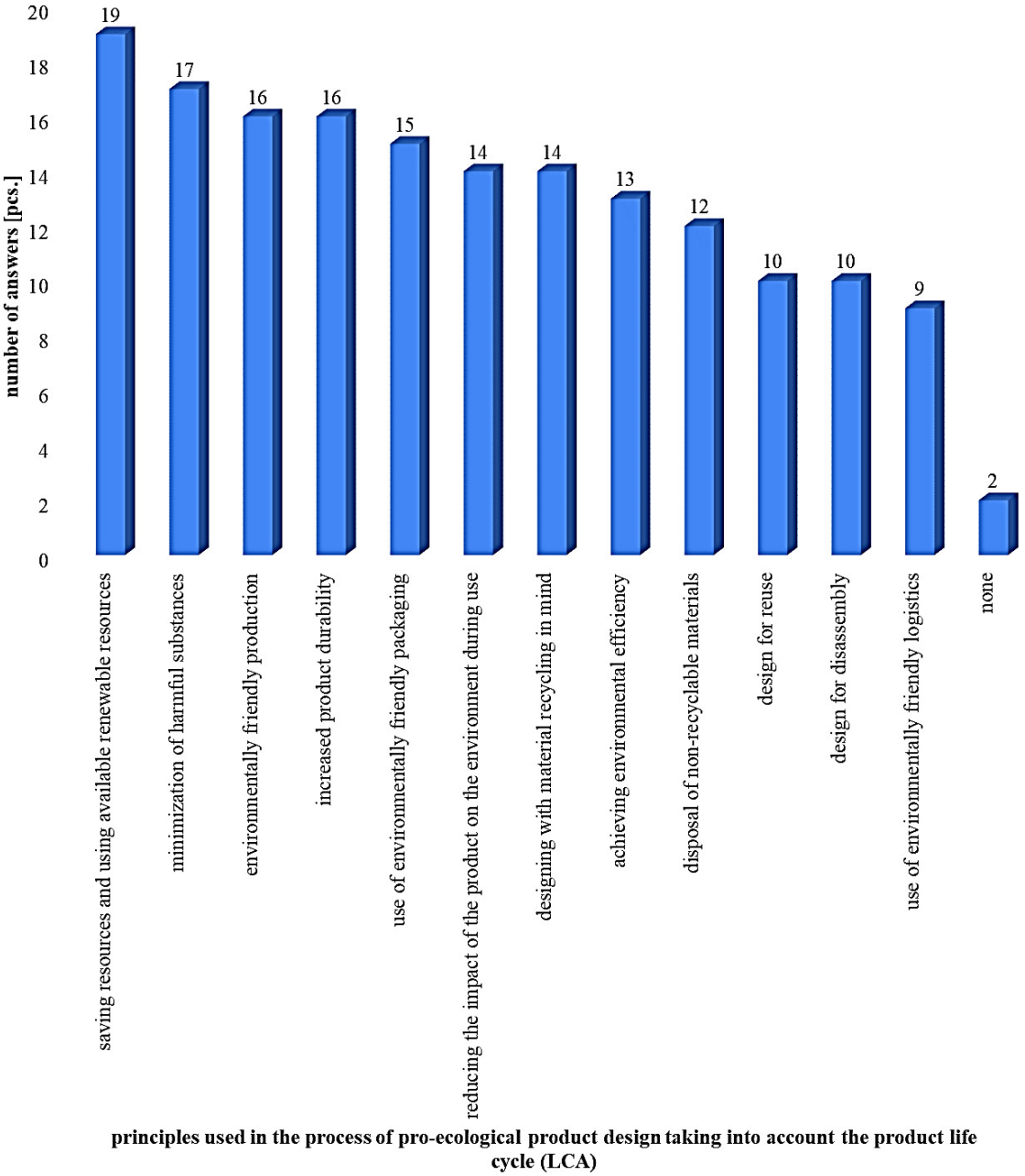


**Figure 3.** Principles used in the process of pro-ecological product design taking into account the product life cycle (LCA) making by selected enterprises from Visegrad Group countries.

The electromechanical industry enterprises analysed from Visegrad Group countries mostly indicated that the principles used in the process of preparing the pro-ecological product taking into account the product life cycle (LCA) are first of all:

- saving resources and using available renewable resources (11%),
- minimization of harmful substances (10%),
- environmentally friendly production (10%),
- increased product durability (10%),
- use of environmentally friendly packaging (9%),

- reducing the impact of the product on the environment during use (8%),
- designing with material recycling in mind (8%),
- achieving environmental efficiency (8%).

The other principles indicated were for example: design for reuse, or disposal of non-recyclable materials.

Then, it was asked if the companies plan investment in pro-ecological solutions in the next three years. The vast majority (63%) declared that they were planning such solutions. Later, the companies were asked why they did not intend to invest in pro-ecological solutions. The result of the responses obtained from all the companies surveyed from the countries of the Visegrad Group is presented in Figure 4.

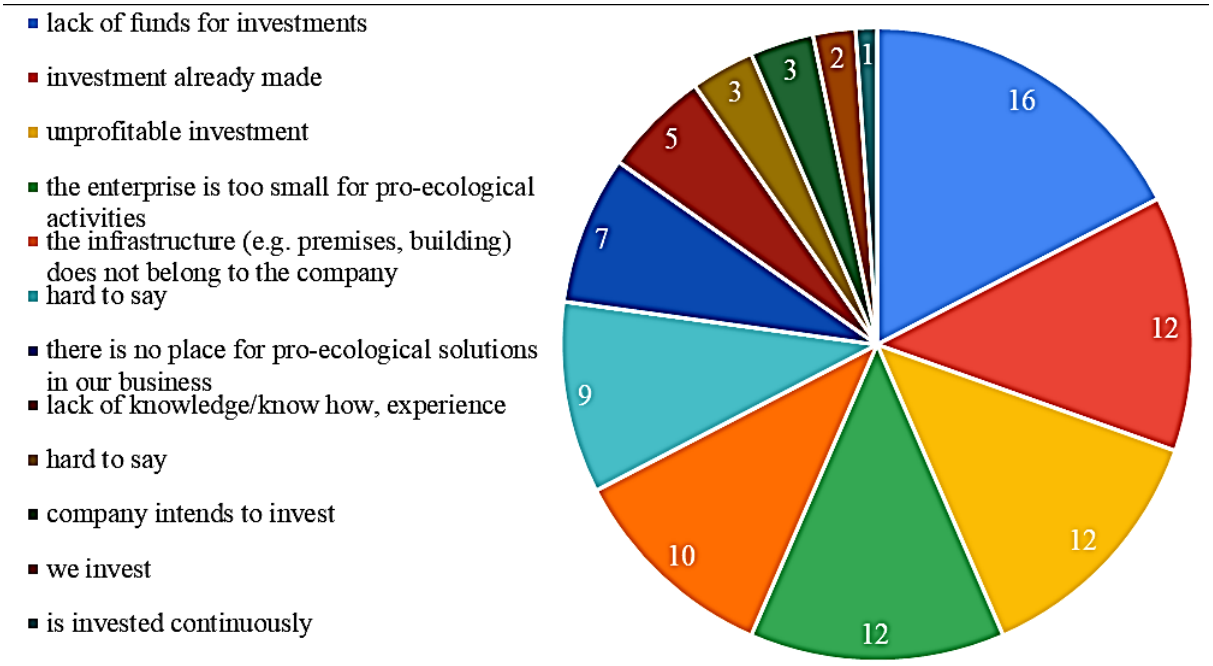


**Figure 4.** Main causes about not intend to invest in pro-ecological solutions in selected enterprises of Visegrad Group countries (Poland, Czech Republic, Slovakia and Hungary).

Based on the visualisation presented of the answers obtained, it was concluded that the main reasons (16 or 12 out of all answers) that conditioned the lack of investment in pro-ecological solutions in selected companies of the Visegrad Group countries were: (i) lack of funds for investments, (ii) unprofitable investment, and (iii) the company is too small for pro-ecological activities. A similar number of responses were given by enterprises declaring that they had already invested in pro-ecological solutions.

The next of the questions, which were verified, is shown in Table 3. The table also contains the number of responses obtained and their percentage share of all the responses provided by the analysed companies in the electromechanical industry of the countries of the Visegrad Group.

**Table 3.**
*Selected results of initial survey research from enterprises of electromechanical industry from Visegrad Group countries (Poland, Czech Republic, Slovakia and Hungary)*

| No. | Question | Number of all responses on the Likert scale | | | | | Percentage of total Likert responses [%] | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 1 | 2 | 3 | 4 | 5 |
| 1 | How often does the company take steps to improve the quality of its products while taking care of the natural environment? | 2 | 9 | 14 | 16 | 10 | 4 | 18 | 27 | 31 | 20 |
| 2 | To what extent does the need to care for the natural environment affect the activities undertaken in the company when improving the quality of products? | 5 | 5 | 23 | 16 | 2 | 10 | 10 | 45 | 31 | 4 |

The electromechanical industry enterprises analysed from the Visegrad Group countries (Poland, Slovakia, the Czech Republic, Hungary) clearly indicated that they often (31%)/ sometimes (27%) take action to improve the quality of their products while caring for the natural environment. Furthermore, the majority of enterprises (45%) declared that the need to care for the natural environment influences the activities carried out in the company to improve the quality of the products to an average degree.

Subsequently, the current approach of enterprises from selected countries in the Visegrad Group to taking actions aimed at improving the quality of products in terms of quality and environment has been discussed. The vast majority of companies (61%) indicated that improving the quality of products in their company is aimed at reducing the negative impact on the natural environment as well as achieving the quality of products that satisfy customers. Half of the responses (33%) were the statement that improving the quality of products is definitely more focused on achieving the quality of products that satisfy customers than on reducing the negative impact on the natural environment. The fewest answers (6%) were concerned with the statement that improving the quality of products is definitely more focused on reducing the negative impact on the natural environment than on achieving the quality of products that satisfy customers.

Subsequently, the need to determine the quality and environmental activities carried out by the surveyed companies to improve the quality of their products was examined. A comparable number of responses (nearly 50%) indicated that:

- activities are undertaken separately, taking into account customer requirements as to the quality of products and taking into account the impact of products on the natural environment, and
- activities are undertaken simultaneously taking into account customer requirements as to the quality of products and taking into account the impact of products on the natural environment.

In turn, in the case of actions performed by enterprises as part of improving products in view of qualitative-environmental, relatively often indicated that:

- surveys of customer satisfaction with the quality of products are conducted (28%),
- specification of products catalogs are being developed (26%),
- satisfaction surveys of customers and interested parties are conducted regarding the impact of products on the natural environment (20%),
- computer software is used to support making quality and/or environmental decisions as a part of the product improvement (15%),
- a catalog of activities aimed at improving the quality of products is kept (9%).

In addition, it was indicated that computer software is used to support quality and/or environmental decision making as part of product improvement (2%).

The last of the questions selected as part of this analysis was to determine the activities that are the most difficult when improving products and/or reducing their negative impact on the environment. The number of responses obtained and their percentage share of all responses provided by verified enterprises in the electromechanical industry of the countries of the Visegrad Group (Poland, Czech Republic, Slovakia, Hungary) are presented in Table 4.

**Table 4.**
*Selected results of initial survey research from enterprises of electromechanical industry from Visegrad Group countries (Poland, Czech Republic, Slovakia and Hungary)*

| Question | Number of responses and their share % |
|---|---|
| selection of quantitative criteria (technical, measurable) | 24 (20%) |
| determination of changes in products required by customers | 21 (18%) |
| selection of quality criteria (subjective, immeasurable) | 20 (17%) |
| selection of pro-ecological criteria | 16 (14%) |
| determination of the rank (catalogue of importance of criteria) ensuring care for the natural environment | 13 (11%) |
| determining the rank (catalogue of criteria importance) ensuring an increase in customer satisfaction | 13 (11%) |
| defining a group of criteria that will increase customer satisfaction while having a pro-environmental impact | 11 (9%) |

The most difficulties activities during improving products and / or reducing their negative impact on the natural environment according to enterprises of the electromechanical industry of countries of the Visegrad Group were: selection of quantitative criteria (technical, measurable) (20%) and similarly determination of changes in products required by customers (18%) and selection of quality criteria (subjective, immeasurable) (17%).

## 4. Conclusions

The Visegrad Group of countries consists of the Czech Republic, Poland, Slovakia, and Hungary. In recent years, companies in these countries have taken various measures to improve quality and protect the environment. This is mainly due to the need to be competitive, to introduce an updated way of managing organisations, and the increasing emphasis on the use of sustainable development tools. This pressure is exerted not only by competitors, but also by customers. It turned out that today it is not enough to ensure high quality of products, but in order to achieve the basic goals of the organisation, it is also necessary to invest in sustainable development. There is resistance in this area, however, related to awareness, but also costs. Activities in this area are varied. Therefore, it seemed advisable to conduct research showing relations in this respect within similar countries of the Visegrad Group. The article contains the results of preliminary research and their analysis, as well as pilot conclusions. On the basis of 51 completed questionnaires, it was found that most of the companies were located in a city with a population of 150,000 to 500,000 inhabitants. These were mainly medium-sized enterprises (18) and internationally active (38). Most of the surveyed enterprises declared that they had implemented the ISO 9001:2015 system, and slightly less than half of the ISO 14001:2015 system. The analysis of the results of the survey conducted on selected questions showed that the vast majority of companies in the countries of the Visegrad Group (68%) carry out quality-orientated activities more often than once a year. It was similar in the case of declaring activities within the improvement of products, taking into account their impact on the natural environment. The organisations surveyed most often described the degree of impact of customer expectations on the pro-environmental improvement of products as average (35%), but slightly fewer responses indicated a high impact (29%). As part of the analysis of the results obtained, it turned out that the most common pro-ecological activities undertaken by the surveyed enterprises were recycling and waste minimisation in production processes (11%), followed by training, education, and raising awareness (9%). Other pro-environmental activities indicated include, for example, eco-design or compliance with environmental principles as part of sustainable development. In the case of the analysis of the applied rules, it turned out that practically all rules are implemented to the same extent in the functioning of the surveyed enterprises. In the case of companies limiting investments in sustainable development, the following were most often cited as the reason: lack of funds for financing, claiming that it is an unprofitable investment, and claiming that the company is too small for pro-ecological activities. The companies analysed also indicated that they take relatively often measures to improve the quality of their products while caring for the natural environment. However, the vast majority of companies admitted that they were taking actions to improve the quality of products in terms of quality and environment. Furthermore, based on the results of the survey, it can be concluded that these activities are combined,

although not in all enterprises and not necessarily at a high level of sophistication. As part of the research, it was additionally shown that computer software is used, albeit to a small extent, to support quality and/or environmental decision making. The most difficult part of improving products and/or reducing their negative impact on the environment turned out to be the selection of quantitative criteria and specifying changes in products required by customers. This fact may warrant further targeted research.

In summary, companies in Visegrad countries undertake various activities for the sake of quality and environmental protection. These activities are not homogeneous and are at the same level of participation. Therefore, it is advisable to continue the research to perhaps observe trends and dependencies that will allow the formulation of the principles of qualitative and ecological improvement of enterprises.

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# GREEN SUPPLIER DEVELOPMENT IN SUPPLY CHAIN – PRACTICAL APPLICATION

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**Purpose:** Reducing negative environmental impacts attracts a lot of attention among company managers around the world, which is related not only to fostering the idea of sustainable development, but also introducing the concept of circular economy. It includes sourcing and purchasing managers that are responsible for the cooperation with suppliers. One of the concepts related to this kind of cooperation is Green Supplier Development (GSD). The purpose of this article is to determine the scope of implementation of the GSD concept in production companies operating in Poland.
**Design/methodology/approach**: The author adopted mixed research design approach. The research methods used in this study are the systematic literature review and a survey conducted using the Computer-Aided Telephone Interview technique (CATI). The reviewed literature is directly related to the concepts of GSD and green supplier evaluation that can be used to select suppliers for GSD programs. The empirical study focuses on the practical aspects of GSD implementation.
**Findings:** The results concern the scope of implementation of the GSD concept, including company involvement in GSD programs, conducting GSD activities, and selecting suppliers for collaboration in the area of GSD. Furthermore, conducting GSD activities might be seen as a part of the cycle that might result in continuous improvement of environmental performance and continuous reducing of the negative environmental impact.
**Practical implications:** The main implication for business is related to the participation in GSD programs. If only the minority of companies in the sectors studied participate in such programs, then this kind of participation might be a source of competitive advantage.
**Social implications:** The main implication for government is related to facilitating possibilities of organising or participating in GSD programs or conducting GSD activities, such as tax reliefs for companies investing in this kind of operation.
**Originality/value:** The originality of this paper lies in determining the scope of implementation of GSD concept and using GSD practices in Poland.

**Keywords:** green supplier development; environmental supplier evaluation; green supplier evaluation, environmental management.

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

# 1. Introduction

We can observe the increasing environmental requirements of clients and the implementation of environmental regulations by institutions in many countries. It is related not only to fostering the idea of sustainable development, but also introducing the concept of circular economy. As a result, management of many companies introduced practices to reduce the negative environmental impact not only in individual companies, but also across supply chains.

The purpose of this article is to determine the scope of implementation of the Green Supplier Development (GSD) concept in production companies operating in Poland. To do so, a literature review was performed and the Computer Aided Telephone Interview (CATI) survey study was conducted.

The originality of this paper lies in determining the scope of implementation of GSD concept and using GSD practices in Poland. It should be noted that there is lack of comprehensive studies on the implementation of the GSD concept, both in Poland and worldwide. It is in contrast to other topics related to reducing negative environmental impact in the supply chain, e.g., green supply chain management.

Different scholars link GSD with the introduction of GSD practices, e.g., Bai et al. (2019), or GSD programs, e.g. Pourjavad and Shahin (2020). To simplify the content of this paper, whenever GSD practice is mentioned, it also includes GSD programs.

This paper is structured in the following way. First, the GSD and green supplier evaluation concepts are described. Second, the research methodology is outlined. The results of the literature review and the CATI study are presented. Then the implications for business and for government are discussed. Subsequently, recommendations for future research are presented. Finally, the conclusion is drawn.

## 1.1. GSD concept

GSD is described as ‘the activities that aim to improve green capabilities of suppliers’ (Blome et al., 2014). Such activities include developing suppliers in case of improvable green performance, instead of terminating cooperation with them, visiting supplier plants in order to help them to improve their environmental performance, communicating with them on green performance matters acknowledging their green performance, e.g. through supplier awards. It should be noted that activities related to GSD might result from green supplier evaluation, as a basis for determining the environmental performance of suppliers.

Bai and Sarkis (Bai, Sarkis, 2010) developed a comprehensive classification of practices related to GSD. It was divided into three groups: green knowledge and communication, investment and resource transfer and management, and organizational practices. The first two groups are related to transferring financial and nonfinancial (both material and nonmaterial)

resources to suppliers. The last group is related to joint planning goals with suppliers and performing joint activities with them. These actions aim to reduce the negative environmental impacts of suppliers.

Fu et al. (Fu et al., 2012) proposed a different approach. They listed three groups of activities related to reducing negative environmental impacts of suppliers: programs related with reducing environmental impacts of suppliers, programs related with environmental compliance of suppliers, and joint development of solutions aimed at reducing negative environmental impacts.

Furthermore, GSD is positively related to green purchasing (Blome et al., 2014). Therefore, the possibility of the existence of the link between these two concepts will be taken into account. Furthermore, GSD is positively related to supplier performance (Blome et al., 2014), innovativeness (Bag et al., 2018) and adoption of green supply chain management (Nkrumah et al., 2021).

GSD practices can be divided into two groups: environmental cooperation and environmental collaboration with suppliers (Sosnowski, 2019, p. 333). Environmental cooperation includes practices requiring passive involvement of suppliers, e.g., monitoring supplier environmental performance using data obtained from a supplier. On the other hand, collaboration includes joint actions with suppliers, e.g. joint planning environmental goals and joint actions with suppliers.

Furthermore, environmental cooperation also includes the use of environmental criteria in supplier selection and supplier assessment, and also the green supplier evaluation (see Table 1).

**Table 1.**
*Overview of GSD practices*

| Type of practice | GSD practices | Source |
|---|---|---|
| **Environmental cooperation** | Monitoring the environmental performance of suppliers | (Bai, Sarkis, 2010; Thakker, Rane, 2018) |
| | Using environmental criteria in supplier selection | (Bai et al., 2019; Bai, Sarkis, 2010) |
| | Using environmental criteria in supplier assessment | (Bai, Sarkis, 2010; Thakker, Rane, 2018) |
| | Conducting environmental supplier evaluation/green supplier evaluation | (Awasthi, Kannan, 2016; Bai et al., 2019; Bai, Sarkis, 2010; Thakker, Rane, 2018) |
| | Green knowledge transfer | (Bai, Sarkis, 2010) |
| | Investing in the environmental practices of suppliers | (Bai, Sarkis, 2010) |
| | Transfer of non-financial resources to suppliers (to enable them to achieve their environmental goals) | (Bai, Sarkis, 2010) |
| | Organization of trainings for suppliers on environmental issues | (Fu et al., 2012) |

Cont. table 1.

| | | |
|---|---|---|
| **Environmental collaboration** | Joint planning of environmental goals with suppliers | (Bai, Sarkis, 2010; Fu et al., 2012; Thakker, Rane, 2018) |
| | Joint planning of environmentally friendly processes with suppliers | (Fu et al., 2012) |
| | Joint design of environmentally friendly products with suppliers (eco-design) | (Fu et al., 2012) |
| | Performing joint environmental activities with suppliers | (Bai, Sarkis, 2010; Fu et al., 2012; Thakker, Rane, 2018) |
| | Introducing environmental programs with suppliers | (Fu et al., 2012) |

Source: own elaboration.

It should be noted that using environmental criteria in supplier selection or supplier assessment is not the same as conducting a green supplier evaluation or environmental supplier evaluation.

### 1.2. GSD and green supplier evaluation

Awasthi and Kannan (2016) described green supplier evaluation as a practice aimed at determining the effectiveness of GSD programs. They took into consideration inputs (time, costs, labor, resources, energy usage, and water), outputs (emissions, noise, waste), and processes (green packaging, green manufacturing, green product design, green transportation, green warehousing, green procurement, and reverse logistics) as criteria categories. It enables the company that has introduced the GSD program to evaluate it through the lens of the activities and results of the suppliers. Criteria for green supplier evaluation may include green design, pollution prevention, green image, green capability, and environmental policy (Akman, 2015).

However, some scholars took a different approach. Bai et al. (Bai et al., 2019) distinguished two types of green supplier evaluation: green supplier evaluation for selection and green supplier evaluation for development. The first kind aims to determine whether the supplier is best suited for cooperation in the context of its environmental impacts. The purpose of the second kind is to establish whether the supplier is best suited for development related to its environmental impacts. They also listed (Bai et al., 2019) environmental performance attributes (resource consumption, pollution release, green products) and environmental practice attributes (e.g., pollution control, green design) for green supplier evaluation for development. Criteria for green supplier evaluation for development (GSD program criteria) include operational performance measures (e.g., cost and time) and environmental performance measures, e.g., energy usage, emissions (Pourjavad, Shahin, 2020).

Sosnowski (2022) defined environmental supplier evaluation as a set of systematic and objective activities - such as preliminary assessment, periodic assessment and assessment of the impact of cooperation with the supplier on the buyer-company and the supply chain - aimed at assessing the supplier's activities, capabilities, and effectiveness in reducing various negative environmental impacts. Hence, it might but does not have to be used as a selection tool for the

GSD program. Additionally, both GSD and green supplier evaluation are listed as areas of green supply chain management (Pourjavad, Shahin, 2020).

The evaluation areas for GSD are the following (Bai et al., 2019; Pourjavad, Shahin, 2020): resource consumption, pollution release, green products (including green design and green packaging), green logistics (including green logistics, green warehousing and green transport) and operational performance (including costs, time, quality, flexibility, innovativeness, labour and process management). In addition to areas related to environmental performance, this list also contains operational performance areas.

## 2. Research methodology

The study consisted of several stages. The first stage was the initial review of the literature. Its purpose was to determine the current state of the literature related to the area of GSD with the special emphasis on conducting GSD practices. The second stage was to choose the literature selection criteria for the main systematic literature review. The systematic literature review was performed then. Subsequently, the CATI study was conducted. Next, the results were discussed. In the end, the conclusion and research implications were determined. The research methodology is visualized in Fig. 1.

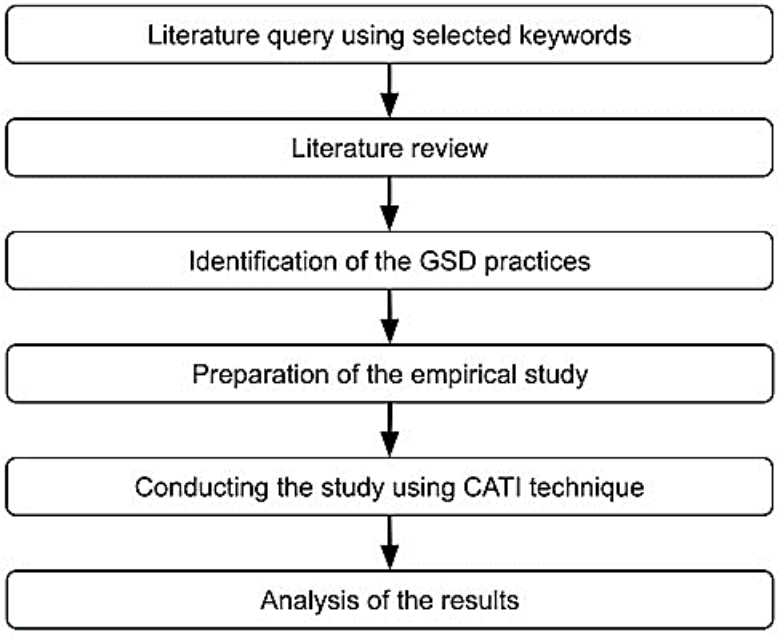


**Figure 1.** Research methodology.

Source: own elaboration.

The results of the initial literature review are presented in the previous chapter of this paper. The main systematic literature review was conducted using SCOPUS as a research database. Based on the results of the initial literature review, the literature selection criteria were chosen:

1. The title, abstract, or keywords contain the phrase 'green supplier development'.
2. The language of the publication is English or Polish.
3. Document types taken into account are articles, reviews, books, book chapters, and conference papers. Editorials and letters are excluded from consideration.

The query returned 23 sources. There was no limit to the date of publication. However, the oldest source is dated 2010. The number of sources found per year is visualised in figure 2. All the publications found were in English. The literature review was conducted in January 2022 and its results are presented in the Findings and discussion section.

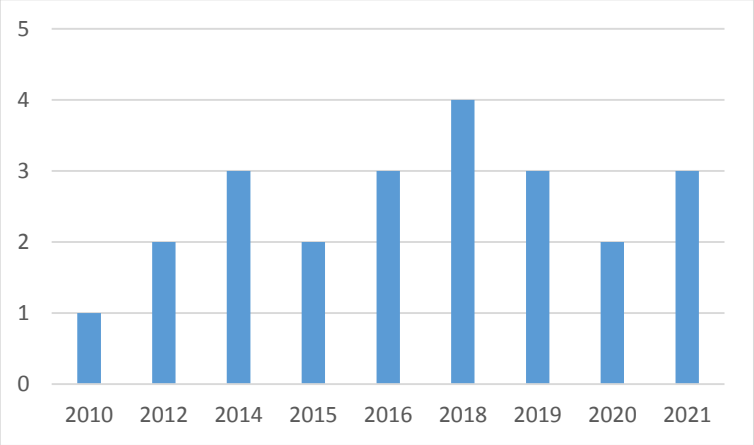


**Figure 2.** Number of sources per year.

Source: own elaboration.

The distribution of sources in each year is steady. However, it does not exceed 4 sources per year. Taking into account the results of the literature review, the research questions were formulated:

Q1. Do companies organize or participate in GSD programs or GSD projects?

Q2. Do companies conduct a green supplier evaluation aimed at starting or continuing cooperation with suppliers in environmental programs?

Q3. Do companies conduct cooperation and/or collaboration with suppliers related to the implementation of the GSD concept?

The survey questions are in accordance with the research questions.

The CATI study was conducted on the group of 101 medium and large companies from the following production sectors operating in Poland in the following sectors: chemical, pharmaceutical, IT and optical equipment, electrical and automotive. The choice of sectors resulted from the relatively high level of environmental impact. The choice of company size resulted from the assumption that bigger companies have more complex management systems than smaller companies and therefore the management in these companies is more willing to

cooperate and collaborate with its suppliers. The size of the company was determined by the number of employees. A medium company employs between 50 and 249 employees, and a large company employs 250 and more employees. The structure of the survey group is illustrated in table 2.

**Table 2.**
*Structure of the survey group*

| The main area of operations* | The main source of capital | Employment volume | | Grand Total |
|---|---|---|---|---|
| | | 250 and more | From 50 to 249 | |
| AUTO | Domestic | 5 | 17 | **22** |
| | Foreign | 6 | 3 | **9** |
| | Total | 11 | 20 | **31** |
| CHEM | Domestic | 10 | 27 | **37** |
| | Foreign | 5 | 3 | **8** |
| | Total | 15 | 30 | **45** |
| IT | Domestic | 3 | 15 | **18** |
| | Foreign | 4 | 3 | **7** |
| | Total | 7 | 18 | **25** |
| **Grand Total** | | **33** | **68** | **101** |

* AUTO – automotive production; CHEM – chemical, pharmaceutical, and plastic production; IT – IT, electronic, and electrical production.

Source: own elaboration.

One can observe that the numbers of companies in the studied sectors are similar to each other. No less than 25% of the companies studied in every sector were big companies that employ 250 or more people.

## 3. Findings

It should be noted that the evaluation for GSD is aimed directly at determining the supplier performance (both environmental and operational). Therefore, the supplier performance in different areas affects the results of the evaluation of GSD programs or practices.

### 3.1. Review of the literature - findings

After conducting a literature review, 10 articles were identified as key sources related to the scope of this article. The full list is presented in Table 3.

**Table 3.**
*Key sources in the literature review*

| Authors, years | Title | Relevance |
|---|---|---|
| Bai, Sarkis, 2010 | Green supplier development: Analytical evaluation using rough set theory | Identifying GSD practices |
| Fu et al., 2012 | Evaluating green supplier development programs at a telecommunications systems provider | Providing a typology of GSD programs |
| Blome et al., 2014 | Green procurement and green supplier development: Antecedents and effects on supplier performance | Determining relationship between green purchasing and GSD |
| Akman, 2015 | Evaluating suppliers to include green supplier development programs via fuzzy c-means and VIKOR methods | Identifying green supplier evaluation criteria |
| Awasthi, Kannan, 2016 | Green supplier development program selection using NGT and VIKOR under fuzzy environment | Determining criteria for GSD |
| Thakker, Rane, 2018 | Implementation of a Green Supplier Development Process Model in the Indian automobile industry | Providing a GSD process model |
| Bag et al., 2018 | Importance of innovation and flexibility in configuring supply network sustainability | Determining relationship between GSD and innovativeness |
| Bai, Satir, 2020 | Barriers for green supplier development programs in manufacturing industry | Determining GSD barriers |
| Pourjavad, Shahin, 2020 | Green supplier development programmes selection: a hybrid fuzzy multi-criteria decision-making approach | Identifying criteria for GSD |
| Nkrumah et al., 2021 | Examining green capabilities as drivers of green supply chain management adoption | Determining relationship between GSD and adoption of green supply chain management |

Source: own elaboration.

The identified key sources focus on various aspects of GSD characteristics, evaluation for GSD and different relationships between GSD and other concepts.

One, and maybe the only way to evaluate GSD practices or programs is through the lens of change of actions and results of suppliers. Therefore, not only supplier performance, but also the change in supplier performance and dynamics of change in supplier performance should be taken into account to precisely evaluate GSD practices. This kind of information can be obtained only over a certain period of time. Therefore, long-term cooperation with the supplier can be a success factor in introducing GSD practices.

There are two ways of practical application of green supplier evaluation in GSD:

1) to determine whether the supplier is best suited for participation in GSD practices,
2) to establish whether GSD practices are effective.

The use of criteria in these two types of evaluation depends on the specifics of the GSD practices.

In addition to that, Thakker and Rane (2018) developed a GSD process framework, with the following elements:

- drivers (government green policies, customers, management, competition for green products),
- key process input variables (e.g., list of GSD programs, GSD implementation strategies, assessment of green suppliers),
- success factors (top management support, proactive procurement management, suppliers' ISO certification),
- enablers (green technology, supplier incentives, mutual trust and relationship),
- key process input variables (e.g., reducing negative environmental impacts, introducing waste management system).

It should be noted that they focused on the GSD process itself, rather than the GSD program introduced in collaboration with suppliers.

Monitoring and reviewing supplier performance related to GSD is also a stage of the GSD model proposed by Thakker and Rane (2018). All stages of this model are the following:

1. Strategy development.
2. Planning and implementation.
3. Supplier relationship management.
4. Performance measurement.
5. Value discovery.

They also listed conducting green supplier evaluation as a way to determine key process output variables (Thakker, Rane, 2018).

Taking into account the stages of the model described above, the GSD practices given in table 1 and the definition of environmental supplier evaluation by Sosnowski (2022), we can determine the order of actions taken by the company management needed to implement GSD (see: figure 3).

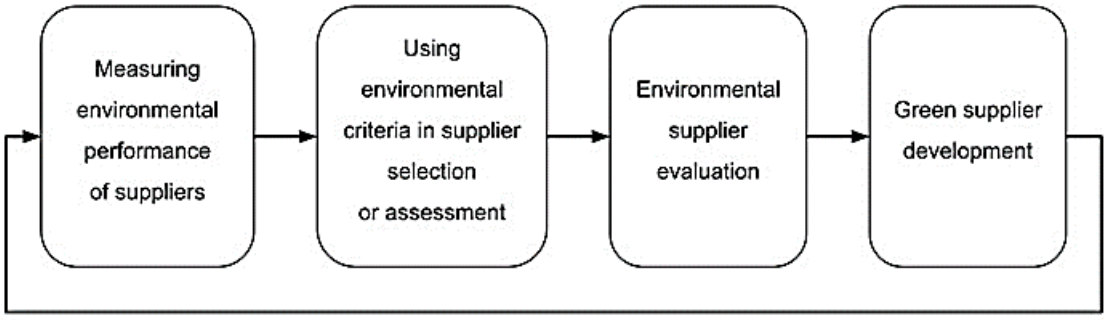


**Figure 3.** GSD implementation cycle.

Source: own elaboration based on Sosnowski, 2022; Thakker, Rane, 2018.

The first stage is measuring environmental performance of suppliers. The second stage is using environmental criteria in supplier selection or supplier assessment. The next stage is environmental supplier evaluation taking into account the information resulting from the

previous stage. The fourth stage is performing GSD practices. After that, the cycle is repeated to determine the results of performing GSD practices, as illustrated in figure 2. Using this cycle might result in continuous improvement of the environmental performance and continuous reducing negative environmental impact.

### 3.2. CATI – findings

More than 40% of all companies studied use environmental criteria in supplier selection and supplier assessment, and most use this kind of criteria in both supplier selection and supplier assessment. It is shown in table 4.

**Table 4.**
*Using environmental criteria in supplier selection or assessment*

| Using environmental criteria in supplier selection or assessment | Number | Percentage |
|---|---|---|
| Yes, in supplier selection | 11 | 10,89% |
| Yes, in supplier assessment | 3 | 2,97% |
| Yes, in both | 27 | 26,73% |
| No | 60 | 59,41% |
| **Total** | **101** | **100%** |

Source: own elaboration.

However, less than 25% of the companies studied organize or participate in GSD programs (see: Table 5) or perform an environmental supplier evaluation (see: Table 6). It should be noted that the question regarding organizing or participating in GSD programs does not include determining the role of the focal companies in such programs. Furthermore, introducing the GSD concept does not necessarily mean introducing GSD program: it might be limited to, e.g., conducting environmental supplier evaluation.

**Table 5.**
*Company involvement in GSD programs or GSD projects*

| Type of involvement | Number | Percentage |
|---|---|---|
| Organisation of GSD programs or projects | 12 | 11,88% |
| Participating in GSD programs or projects | 13 | 12,87% |
| None | 76 | 75,25% |
| **Total** | **101** | **100%** |

Source: own elaboration.

Hence, there are companies that use environmental criteria in supplier selection and/or supplier assessment, but do not conduct environmental supplier evaluation. However, more than 75% of all companies studied neither organize nor participate in GSD programs or projects.

**Table 6.**

*Conducting environmental supplier evaluation*

| Conducting environmental supplier evaluation | Number | Percentage |
|---|---|---|
| Yes, in order to start or continue cooperation with suppliers | 16 | 15,84% |
| Yes, in order to select suppliers to GSD programs or projects | 5 | 4,95% |
| Yes, both reasons | 5 | 4,95% |
| No | 75 | 74,26% |
| **Total** | **101** | **100%** |

Source: own elaboration.

Less than 20% companies studied conduct cooperation and/or collaboration with suppliers related to the implementation of the GSD concept. It is shown in Table 7.

**Table 7.**

*Conducting cooperation and/or collaboration with suppliers related to the implementation of the GSD concept*

| Conducting cooperation and/or collaboration with suppliers related to implementing the GSD concept | Number | Percentage |
|---|---|---|
| Yes | 19 | 18,81% |
| No | 82 | 81,19% |
| **Total** | **101** | **100,00%** |

Source: own elaboration.

Hence, more studied companies organise or participate in GSD programs than cooperate and/or collaborate with suppliers in order to implement the GSD concept.

Furthermore, only one GSD practice is conducted by more than 10 studied companies: monitoring the environmental performance of suppliers (see: table 8). Although it should be noted that without monitoring the environmental performance of suppliers, it might be impossible to implement any other GSD practice.

**Table 8.**

*Conducting GSD practices*

| Type of practice | GSD practices | Yes | No |
|---|---|---|---|
| **Environmental cooperation** | Monitoring the environmental performance of suppliers | 15 | 4 |
| | Green knowledge transfer | 3 | 16 |
| | Investing in the environmental practices of suppliers | 5 | 14 |
| | Transfer of non-financial resources to suppliers (to enable them to achieve their environmental goals) | 3 | 16 |
| | Organization of trainings for suppliers on environmental issues | 3 | 16 |
| **Environmental collaboration** | Joint planning of environmental goals with suppliers | 6 | 13 |
| | Joint planning of environmentally friendly processes with suppliers | 8 | 11 |
| | Joint design of environment-friendly products with suppliers (eco-design) | 6 | 13 |
| | Performing joint environmental activities with suppliers | 7 | 12 |
| | Introducing environmental programs with suppliers | 0 | 19 |

Source: own elaboration.

Taking into account the results shown in table 8 we can distinguish GSD practices that are used more often: monitoring the environmental performance of suppliers, joint planning of environmentally friendly processes with suppliers, performing joint environmental activities with suppliers, joint planning of environmental goals with suppliers, and joint design of environment-friendly products with suppliers (eco-design).

The low number of companies that are cooperating and/or working in collaboration with suppliers related to the implementation of the GSD concept could result from a low level of environmental awareness of management, economic disruptions related to the Covid-19 pandemic or an early stage of the implementation of this concept: the questions in the survey were about involvement in GSD programs and the implementation of GSD practices without taking into account planning such activities.

In addition, no company selected the introducing environmental programs with suppliers. It might result from the fact that it is not necessary to implement environmental programs with suppliers. It can be done without collaboration, with suppliers only as participants.

## 4. Implication for business

The main implication for business is related to the participation in GSD programs. If only the minority of companies in the sectors studied participate in such programs, then this kind of participation might be a source of competitive advantage. Provided there are more possibilities of this kind than companies willing to participate.

One of the possibilities of practical implementation of the GSD concept is introducing the GSD cycle consisting of measuring environmental performance of suppliers, using environmental criteria in supplier selection or supplier assessment, environmental supplier evaluation, and performing GSD practices.

## 5. Implication for government

The main implication for government is related to facilitating possibilities of organising or participating in GSD programs or conducting GSD activities, such as tax reliefs for companies investing in this kind of operation. As a result, it might help reduce the negative environmental impacts of these companies.

## 6. Recommendations for future research

The main recommendation for future research is determining the relationship between change in supplier performance, the dynamics of change in supplier performance, and evaluation of GSD practices.

Another recommendation is the study on the determinants of GSD implementation: drivers, barriers, and enablers. A similar study was conducted by Thakker and Rane (2018), but did not include barriers to GSD implementation. Identifying this kind of barrier might be significant to the limited popularity of GSD programs.

The last recommendation is to identify the relationship between the implementation of GSD practices and the practical application of the GSD concept. It might be aimed to answer the question: do companies use GSD as a coherent, stand-alone management tool?

## 7. Conclusion

In summary, evaluating GSD practices includes evaluating supplier activities and results. Therefore, the success factors of the introduction of GSD practices include the environmental performance of the suppliers, the change in the supplier performance, and the dynamics of change in the supplier performance.

The answers to the research questions were formulated in the Findings and discussion section of this paper. However, due to the scope of conducting GSD practices by the companies studied, it may not be justified to generalize the results with respect to Q3 to all companies in the focal sectors.

One of the possibilities of practical implementation of the GSD concept is introducing the GSD cycle consisting of measuring environmental performance of suppliers, using environmental criteria in supplier selection or supplier assessment, environmental supplier evaluation, and performing GSD practices. Using this cycle might result in continuous improvement of environmental performance and continuous reduction of negative environmental impact.

Further research on the determinants of GSD implementation could provide a basis for other possibilities of practical application of GSD.

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# ORGANIZATIONAL SUPPORT AS A DETERMINANT OF THE WELL-BEING OF MANAGERS

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**Purpose:** The aim of the article is to indicate the role of organizational support as an important factor influencing the well-being of employees. Building the well-being of key employees in the organization is a priority task for many companies today.
**Design/methodology/approach:** The aim of the literature research is to analyze the achievements to date in the field of the role of organizational support in creating a manager's well-being. The analysis of the literature on the subject was enriched with research based on interviews concerning the perception of the organizational support in the context of the tasks performed.
**Findings:** Managers expect more psychological support from specialists in psychology and sociology of work. This applies to the ability to deal with difficult, non-standard situations, solving unusual problems, conflicts, building appropriate relationships, atmosphere and cooperation. Out of concern for the safety and well-being of the manager and the team, there is an increasing need to pay attention to the behavior of people in the managed team and the ability to identify such behavior.
**Research limitations/implications:** The analysis is based on respondents' subjective declarations.
The research results and practical recommendations can be useful to the managerial staff and HR departments in the process of designing work and implementing programs that enhance the well-being of managers.
**Social implications:** The research results can help in creating a higher quality of life not only for managers but also for lower-level employees, indicating the role of organizational support in the process of creating employees' well-being.
**Originality/value:** The article is addressed to HR departments as well as managers who have an impact on management processes and procedures in the organization.

**Keywords:** organizational support of managers, well-being of managers, perception of organizational support.

## 1. Introduction

The negative consequences of the fast pace of life, a pandemic or a sense of uncertainty and threat affect the functioning of most employees. Emotional exhaustion, poor mental and physical condition of employees visible in the post-pandemic times resulted in a re-evaluation of the most important goals of many people, causing the so-called a *wave of great resignations*. This resulted in employers undertaking many activities aimed at consciously creating a high quality of professional life and well-being of employees at the workplace. Building the well-being of key employees in the organization is a priority task for many companies today. It allows not only for the retention of the key employees but also for innovation of the organization and the creation of added value. The group of managers is of particular concern to employers. This is the group of employees that is the most mobile and without which many employers are unable to carry out their activities, and at the same time the group that is most exposed to occupational burnout. Therefore, building the well-being of these employees seems necessary to keep them within the organization for longer time.

According to the model of Job Demands-Resources Model (Bakker, Demerouti, 2007), well-being is understood as an appropriate balance between job demands and job resources. Organizational resources, including organizational support, play an important role in building employee well-being. In the literature, there is a scarcity of research concerning this matter in the context of the managerial work (Stańczyk, 2018). Thus, the aim of this paper is to indicate the role of organizational support as an important factor influencing the well-being of managers.

The first part of the article shows the existing literature on the role of organizational support in creating a manager's well-being. The theoretical analysis of the literature is enriched with the results of surveys on the managers' perception of the organizational support offered in the context of the tasks performed. The conclusions from the research are used to outline practical recommendations for employers.

## 2. Well-being of managers in the workplace

It is difficult to find out a single definition of employee well-being in the workplace which is shared by most researchers as the concept is multifaceted and complex (EU-OSHA, 2013). In the literature, considerations are most often conducted in the context of positive organization, care for the health of employees - especially the prevention of the negative phenomena - occupational burnout, and building a socially responsible organization (Puchalska-Kamińska, Łądka-Barańska, 2019). Workplace well-being is defined as a pleasant or positive emotional state resulting from the evaluation of work or professional experiences (Locke, 1970 after:

Rożnowski et al. 2019). A similar definition focusing on job satisfaction and the quality of working life was presented by Mendryk and Rakowska (Mendryk, Rakowska, 2016). According to the World Health Organization, it is the state of an employee in which he or she understands his or her abilities, copes with life stress, works productively and contributes to the community (Misselbrook, 2014). The definition of the European Working Conditions Observatory (EWCO, 2011) is also significant for understanding the phenomena - wellbeing at work means safe, healthy and productive work in an organization well run by competent employees and employee communities. The above definitions focus on the employee's job satisfaction, commitment and the ability to perform their tasks in the workplace.

Dodge, Daly, Huyton and Sanders (2012) go a bit further, pointing out that well-being at work is determined by an appropriate balance between the psychological, physical and social resources of the individual and the challenges that the individual encounters in these areas at work. This understanding analyzes the well-being of employees as a relationship that depends on the attributes of both the individual employee and the employer. In this aspect, well-being at work is a particularly important issue in relation to managers whose work is burdened with high pressure and stress, and for whom the requirements of the environment and various stakeholders are constantly increasing. This perception of well-being is in line with the proposed Model of Requirements and Resources by Bakker and Demorouti (Job Demand-Resources) (2007, pp. 309-328). Disproportions between too high requirements and insufficient resources will lead to excessive workload and even professional burnout (Puchalska-Kamińska, Łądka-Barańska, 2019). High demands of work may lead to the draining of physical and mental strength, and thus to the decline in the well-being of managers. Among these factors related to high requirements at workplace are: physical workload, time pressure, recipient contact, physical environment as well as shift work. Those job demands can lead to exhaustion and lack of well-being.

Well-being in the workplace is closely related to the quality of working life (Rakowska, Mendryk, 2017). Therefore, the creation of well-being is primarily supported by activities aimed at increasing both the personal resources of employees and organizational resources. When increasing the managers' resources at work it is possible to offer, for example, various forms of trainings that will result in higher competences of particular manager and therefore allow him or her to cope better with the job demands. On the other hand, the employer may take actions leading to an increase in organizational resources. By improving procedures, implementing new technologies, ensuring greater independence, care for social relations and workplace equipment, as well as by appropriate organization of work, the employer will support the managers and build their well-being at work. Employer's activities aimed at increasing and improving organizational resources increase the well-being of managers in the workplace.

Among those job resources that influence managerial well-being are: feedback, rewards, job control, participation, job security as well as supervisor support (Bakker, Demerouti, 2007). These activities are understood as organizational support of managers.

## 3. Organizational support of managers

The topic of organizational support of managers has not been often addressed in scientific publications so far. Some authors underline its role and indicate that organizational support is important for: increasing engagement and job satisfaction (Eisenberger et al., 1986), reducing the workload of managers (Kossek et al., 2016) and influencing desired behavior in the organization (Wayne, McFarlane, 1993). However, researchers also show that organizational support is crucial for reducing the level of psychological and professional stress (Sawang, 2010; Gunkel et., 2015), stimulating the professional development of managers (Torun, 2013), building the autonomy of managers (Williams et al., 2014) as well as building the appropriate relationships in the organization (Gajdzik, 2012).

The organizational support of managers in the context of the safety of their work may be divided into dimensions, which include the following (Stańczyk, 2018):

- psychological dimension – psychological aid, mentoring, coaching, sociological aid, consulting relating to the evaluation of subordinates,
- structural - personal matching of managers to work positions, regulation of work, level of autonomy, allocation of tasks, forms of employment, designing organizational structures that have an impact on the work efficiency of managers, organizational consulting,
- relational – relation factors, organizational culture, communication, values,
- controlling – plans of employment structure, budget, controlling, utilization of new possibilities of organization, knowledge resources, competences in effective management of an organization and the accomplishment of goals,
- educational – improving the leadership competences, as well as entrepreneurial behaviour, the appropriate training, shaping the paths of education, programs of knowledge management, building career paths for subordinates, knowledge base,
- systems supporting the managerial decisions - technical systems, e.g. IT solutions, IT systems, Business Intelligence.

Supportive social-organizational environment at work is perceived as a key factor in healthy organizations that create employee well-being (Badarinarayan, Shankar, Pawar, 2020). This support, necessary in creating the involvement of managers, is more important than financial factors (Judge et al., cited in: Mendryk, Rakowska, 2017).

Despite the growing popularity of the well-being it is difficult to find research on creating managers' well-being. Organizational support is particularly important in building the manager's well-being in the workplace, as the demands at work are very high, hence they are particularly exposed to professional burnout.

## 4. Methodology

The aim of the research was to obtain information from managers on how the organization supports them in their daily work to build their well-being.

In order to find answers to interesting research questions, the diagnostic survey method was used with the use of semi-structured interviews (Thomas, James, 2006). The research took place in 2018. The interviews lasted in total 12 hours. The semi-structure interviews were conducted on the basis of the dimensions of organizational support identified in the literature.

The selection of respondents was purposeful, the respondents were representatives of the senior management staff who were directors of individual functional divisions in a chosen organization, so they were the main management staff (12 managers). They were representatives of the Krakow branch of an international company from the shared services industry, offering services in the field of HR, IT and finance. It employs over a thousand employees. The vast majority (9 managers) had 6 to 10 years of work experience in a managerial position; two employees had work experience from 11 to 20 years and one over 20 years. The age of the respondents is 31 to 40 years (11 people) and one is over 40.

## 5. Research results

The following results were obtained regarding the dimensions of organizational support for managers identified in the previous section in the context of building well-being at work in these positions.

As part of the psychological support, the managers had the opportunity to consult with an occupational psychologist, personal advisor, coach, mentor, in the case of emerging conflicts. From the presented aggregate results, it can be concluded that there is a possibility to obtain organizational support from the professionals. Such a situation is characteristic for outsourcing organizations, where branches of foreign enterprises are created that have already reached a certain maturity regarding the management of managers' competences. The employer shows the importance of psychological support, which seems essential in the light of the manager's well-being.

In terms of relational support, it was important to obtain information on those aspects that build healthy relationship according to the respondents. The interviewed managers had the feeling of professional success and career development opportunities. They also pointed that they manage employees who poses appropriate competences. Moreover, there is a set of corporate values and a code of ethics. In this area, a positive impact on the well-being of the manager's work can be noticed.

The questions regarding controlling support concerned the possibility of access and the influence of managers on individual indicators or cost items. Managers have access to and use budget planning capabilities for the managed organizational unit; affect the level of employment, its structure and the level of labor costs. They have the ability to use positive and negative reinforcement in their current job. The problem arises with obtaining an impact on the size of labor cost components - here it can be seen that, these levels are determined by the management board and distributed according to criteria selected in a given organization.

Structural support in the organization manifests in the possibility of help of specialists building organizational structures, solving problems regarding the form of task relations, documentation of division and settlement of tasks; whether and which specialists dealing with process optimization. In this regard, the loneliness of the manager in the search for appropriate specialists can be seen. Only his knowledge and good orientation in the organizational structure can help him find the right person. However, when the right specialist is identified, support is provided efficiently. Structural solutions are mainly dealt with by HR specialists, extended structures, e.g. of HR Business Partner. Such a situation may again indicate the type of management model employed in a given enterprise. However, systemic solutions are not used to quickly obtain immediate advice, e.g. internal hotlines. Changes are handled by the managers themselves and the team, and there is a special process optimization unit in the structure. In addition, the philosophy of Kaizen and Lean Management is implemented. Managers unanimously stated that they are overburdened with operational work - this area requires deeper consideration in the context of building well-being.

Educational support refers to organizational support before and after the manager takes up his or her position. The managers unanimously stated that they were selected for this position because they had the appropriate competences. They also had the opportunity to participate in external training on team management. Few attended the Manager's Academy. According to managers, workshops are organized to improve social skills. The second possibility of developing competences is post-graduate studies. Other types of professional development indicated in the table above are implemented sporadically.

According to the interviewed managers, support with managerial decision support systems is carried out on the basis of specially prepared internal information systems and a competency assessment system. When analyzing this dimension of support, one should pay attention to the lack of a management information system (SIK), which is dedicated only to the surveyed group.

The research results have been arranged thematically in the Table 1.

**Table 1.**
*Analysis of the dimensions of organizational support*

| Support dimensions | Activities |
|---|---|
| Psychological support | - there are positions such as: coach, work sociologist; mentor<br>- additionally: HR Business Partner, HR Manager |
| Relational support | - conflicts resolved mostly by themselves, sometimes by a work sociologist<br>- employing people with appropriate competences<br>- there is a need to care for employees with the highest competences<br>- there is a set of corporate values, a code of ethics, an anti-mobbing code |
| Controlling support | - budgeting system<br>- managers have an impact on budget planning for the unit they manage; on the level of the team's labor costs<br>- have information on personnel controlling indicators |
| Structural support | - properly equipped workstation<br>- the possibility of an individual work schedule<br>- special teams are appointed to change the structure (HR+interested manager)<br>- task and MBO cards |
| Development support | - dedicated workshops, training on the so-called "soft" competences<br>- training on cultural differences<br>- individual training, courses, coaching sessions<br>- postgraduate studies |
| System support | - implemented Lean Management and Kaizen<br>- a special organizational unit for process optimization - MBO<br>- competency assessment system<br>- budgeting system<br>- business continuity management |

Source: own research.

Summing up the dimensions of organizational support, it should be stated that most activities in the organization are standard. There are few interesting, innovative solutions characteristic of the surveyed company, which would increase the comfort of the manager's work and their well-being. Such as support for the manager at work on-line, work ergonomics workshops, personal training, minimizing stress at work, support related to the mental condition of the manager, building positive relationships in the team (https://raport.activy.app). During the research, managers were asked about the barriers they face while performing everyday tasks. According to the respondents, these barriers that affect wellbeing of the managers at work are:

- insufficient work-life-balance programs,
- lack of coherent policy of action in accordance with strategic goals, insufficient control of the implementation of tasks in accordance with the principles and rules,
- loneliness of the manager when making unpopular decisions,
- lack of sufficient psychological, systemic and negotiation support,
- insufficient support in the field of personnel consulting,
- insufficient support of the organization in dealing with a conflict situation or in crisis management.

## 6. Conclusions

Organizational support is one of the key aspects of building manager well-being at work. The results of the research allowed to indicate crucial dimensions of organizational support, important to the surveyed managers. The research conducted is novel, there is no reference to other research on organizational support of managers in this area. The topic undertaken is new to the Polish market. Respondents indicated that they were particularly interested in psychological support from specialists in the field of psychology and sociology of work. This applies to the ability to deal with difficult, non-standard situations, solving unusual problems, conflicts, building appropriate relationships, atmosphere and cooperation. There is also a need to increase support within personnel consulting, which will actually act as a business partner in relation to directors of a given division or function. Personnel consulting carried out at the appropriate level causes less psychological burden related to decisions made, faster coping with a crisis situation and affects the well-being of the manager and even the team. Increasing business awareness, improving leadership competences and the ability to create appropriate business models becomes one of the priorities in this particular organization. Another important aspect of building manager well-being is to reduce the operational workload of managers, which will certainly reduce stress at work and increase the comfort of decision-making. As part of improving the competencies of managers at higher management levels, it is appropriate to use non-standard methods (e.g. participation in conferences as panelists). The introduction of modern technological solutions, e.g. Business Intelligence, seems extremely important in the context of management efficiency and the feeling of work comfort and making appropriate decisions.

The indicated dimensions of organizational support, important to the surveyed managers, can significantly help to shape well-being at work in managerial positions. However, they require further in-depth research spread over time, so that changes in managers' behavior after receiving such support could be checked. Furthermore, research should be directed to more diverse organizations in terms of size, scope of operation or industries.

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# THE ROLE OF FEEDBACK IN BUILDING DIALOGUE CULTURE OF A CHEMICAL ENTERPRISE

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**Purpose:** Verification of the hypothesis that process feedback is one of the key tools supporting managers in effective management through communication.
**Design/methodology/approach**: The aim of the survey is to indicate the actual indicators of the functioning and effectiveness of process feedback in the workplace. The survey started on September 13, 2022. until October 15, 2022. The research was carried out using a questionnaire that was available on Google Drive in the form manager. The research questionnaire contained 37 questions.
**Findings:** The assumed hypothesis has been confirmed. Based on the research, it was found that the ability to work with feedback requires significant improvement. Employees' expectations towards managerial competences in this area are not reality, which means that the management, despite knowing the rules of the feedback, leaves too much space for intuitive actions.
**Research limitations/implications**: The research was carried out in one of chemical companies, which agreed to condusct the research but reserved anonymity. It is recommended to conduct research in the analyzed topic with the wider scope, as well as covering other industries.
**Practical implications:** It is recommended to implement process feedback in organizations in chemical enterprises, combined with training of managerial staff and their subordinates.
**Originality/value:** The research proves that although feedback is one of the key tool supporting managers, only the process approach to feedback supports effective management by communication. The series of specific actions, as an organized and logical process, involves the sender and the recipient equally.

**Keywords:** process feedback, dialogue, management tools.

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

## 1. Introduction

Communication accompanies people from birth. The main idea of communication is effectively reach our interlocutor with the message. Gestures and words help us understand and define the surrounding world, express our opinion, signal expectations, argue needs. We usually enter adult life using the language of communication freely, choosing words appropriate to the situation (e.g.: Yeomans, FitzPatrick, 2017; Hedenbro, Rydelius, 2019; Dewhurst, FitzPatrick, 2019; Stewart, 2020; Yue, Men, Ferguson, 2021).

However, for many people communication remains only an intuitive tool for transmitting and receiving information. Thanks to this tool, the sender can provide new information or expand his thoughts on the topic under discussion. And although intuition very often suggests the correct forms of communication, there is a risk that was intriguingly described by GB Shaw in the statement that "the biggest problem in communication is the illusion that it happened". This observation seems to be particularly worth paying attention to in business areas, because the risk of contaminating the information flow may turn out to be very costly for the organization (Montague-Jones, 2010).

The process of communication in business relations is a sequence of cause-and-effect events observed in the framework of human resource management (Berger, 2008). In order to avoid the aforementioned risk, an effective flow of information should have an objective and motivating influence on the actions of employees. Consequently, it should lead to the expected profits, both in the form of visible results of teamwork and clearly noticeable progress in the individual development of employees (Dewhurst, FitzPatrick, 2019).

In order to obtain the best results in this area, managers use, inter alia, feedback as a development tool for planning activities and accounting for employees for entrusted tasks (e.g.: Baker, Perreault, Reid, Blanchard, 2013; Mulder, Ellinger, 2013; Greve, Gaba, 2017). However, the observation of the work of teams in many organizations shows that the effectiveness of human potential management, using popular models of feedback often fails. More insightful analyzes indicate disruptions in the consequences of feedback work and contamination in the fluidity of information flow (Besieux, 2017). Therefore, what are the causes of is the result of inadequate and ineffective feedback management? Where is the source of misunderstandings in the communication between the manager and the employee? What key factors should be taken into account to make feedback a profitable management tool?

This publication is an attempt to verify the hypothesis regarding feedback as one of the main element of the culture of dialogue in the organizations with a chemical profil. The issue of publication is based on the analysis of process feedback effects as a tool supporting managers, e.g. team leaders in chemical companies, in building communication strategies in organizations and in managing human potential. The aim of the study is to indicate the need to use feedback as an important activity in the manager’s work with employees.

## 2. Literature review

### 2.1. The role of feedback in the communication process

Nowadays, human resource management indicates the advanced influence of a person and his ability to manage himself and relations in the business environment on the results achieved by an employee as an individual. As a consequence, we can observe how the efficiency of an employee affects the results of the entire enterprise. After all, in business people are the most important. Relationships based on the high value of information flow are the foundation for the proper functioning and development of the organization (Keashly, Neuman, 2009).

Currently, the successes of companies are largely measured by the effectiveness and efficiency of interpersonal communication (Dewhurst, FitzPatrick, 2019). However, it is necessary to point out the differences between the information models that function in the company's communication channels. Management by communication is a set of all processes, based on the exchange of information, important from two perspective of company management: the implementation of business plans and building the company's strategy. Interpersonal communication enables the exchange of opinions and views, engaging both, the experiences and emotions of the participants in the dialogue (e.g.: Wilczewska, 2019; Dewhurst, FitzPatrick 2019; Stewart, 2020). It can be done from the level of regular messages, issued instructions, as well as advanced feedback. Messages and instructions are necessary tools thanks to which employees learn about the company's assumptions, they know what are set targets and they also learn about the specificity of the tasks delegated to them. And what's more, they know the methods of verifying their activities, as well as the rules of settlements and employee evaluation indicators. On the other hand, feedback from the supervisor is a very important element of the information flow, supporting the shaping of the employee's attitude and its development. It is a prerequisite for successful goal settings and also allows to verify the course of action on the path of implementation (McShane, 2006).

Recent years were full of emphasizing the special importance of feedback for the efficiency and effectiveness of employees in organizations. Currently, feedback seems to be a main tool in effective management through communication, and as the results of the Human Engineering Laboratory study show, communication is a focal point in the dialogue between managers and members of their teams, because it takes up 75% of manager's working time (Wilczewska, 2019).

### 2.2. A management style based on the culture of dialogue

Management by communication supports the organizational culture of dialogue (e.g. Baker, 1980; Amann, Khan, 2011). On the other hand, shaping the culture of dialogue is a process fully dependent on all persons participating in the flow of information. The complexity of the personality and diversity of employee experiences, as well as the need to integrate these factors

into teamwork, may prove to be a big challenge for many of them. The synergy of activities, despite the possible high efficiency, requires from employees a huge commitment, both active and emotional, as well as openness to acceptance or constructive analysis of opposing perspectives. The manager who leads and supports the team is not only a leader and a liaison (interpersonal roles), or an observer and propagator (information roles), but also an entrepreneur and negotiator who reacts and counteracts possible disruptions (decision-making roles) (Pocztowski, 2008). The culture of dialogue is therefore a process created in cooperation between the manager and subordinates. However, it is the manager who acts as a moderator of the actions taken and the course of this process. The effects of these activities will be noticeable both, as part of the development of personnel structures and the implementation of the organization's business strategy (e.g.: Schein, 1993; Hofstede, 2000; Fairhurst, Connaught, 2014; Sułkowski, 2020).

### 2.3. Elements of shaping the culture of dialogue

The literature on the subject focuses on organizational culture as a desirable factor supporting the achievement of the company's strategic goals (e.g.: Schein, 1993; Hofstede, 2000; Sułkowski, 2020). It devotes less attention to the culture of dialogue, which is an integral part of a full organizational culture.

As Pocztowski (2008) notes, an important aspect of human resource management are managerial skills, understood as the behavior of leaders towards subordinates. Among the six main competences he mentions, based on the analyzes by Stephen Robbins, all of the following have a direct impact on shaping the culture of dialogue:

- the ability to monitor changes and take appropriate responses,
- the ability to build and maintain relationships while carrying out tasks,
- the ability to communicate and transfer information efficiently,
- the ability to arrange a climate of mutual inspiration, serving the development of the entire team,
- the ability to release sources of motivation and manage conflicts,
- the ability to responsibly engage in decisions made.

The listed skills are the foundation of the standards of working with the team. Effective use of the possessed competences allows at the same time to define the framework of business relations, in accordance with the essence of coherent values. Regardless of the differences in character, personality, temperament or the level of emotional intelligence, it is important for team members to implement their different experiences in the company's activities, while adhering to common values. Thanks to this, the achievement of strategic assumptions of the company is based on multiple perspectives in case studies, striving for a common goal, in accordance with business ethics and the policy of cooperation and relations in the company.

Active listening and creative thinking skills are also important factors supporting a culture of dialogue (Shein, 1993). This means not only paying attention to the fact that the employee expresses his opinions, but also showing interest in his point of view, entering into a dialogue on differences of views, without judgment, and characterized by curiosity and openness. Covey (2005) using a cognitive experience experiment, involving different interpretations of the same image, points to the need to break the usual patterns. This allows to look at the same issues from different perspectives. He also points out that everything can be subject to many interpretations, and understanding communication based on listening helps to reach agreement. This is an important guideline for those managers who are still closer to autocratic management and who focus only on creating conditions for achieving high work results (Pocztowski, 2008).

According to Covey (2005), the source of ineffective communication is semantics, because people define words differently. Therefore, active listening is crucial, based on asking and clarifying information, which will allow to determine the meaning of a given word in the transmission of information. This observation is confirmed by numerous authors, incl. Kahneman (2012) or Nęcki (2000, 2013), suggesting that complicated language should be avoided whenever it possible. Thanks to this, the person communicating the information is perceived as credible and intelligent.

The openness and curiosity of others, as well as the simplicity of language, are also consistent with the assumptions of the transactional analysis created by the American psychiatrist Eric Berne (Stewart, Joines, 2018). The assumptions of AT concern: human nature, relations with the environment, style of communication and the perception of changes in the environment. They constitute a specific starting point for open communication, which is a crucial element in the culture of dialogue. The main values in the transactional analysis are presented in the table (Table 1).

**Table 1.**
*Assumptions of the Transaction Analysis*

| **Assumptions of the Transaction Analysis** | |
|---|---|
| People are ok | I consider people equal<br>I have respect for others<br>I avoid taking a dominant position<br>I adhere to the principle that there are no better or worse people, and that each of us has his own dignity and value |
| People are capable of thinking | I do not consider myself to be a person who knows better than others<br>I believe that everyone has the right to their point of view<br>I believe that people can draw conclusions that are right for themselves<br>I adhere to the principle that people draw inspiration, knowledge and skills to benefit from it |
| People decide their destiny and have the right to change their decisions | I know people have the right to make decisions about changes<br>I know that decisions made can be changed<br>I remember that people have the right to act autonomously, deciding on their plans and changes |

Source: own study based on the literature: Stewart, Joines, 2018, p. 8.

As the authors of the publication, Stewart and Joines (2018) explain, the intention of Eric Berne was to draw attention to the acceptance of the person, which does not mean accepting behavior when it deviates from established social norms or specific values. In team communication, it also means being open to the employee's perspective in expressing views, recognizing the right to express a different opinion, but also the manager's right and obligation to react to the employee's actions, if they distract him from the tasks entrusted to him, are inconsistent with the company's vision, disrupt the work of other team members or have a negative effect on the results of work (Sinickas, 2006).

### 2.4. Responsibility in the culture of dialogue

The elements shaping the culture of dialogue significantly affect both the efficiency of work and its atmosphere. A tool supporting effective management through communication is transparent communication, sensitive to the elimination of contamination. The awareness of the existence of communication noises in the flow of information (Nęcki, 2000, 2013) allows to diagnose unwanted stimuli and to control the recipient's reactions to the received message.

Bearing in mind that the sender encodes the content of the message in words, intonation, style of communication and body language, and the recipient decodes the received message, interprets and reacts, it is worth considering which side of interpersonal communication is responsible for the transparent flow of information. In order to provide a reliable answer, the concept of communication noise should be defined. This is an open catalog of confounding factors. Interestingly, a clear message can be contaminated not only by physical noise, such as screaming, inappropriate ambient temperature, poor well-being, or uncomfortable conditions in which dialogue is conducted. The transparency of communication is also significantly influenced by factors derived from the source of the relationship between the sender and the recipient and the emotions associated with them.

It used to be assumed that a manager takes responsibility for the effectiveness of communication in the team. It seems obvious, because manager’s role is to delegate tasks, coordinate the process of implementation, and as a result summarize, present conclusions and account for the results of the team's work. Meanwhile, the communication process takes place in a closed loop. Therefore, neither party should ignore signals that raise doubts as to the clarity of the message and the properties of the reception, and, consequently, may lead to disturbance of the communication value. Such action is contrary to the idea of a culture of dialogue. This means that the responsibility for the process of interpersonal communication refers to both sides of the dialogue, and each side is responsible for their position. Information gains value when the sender and recipient are equally involved in the well-thought-out content of the exchanged messages, when they take care of the ethics of the word and if they present a high level of emotional intelligence.

The same approach is presented by Lindemann and Heim (2016). The new approach to communication is defined by them, as constructive communication based on cooperation and trust (e.g.: Miller, 2006; Keashly, Neuman, 2009; Burke, 2010; Ellis, 2012). In their opinion, this type of communication is dedicated to both superiors and subordinates who, having a choice between the individual responsibility of each person and top-down human resource management, definitely prefer the first approach. The language of constructive communication is understandable and action-oriented. As a result, it the needs of all parties involved in the conversation, taking care of the quality of contact. On the other hand, achieving better interpersonal contact improves communication between people and increases work efficiency, regardless of what the conversation is about.

The culture of dialogue in the organization is the foundation on which the attitudes of employees and managers are created, that allow:

- work in an atmosphere of mutual respect,
- be consistent in actions, aiming at a clearly defined goal,
- prevent destructive conflict situations,
- solve problems in an atmosphere of understanding,
- openly accept other people's perspective,
- avoid working in chaos,
- eliminate errors resulting from misunderstandings.

Such activities are conducive to building long-term relationships in the company, reduce stress and help to cross borders in the search for valuable solutions (McShane, 2006). Thus, these activities contribute to achieving the intended effects and achieving the goals set in the organization's strategy.

### 2.5. Development and essence of the feedback culture

The culture of dialogue in an organization will not function properly if there is no important link, which is feedback. The basic definition of feedback in an organization usually refers to the space in interpersonal communication, oscillating between the sender (manager) and the recipient (employee).

Research, dating back to 1979 (Fisher, 1979), indicates the need for a source of knowledge from which employees can obtain information about the desired way of performing their duties, which is then reflected in work motivation, management by goals and evaluation of effectiveness.

The essence of the feedback is to identify the employee's potential, develop the selected talent, as well as diagnose competency gaps, search for valuable solutions and correct actions, thanks to which employees can fully use their capabilities and constantly develop.

Spreitzer and Porath (2020) shows how measurable benefits are brought by work based on the employee's potential. The researchers invited over 1.2 thousand employees from various industries, performing both mental and physical functions, to check to what extent the potential of employees influences the effects of their work. The collected material clearly indicated higher results in those employees who used their capabilities to the full. Interestingly, the differences were respectively 16 percent in the group of white-collar workers and as much as 27 percent in the case of blue-collar workers.

Performance Feedback Culture Drivers Business Impact, a study conducted in contemporary organizations as part of a joint project Institiute for Corporate Performance and Center for Effective Organizations (Ledford, Schneider, 2018; Chandler, Grealish, 2020) showed that the implementation of a feedback culture had the most significant impact on the increase in results. The conclusions from the study indicate an increase in the development of a feedback culture as a result of managers' actions in the field of effective evaluation of results, by providing a good example with their behavior, consistent and diverse communication, providing training support, as well as monitoring the course of tasks and openness to recognition and reward for properly performed work. Moreover, the conclusions of the study (Ledford, Schneider, 2018) indicate that apart from the positive consequences in terms of personnel structures, a developed culture of feedback exerts a strong influence on the financial success of enterprises. Moreover, the feedback culture turns out to be more effective than performance management techniques. Performance management supported by a feedback culture brings tangible results.

The cited research shows, that feedback influences the attitude of the employee. Therefore, it is also important to define the responsibility for the structure and content of the feedback, analogically to the responsibility for the culture of dialogue. I should be detailed that the value of the feedback and the style of the message (manager's responsibility), commitment to perceiving the value resulting from the feedback (employee responsibility) and cooperation of both parties to the dialogue in implementation of the transferred value are important. A feedback culture built in such a way shapes effective management through communication (Wilczewska, 2019).

The feedback culture is noticeably a tool that supports managers in effective team management, and employees in the effective performance of their professional duties. Therefore, it is worth considering the results of the survey research, which will explain how to strengthen the formation of a feedback culture and how to work with feedback brings the greatest results.

## 3. Methods

In accordance with the assumption that the research goal should be a research method, which in turn should be the simplest path to achieve this goal, the universal method of the survey in question was chosen, based on the statistical population (general population) (Klepacki, 2009). The survey started on September 13, 2022. until October 15, 2022.

Having a list of the e-mail addresses in the researched company, emploing 216 emploees, madfe available for the purposes of the study, a link to the online questionnaire was sent to all of them. The survay was voluntary and anonymous. As a result of using this method, the questionnaire was successfully completed and sent by 168 people, which is 78% of the research sample.

The study, which is the subject of this publication, is aimed at indicating the practical version of the functionality of feedback in business, based on the experience of respondents. There are beliefs about which we are almost sure, such as the fact that feedback is ubiquitous today, much is said about it, it is part of managerial training, so it is probably applied and brings the intended effects. However, in order to be able to fully believe this belief, which is based on this stage of the considerations about the "reality of the contract", it is also necessary to approach the "contract of experience" and thus base the claim on both logic and empirical evidence (Babbie, 2004). There are also beliefs in which practice is at odds with theory.

The aim of the survey is to indicate the actual indicators of the functioning and effectiveness of process feedback in the workplace.

An attempt was made to verify the hypothesis regarding feedback as one of the key elements of the culture of dialogue in the of a chemical company.

## 4. Results and discussion

### 4.1. Characteristics of the respondents participating in the study

Both, managers and regular employees were invited to participate in the study. It is an intentional activity aimed at identifying similarities and / or differences with regard to the actual functioning of feedback in the workplace, from two perspectives - the employee and the manager.

168 respondents accepted the invitation to the survey, of whom 60.7% were women and 39.3% men. This means that 102 women and 66 men took part in the study, which is Figureically presented in figure (Figure 1).

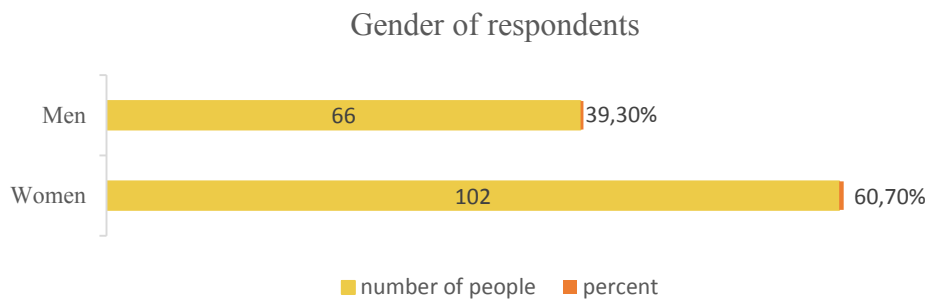


**Figure 1.** The size and sex of the studied population.

Source: Own elaboration based on the conducted research.

The age group of respondents participating in the survey oscillated between 20 and over 51 years of age, without the upper limit being indicated.

The analysis of the age range (Figure 2) shows that the most frequent opinions were expressed by people aged 41 to 50 years (59 people, 35.12%). Slightly less, 51 people (30.36%) are between 31 and 40 years old. The invitation to the study was also accepted by people aged 20-30, in the number of 31 (18.45%) and respondents over 50, who were recorded in the number of 27 people (16.07%).

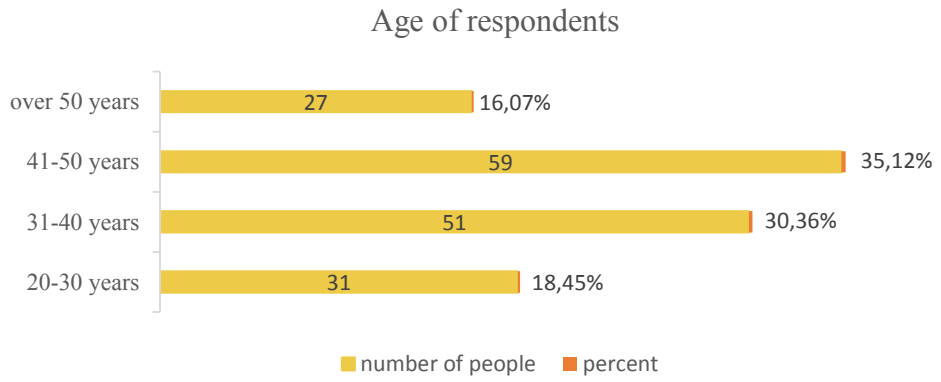


**Figure 1.** Age of respondents.

Source: Own elaboration based on the conducted research.

The vast majority of respondents are people with higher education (141 people, which is as much as 83.93%), including bachelor's degrees and completed postgraduate and doctoral studies. 27 respondents (16.07%) are people with secondary education. Figure 3 presents the proportions of education among the surveyed respondents.

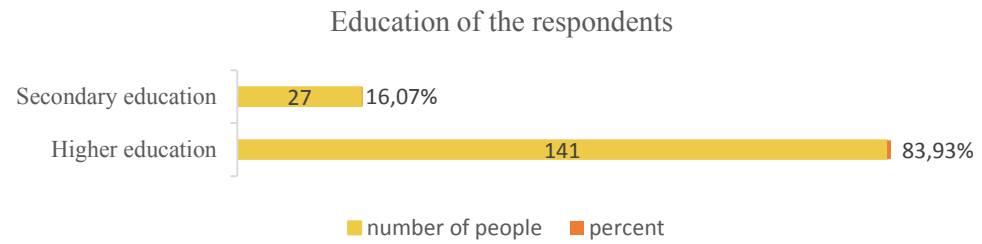


**Figure 2.** Education of the respondents.

Source: Own elaboration based on the conducted research.

In line with the fundamental principle of social research ethics, the respondents were invited to the study, having complete freedom to choose to be present in it (voluntary participation) (Babbie, 2004).

This action also prevented submissions that would not add value to the study.

### 4.2. Analysis of key roles and effects of feedback as a management support tool through communication

One of the important factors having a direct impact on the effectiveness of feedback is the attitude of superiors and subordinates they adopt in the flow of communication. Almost 71.5% (120 people) of the respondents who expressed their opinion rightly expressed the belief that both sides of communication, manager and the employee, are responsible for feedback. According to 45 people (26.7%), this responsibility, as well as the effectiveness of the team, lies on the manager's side. Figure 4 presents all statements of the respondents on this subject.

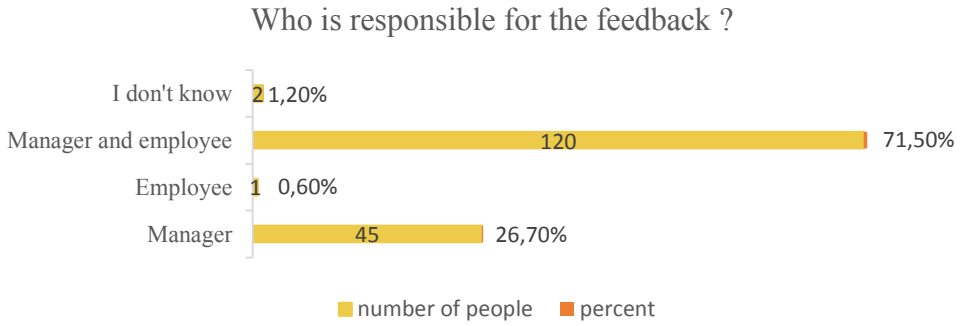


**Figure 4.** Responsibility for feedback according to the respondents**.**

Source: Own elaboration based on the conducted research.

The approach to divide the responsibility for the effectiveness of feedback into both sides of the communication is the right approach. Therefore, the awareness of almost of ¾ respondents in this respect is encouraging.

It should be remembered that despite the shared responsibility, the superior most often initiates the feedback flow process. Therefore, it is worrying that as many as half of the respondents ascribed to managers the lack of ability to provide motivating feedback.

Meanwhile, almost 60% of the respondents stated that their superiors were unable to adapt the communication of the employee's work analysis to the model of his personality.

These are very important indicators, especially since the respondents indicated the function of motivating feedback as one of the most important (indicated by 107 people, i.e. 63.7%), right after the function supporting the development and efficiency of the employee (indicating 116 people, 69.04%). Meanwhile, there are various patterns of appreciating and analyzing the subordinate's mistakes, thanks to which the feedback, despite the elements of criticism contained in it, does not show symptoms of demotivation. Figure 5 shows all the key roles that respondents believe feedback should fulfill.


**Figure 3.** The roles that all respondents believe should be played by feedback in the workplace.
Source: Own elaboration based on the conducted research.

Interesting conclusions are also provided by the analysis, which shows that employees don't emphasize the need to strengthen their potential, but it is important for them to support their development and efficiency (69,05%), although both factors (potential and efficiency) seem to be inseparable. This result may indicate too strong focus on efficiency. According to regular employees, an important function of feedback is also motivating (63,69%). This is logical, because the respondents indicated equally high openness to diagnosing and correcting competence gaps (58,33%). Feedback functions relevant to the employees are presented in Figure 6.

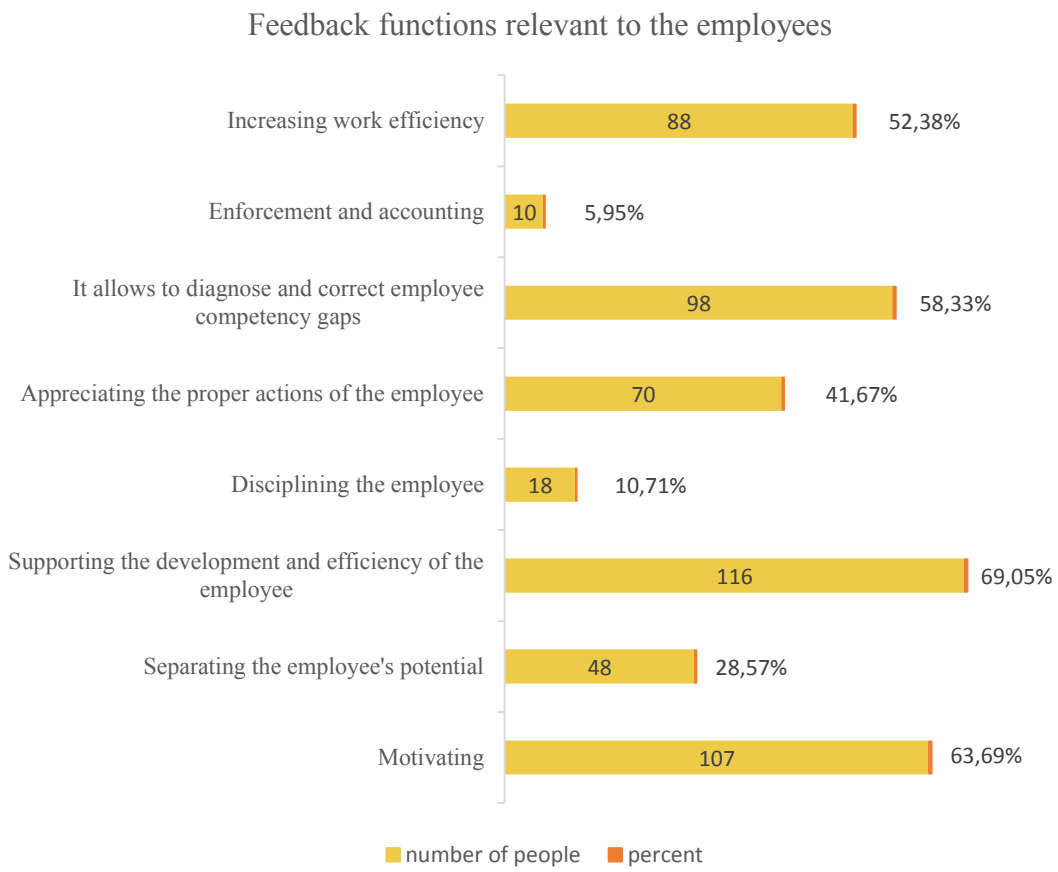


**Figure 6.** The ratio of the feedback functions relevant to the employees.

Source: Own elaboration based on the conducted research.

The respondents participating in the research (apart from indicating the role that, according to them, feedback should play in the organization) also had the opportunity to comment on the effects of effective feedback in business. The question about the effects was asked in two configurations, in relation to the expectations of respondents in working with feedback and in relation to the actual results in this area. In addition to increasing the effectiveness of the entire team, as indicated by 118 people (70%), the respondents also confirmed the increase in employee effectiveness (111 people, 66.07%), but also noticed the value in increasing trust in the company (104 votes, 61.9%) and in improving the relationship between the superior and the subordinate - almost 44% (73 votes) (Figure 7).

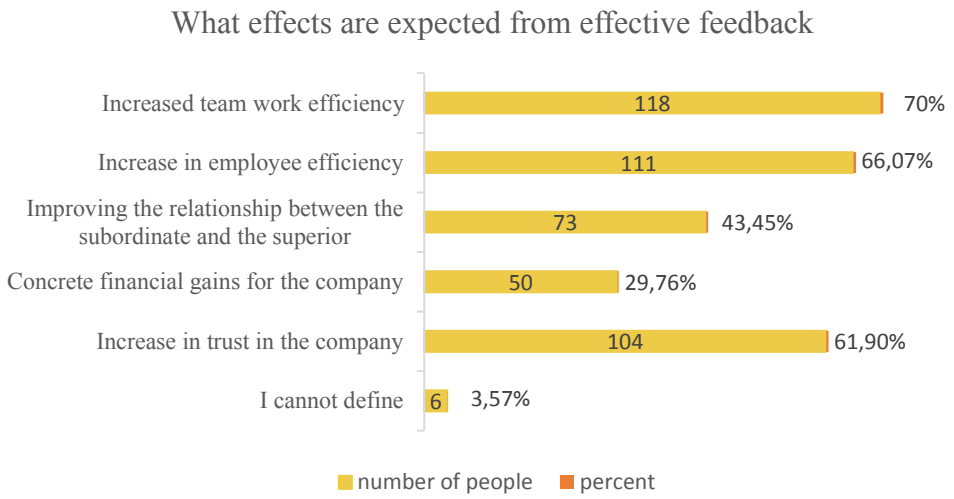


**Figure 7.** The respondents' expectations regarding the effects of effective feedback.

Source: Own elaboration based on the conducted research.

In the light of these expectations, it seems reasonable to verify the facts. As can be seen in Figure 8, unfortunately the feedback currently occurring in the organizations represented by the respondents does not bring the intended results.

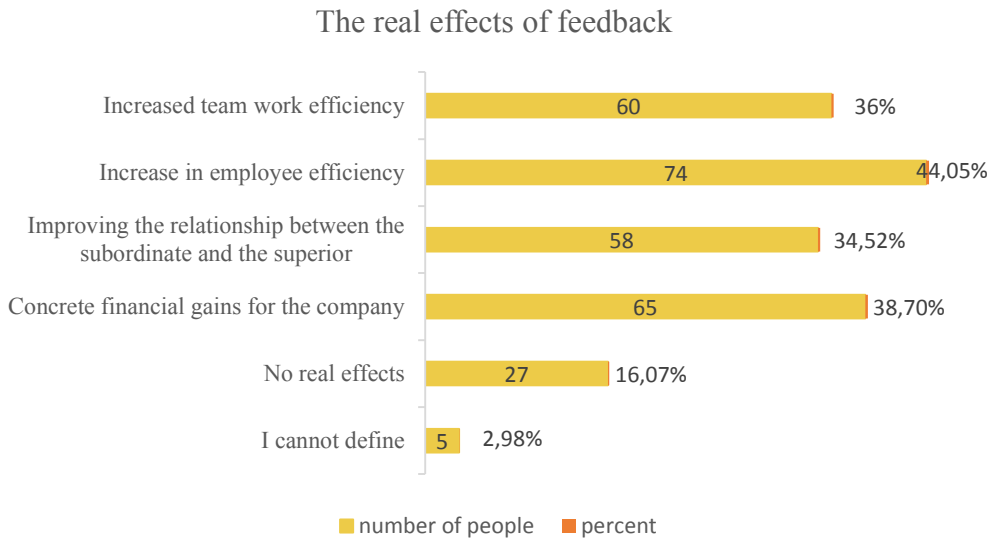


**Figure 4.** The actual effects of feedback, according to the survey respondents.

Source: Own elaboration based on the conducted research.

The expectations are particularly different from the reality with regard to the increase in the efficiency of the team's work, where a difference can be seen in the decrease by half of the votes cast (from 70% to 36%). All other assumptions also fell. It is worth noting that in terms of actual effects, the respondents didn't comment on trust in the company at all, which was one of the most important expectations. The lost percentage points from the higher indicators typed in the expectations created a new element regarding the lack of actually noticeable effects in reality (27 people, 16.07%).

It is wondering, what may be the reason for the discrepancy between expectations and business reality. Perhaps the reasons should be sought in very irregular meetings, during which managers analyze on the basis of feedback. Respondents were asked to provide additional information about the frequency of such meetings in their enterprise (Figure 9).

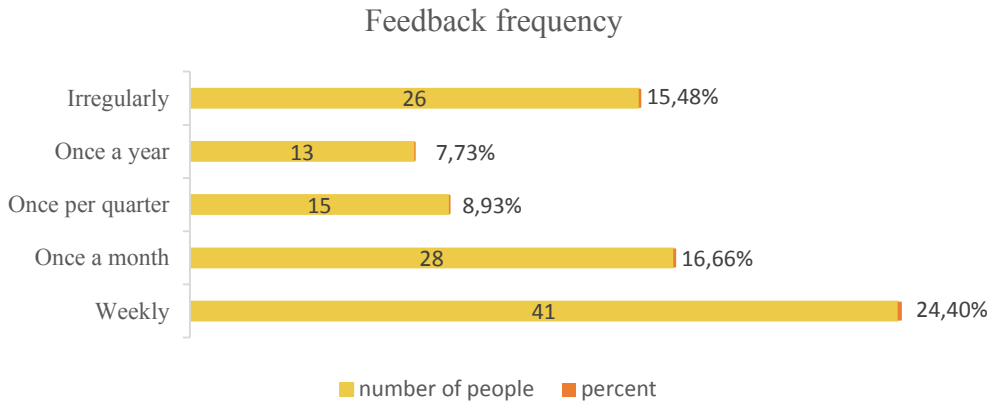


**Figure 5.** The frequency of providing feedback in the organizations represented by the respondents.
Source: Own elaboration based on the conducted research.

The Figure shows that only less than a quarter of them observe the systematic, weekly practice of working with feedback in their organization, less than half of the monthly practice. In other cases, feedback is given very rarely and / or irregularly.

Respondents were also asked to assess the level of feedback culture in their enterprise (Figure 10).

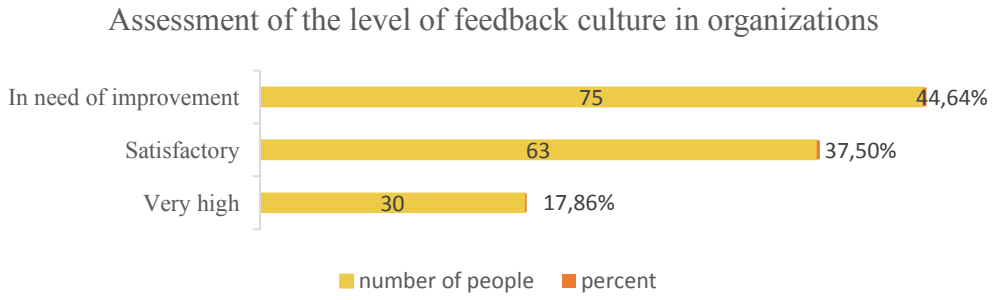


**Figure 6.** Assessment of the level of feedback culture in organizations according to the respondents.
Source: Own elaboration based on the conducted research.

When analyzing the data presented in Figure 7-9 in particular, it is not surprising that almost 45% of respondents believe that the level of feedback culture in their enterprise requires improvement (Figure 10).

## 5. Conclusions

At the beginning of this study, the words of GB Shaw, who used to say that "the biggest problem in communication is the illusion that it happened" were quoted. These words refer to the risk of contamination in the flow of information in business. Does the analysis of the functionality of feedback in the workplace confirm the existence of such a risk? Based on the conducted research, can we unequivocally state that managers effectively use feedback as a development tool for human potential management? Have the research confirmed the hypothesis that feedback is one of the key elements of the culture of dialogue in an organization? And finally, is the actual process approach to feedback, according to the interested parties, a desired practice supporting effective management by communication?

Certainly, the issues presented in this study do not cover the entirety of such an extensive issue as the importance of feedback in team management, building a communication strategy and implementing business goals with it. The more difficult this task is that in the subject literature, the feedback seems to be only a minor supplement to the subject of management. The more interesting, however, that feedback is still a niche issue, somewhat left to the intuitive course, which allows you to explore areas where there is still a lot to be discovered, despite the popularity and prevalence of the concept of feedback itself.

The assumed hypothesis that process feedback is one of the key tools supporting managers in effective management by communication has been confirmed. However, based on the research conducted, it was found that the ability to work with feedback requires significant improvement. It is interesting that the expectations of employees towards managerial competences in this area are not reality, which means that the management staff, despite knowing the rules of the feedback, leaves too much space for intuitive actions. This in turn creates room for contamination in the information flow. On the other hand, the openness of both sides of communication, subordinates and superiors to changes in the area of feedback management is optimistic. This is confirmed by the awareness of the mutual responsibility for the effectiveness of the feedback information.

Summing up, the study clearly indicated that process feedback is a desirable tool, but its effectiveness requires raising managerial competences in terms of its provision and enforcement in a way that does not disturb the employee's motivation. We all function more effectively when we are cyclically supported by positive energy and constructive analysis of activities, encouraging further development. This is the right approach to eliminate the illusion that you are a toy car that can be winded up to run until the spring is unscrewed (Adair, 2000).

The authors hope that the collected materials will encourage the implementation of feedback in terms of processes, and thus allow the development of a culture of dialogue in the surveyed enterprise and in enterprises from other industries whose management staff, after reading this study, will notice the importance of implementing and using process feedback in the structures of their company.

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# SUSTAINABLE DEVELOPMENT ACTIVITIES IN CHEMICAL COMPANIES IN POLAND: LINKS BETWEEN SDGs AND ESG

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**Purpose:** The main aim of the article is to explore sustainable development activities undertaken by the chemical companies in Poland. Three research objectives were established: (1) identification of key Sustainable Development Goals (SDGs) for chemical companies, (2) identification of activities related to each of the three ESG (Environmental, Social, Governance) elements in chemical companies, and (3) linking specific SDGs and ESG elements in the case of the chemical industry.
**Design/methodology/approach**: To achieve the aim of the article, the content analysis was used. Documents of chemical companies regarding sustainable development were analyzed, i.e. strategies, policies and reports.
**Findings:** Firstly, the analysis of strategies and policies allowed to identify 13 key SDGs for the Polish chemical companies. Secondly, analysis of the reports, allowed the discovery of numerous activities of the chemical companies in the environmental, social and governance areas. Finally, the links between specific SDGs and ESG elements in the chemical sector were presented.
**Practical implications:** The paper contributes to the better understanding of the chemical companies' sustainable development activities. In terms of practical implications, the results could guide chemical companies in the development of their ESG strategies.
**Originality/value:** The review of the literature has shown that problems such as SDGs and ESG in the context of the chemical industry have rarely been addressed so far. The links between SDGs and ESG in the chemical industry have also not been studied. To the best knowledge of the author, this is one of the first known studies to investigate the SDGs and ESG issues in chemical companies in Poland. The article is intended for researchers and practitioners interested in the sustainable development issues.

**Keywords:** Chemical industry, ESG, SDGs, Sustainable development, Sustainable development goals.

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

## 1. Introduction

The issues of sustainable development are becoming more and more popular among researchers and since 2015 this process has intensified (Allen et al., 2016; Sarangi, 2017; Sullivan et al., 2018; Mio et al., 2020; Krasodomska et al., 2022; Budzanowska-Drzewiecka et al., 2023). This is due to the adoption of the 2030 Agenda for Sustainable Development by the United Nations (United Nations, 2015), including a declaration of 17 Sustainable Development Goals (SDGs). Topics related to the SDGs discussed in the literature of management most often cover the role of specific organizations and sectors in taking action to implement SDGs and the incorporation of SDGs into business strategies (Krasodomska et al., 2022). However, some scholars admit that the ways in which SDGs can be integrated into business strategies remains an unsolved problem (Berrone et al., 2023).

Sustainable development aspects in managing organizations are not only about incorporating SDGs into the business strategies, CSR strategies or ESG (Environmental, Social, Governance) strategies. Sustainable development calls for financial discipline and greater transparency (PwC, 2022). The response to this requirement manifests itself in the disclosure of sustainable development information in various types of reports (e.g. integrated reports, non-financial reports). Interestingly, the first separate environmental reports were published in 1989 (Kolk, 2004). Then, the number of organizations that publish sustainability reports have been increasing significantly (Kolk, 2004). In 2021, 96% of the S&P 500 companies, published a sustainability report (G&A, 2022). Since 2006, when the framework of ESG was integrated by the United Nations into the Principles for Responsible Investment, ESG became a hot topic in academia and practice (Lee et al., 2022; Tylec, 2022; Zyznarska-Dworczak, 2022; Yu, Xiao, 2022; Wang et al., 2023). This is due to e.g. growing regulatory and market pressure, ownership requirements and the possibility of obtaining financing.

The chemical industry plays a key role in the implementation of the ESG concept and the 17 SDGs. The chemical industry is very diverse and has a significant impact on the global economy, the environment, and society. It provides products and materials that are the basis for production processes in almost all industries. Moreover it is a source of fuel, enabling the functioning of the transport sector. Thousands of substances that are present in countless chemicals play a fundamental role in everyday people's lives. Among them, there are consumer goods and chemicals which contribute to water and food security and help protect health. However, some substances that can cause adverse effects. Additionally, production plants are often perceived as places that harm environment and emit dangerous substances. To change these negative chemical industry perceptions, companies are engaging in environmental issues. In particular, some enterprises belonging to environmentally sensitive industries, such as the oil industry, present sustainable development activities information more often than other organizations, mainly in order to legitimize their activities and neutralize the stigma of

poisoners (Tylec, 2022). Notwithstanding, it is to be hoped that the true motivation of chemical companies is the pursuit of sustainable development which "meets the needs of the present without compromising the ability of future generations to meet their own needs" (United Nations, 1987, p. 16).

Although the issue of sustainable development in the context of the chemical industry has been and is taken up by researchers (Beloff et al., 2005; Jianchun et al., 2011; Mitra et al., 2015; Chen, Reniers, 2020; Kostal et al., 2022), topics such as SDGs and ESG have so far been rarely addressed (e.g. Pan Fagerlin et al., 2019; Nechita et al., 2020). Since there are limited studies that focus on SDGs and ESG in the chemical industry, this paper fills the gap. Therefore, the main aim of this article is to explore sustainable development activities undertaken by the chemical companies in Poland. Three research objectives were established: (1) identification of key SDGs for chemical companies, (2) identification of activities related to each of the three ESG elements in chemical companies, and (3) linking specific SDGs and ESG elements in the case of the chemical industry. To achieve the goal, the content analysis was used. Documents of chemical companies in Poland regarding sustainable development were analyzed.

The article consists of five parts. Firstly, the main findings of the literature review on incorporating SDGs and ESG into business strategies and reports are presented. Secondly, the research method is explained. The results of the study are summarized in the following section. The article ends with the discussion and summary.

## 2. Incorporating SDGs and ESG into business strategies and reports

Sustainability is often understood as a long-term goal, while sustainable development refers to the many activities to achieve it. To create a more sustainable world, Sustainable Development Goals, which describe major development challenges for humanity, are to be reached. The 2030 Agenda for Sustainable Development includes a declaration of 17 SDGs and 169 targets, along with monitoring and review measures. SDGs were designed to eliminate poverty, preserve the planet and ensure prosperity. They address for a collective action to achieve more sustainable future for all, solving the social, economic, and environmental issues that hinder global progress towards sustainability (United Nations, 2015). The 17 SDGs are (United Nations, 2015, p. 14):

"Goal 1. End poverty in all its forms everywhere.

Goal 2. End hunger, achieve food security and improved nutrition and promote sustainable agriculture.

Goal 3. Ensure healthy lives and promote well-being for all at all ages.

Goal 4. Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all.

Goal 5. Achieve gender equality and empower all women and girls.
Goal 6. Ensure availability and sustainable management of water and sanitation for all.
Goal 7. Ensure access to affordable, reliable, sustainable and modern energy for all.
Goal 8. Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all.
Goal 9. Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation.
Goal 10. Reduce inequality within and among countries.
Goal 11. Make cities and human settlements inclusive, safe, resilient and sustainable.
Goal 12. Ensure sustainable consumption and production patterns.
Goal 13. Take urgent action to combat climate change and its impacts.
Goal 14. Conserve and sustainably use the oceans, seas and marine resources for sustainable development.
Goal 15. Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss.
Goal 16. Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels.
Goal 17. Strengthen the means of implementation and revitalize the Global Partnership for Sustainable Development".

SDGs are "integrated and indivisible, global in nature and universally applicable, taking into account different national realities, capacities and levels of development and respecting national policies and priorities" (United Nations, 2015, p. 13). Additionally, SDGs are interrelated (Fonseca et al., 2020). All countries have committed to SDGs, but each sets its own national targets, taking into account national circumstances. However, governments of both developed and developing countries do not have the resources to ensure the implementation of all actions necessary to achieve SDGs (Sullivan et al., 2018). On the one hand, Sullivan et al. (2018) point out that the private sector will play the first fiddle in actions for sustainable development. On the other hand, the management literature does not provide a full answer to the question of to what extent enterprises contribute to sustainable development (van der Waal et al., 2021). What can be observed, is the trend of enterprises including SDGs in their business strategies and informing about completed activities related to these goals in their sustainability reports.

Incorporating sustainability into an organization's strategy is not an easy task. One may come up with an endless list of environmental, economic, and societal needs that should be addressed. Depending on the sector in which the company operates, specific SDGs will be more or less important. This is why organizations set priorities due to their business activities. Mhlanga et al. (2018) show that there are industries where a direct link between a particular

SDG and the specific products and services offered by the enterprise within the sector can be easily identified. For example, this connection manifests itself as follows: food companies and SDG 2 Zero hunger, pharmaceutical companies and SDG 3 Good health and well-being, or energy companies and SDG 7 Affordable and clean energy. Some enterprises prioritize several SDGs in their strategies. Others have either decided to engage with most of SDGs or do not provide any information about priority SDGs at all (Mhlanga et al., 2018). Mhlanga et al.'s (2018) studies have proven that there is a lack of consistency in how specific organizations determine which SDGs are key ones, as well as there is limited sector-level consistency.

Organizations disclose information on their sustainable development activities in relation to SDGs in their reports. Among the reasons that lead them to do so, there are engagement in social and environmental issues, the use of Global Reporting Initiative (GRI) standards and the requirements of stakeholders (Krasodomska et al., 2022). Calvo-Centeno et al. (2022) shows that the enterprises incorporated an average of ten SDGs in their 2019 reports. Wherein the largest number of entities took into account four goals, i.e. SDG 8 Decent work and economic growth, SDG 13 Climate action, SDG 4 Quality education and SDG 9 Industry, innovation and infrastructure. The companies studied were the least likely to refer to the goals: 14 Life below water and 2 Zero hunger (Calvo-Centeno et al., 2022).

In addition to the fact, that organizations in their strategic documents and sustainability reports refer to SDGs, they also relate to three elements of ESG. This is reflected in management literature, however mainly in the context of reporting (e.g. Tylec, 2022; Zyznarska-Dworczak, 2022; Yu, Xiao, 2022). ESG elements in development strategies are rarely the subject of research (e.g. Cho, 2022). Cho (2022) notices that the primary drivers for companies to adopt the concept of ESG at the strategic level are probably the following: interest in social contribution, government policies and the belief that ESG activities will have a positive impact on the company's performance. She determined that ESG strategies have a positive effect on enterprise value (Cho, 2022).

ESG is a framework made up of factors that should be taken into account in the organization's activities in the field of environmental, social and corporate governance. Tylec (2022), after analyzing the meanings attributed to the three ESG elements in the literature on this subject, summed them up accurately. Namely, the "E" stands for striving to care for the environment and responsible use of natural resources. "S" is referred to as the concept of corporate social responsibility, which is an obligation of the organization to be consistent with the objectives and values of the society. The "G" element includes the structure of the organization and its management, taking into account the requirements of stakeholders (Tylec, 2022).

The concept of ESG is becoming more and more important to organizations. This is due to the market pressure, regulatory pressure (e.g. The Corporate Sustainability Reporting Directive that has entered into force on 5 January 2023 in the EU), ownership requirements and the possibility of obtaining financing. Especially the latter premise is valid, as investors and rating

agencies expect greater visibility of non-financial metrics to better understand diverse environmental, social and governance risks. Non-financial information can contribute to a true reflection on the sustainable development activities of the organizations (Calvo-Centeneo, 2022).

The mentioned Corporate Sustainability Reporting Directive (CSRD) (Directive (EU) 2022/2464) obliges large companies, as well as listed small and medium enterprises, to report on sustainability, in accordance with the proposed reporting standards. These standards ensure that investors and other stakeholders have access to the information to assess investment risks arising from environmental, social and governance issues. The sustainability reporting standards specify the information that organizations are to disclose regarding to three groups of factors (Directive (EU) 2022/2464):

- environmental factors: (1) climate change mitigation; (2) climate change adaptation; (3) water and marine resources; (4) resource use and the circular economy; (5) pollution; (6) biodiversity and ecosystems,
- social factors: (7) equal treatment and opportunities for all; (8) working conditions; (9) respect for the human rights, (10) fundamental freedoms, democratic principles and standards,
- governance factors: (11) the role of the organization's bodies with regard to sustainability matters, and their composition; the main features of the organization's internal control and risk management systems; (12) business ethics; (13) activities related to exerting its political influence; (14) the management and quality of relationships with stakeholders.

The above 14 ESG factors largely overlap with the SDGs. Both SDGs and ESG are concepts for resolving environmental and social problems to achieve a more sustainable world. The difference between them is that SDGs are more general as they apply to all countries, although the burden of implementing them rests with enterprises. Whereas, ESG framework concerns companies and how they communicate activities undertaken in the areas of environmental, social and governance. Interestingly, the pressure from the United Nations to overlay ESG data with SDGs is noticed.

An attempt to link specific SDGs with the economic, social and ecological aspects was made by Rockström and Sukhdev (2016). On the one hand, Rockström and Sukhdev have assigned specific SDGs to one of the three areas. The ecological area (biosphere) includes SDG 6 Clean water and sanitation, SDG 13 Climate action, SDG 14 Life below water and SDG 15 Life on land. Society area involves SDGs numbered 1 No poverty, 2 Zero hunger, 3 Good health and well-being, 4 Quality education, 5 Gender equality, 7 Affordable and clean energy, 11 Sustainable cities and communities and 16 Peace, justice and strong institutions. In turn SDGs numbered 8 Decent work and economic growth, 9 Industry, innovation and infrastructure, 10 Reduced inequalities and 12 Responsible consumption and production are associated with the area of economy. On the other hand, the vision of Rockström and Sukhdev

is a move away from the sectorial approach where social, economic, and ecological development are seen as separate parts, as SDG 17 Partnerships for the goals pervades these three areas.

To sum up, the review of the literature shows that both SDGs and ESG framework are becoming more and more important for organizations. They are incorporating SDGs and ESG into strategies and then strive to achieve them. Subsequently, the activities implemented in the field of sustainable development are disclosed in reports. In this way, organizations contribute to sustainable development in the economic, social and environmental fields.

## 3. Method

The review of the literature shows that problems such as SDGs and ESG in the context of the chemical industry have rarely been addressed so far. To the best knowledge of the author, the links between SDGs and ESG in the chemical industry have also not been studied. This research gap encouraged the author to pose three research questions:

RQ1: Which of the 17 SDGs are crucial for companies in the chemical sector?

RQ2: What activities are carried out within each of the three ESG elements in companies in the chemical sector?

RQ3: How are specific SDGs linked to ESG elements in the case of the chemical industry?

To answer the above questions, the content analysis was used. The content of the various documents on sustainable development as well as the websites of entities operating in the chemical sector in Poland were analyzed, as of January 2023.

The Polish chemical industry has a rich past. Its history goes back to the 19th century, when Łukasiewicz, a pioneer of the oil industry processed crude oil and used it on a massive scale. The chemical industry occupies one of the key positions among the sectors of the economy in Poland. It consists of four areas: (1) bulk chemistry (mass chemistry, high-volume chemicals), (2) chemical processing, (3) fuels and refined petroleum products, and (4) low-tonnage chemistry (PCCI, 2022). In 2021, its input in industrial production was valued at approximately PLN 341.3 billion, which was 16.9% of the Polish industrial production sold. It was the third largest industrial sector in Poland in terms of employment, creating an average of 335,000 jobs, which is 12% of total employment in the Polish industry. Furthermore, 13 thousand chemical companies operated in Poland (PCCI, 2022). Among them there are entities of various sizes and specializations, from large integrated chemical groups to medium and small chemical processing plants. For example, the segment of fuels and refined petroleum products is dominated by PKN ORLEN S.A. Other largest entities producing mainly high-volume chemicals are the AZOTY Group, the CIECH Group, SYNTHOS S.A. and PCC ROKITA S.A.

The first step in the research procedure was to select the cases for analysis. A list of members of the Polish Chamber of Chemical Industry (PCCI) was used for this purpose. This choice is justified by the fact that it is the only organization in Poland representing the chemical industry in public administration bodies and international organizations. To select chemical companies, the range of activities of all 148 organizations belonging to the PCCI was considered. Among the PCCI's members, there are chemical producers, consulting agencies, law firms, industrial installation and construction companies, scientific institutes, representative offices of foreign companies, transport and distribution companies, and a few NGOs (Figure 1).

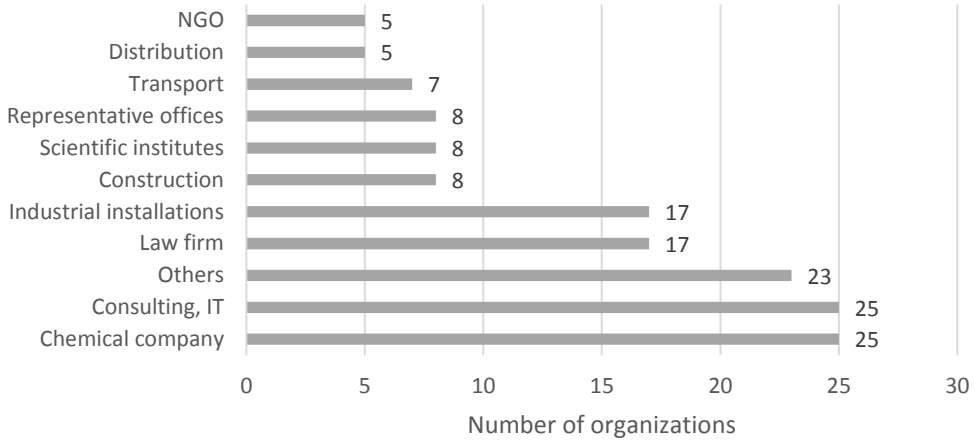


**Figure 1.** Types of organizations of the PCCI members, as of 15 February 2023.

Source: own study based on: Polska Izba Przemysłu Chemicznego. Retrieved from: https://pipc.org.pl/czlonkowie/, 15.02.2023.

As a result of recognizing the activity profile of the PCCI members, 25 chemical companies were identified, which are cases for further research. This group includes entities from all areas of the chemical industry, and most of them represent mass chemistry.

In the next stage of the study, the text material was selected. Available on 25 chemical companies' websites, documents were searched. These were all documents related to sustainable development and general documents, which contain issues related to sustainable development in the separate sections (Table 1).

**Table 1.**
*Types of sustainable development documents in the analyzed chemical companies*

| Name of the company | Name of the group | Name of the document (valid for january 2023) |
|---|---|---|
| CIECH S.A. | CIECH Group | ESG Strategy, Annual Non-Financial Report 2021 |
| GRUPA AZOTY S.A. | AZOTY Group | ESG Strategy (part of the GRUPA AZOTY Strategy for 2021-2030), CSR Policy, GRUPA AZOTY's integrated report for 2021 |
| GRUPA AZOTY Zakłady Azotowe „PUŁAWY" S.A. | | |
| GRUPA AZOTY Zakłady Azotowe Kędzierzyn S.A. | | |
| GRUPA AZOTY Zakłady Chemiczne „POLICE" S.A. | | |

Cont. table 1.

| | | |
|---|---|---|
| ANWIL S.A. | ORLEN Group | Strategy of the ORLEN Group until 2030, ORLEN Group Sustainable Development Strategy for 2021-2023, Report on Non-Financial Information of the ORLEN Group and PKN ORLEN S.A. for 2021 |
| ORLEN Południe S.A. | | |
| PKN ORLEN S.A. | | |
| BASF Polska Sp. z o.o. | Not applicable | Integrated Policy |
| PCC ROKITA S.A. | Not applicable | Diversity Policy, Sustainable Purchasing Policy, Environmental Policy, CSR and Sustainable Development Policy |
| PETROCHEMIA-BLACHOWNIA S.A. | Not applicable | Integrated Management System Policy, Environmental and Health and Safety Report |
| SYNTHOS S.A. | Not applicable | CSR Strategy |

Note. BASF Polska Sp. z o.o. belongs to BASF Group, however, due to the adopted limitation to the Polish chemical industry, BASF Group documents were not analyzed.

Source: own study based on the websites of the analyzed chemical companies.

Table 2 presents only the most important and selected documents related to sustainable development. For example, the ORLEN Group also has the following documents in place: Charity Policy, Purchasing Instructions, Code of Conduct for Suppliers, Anti-Corruption Policy, Diversity Policy, Principles of Accepting and Giving Gifts, Integrated Management System Policy, Code of Ethics, Remuneration Policy for Members of the Management and Supervisory Boards, Age Management Policy, Wellbeing Policy, Energy Policy, Enterprise Risk Management Policy and Procedure, Anti-Corruption Policy, that do not appear in the above Table. Table 1 also does not include the names of the 13 companies (out of 25) that did not publish information on sustainable development activities on their websites at all, or provided only partial descriptions of these activities, without publishing documents.

In the case of companies belonging to the group, documents prepared for the group were analyzed. As a result, documents of seven entities were submitted for further analysis. The cases for analysis were: CIECH Group, AZOTY Group, ORLEN Group, BASF Polska Sp. z o.o., PCC ROKITA S.A., PETROCHEMIA-BLACHOWNIA S.A. and SYNTHOS S.A. Taking into account the types of published documents, the entities under study were divided into two groups: (1) large integrated chemical groups that publish both strategic documents and reports (hereinafter referred to as integrated groups) and (2) other chemical companies (hereinafter referred to as other companies), which provide one of the documents: strategy or report, as well as other documents such as policies.

Then, as part of operationalization, textual units of analysis were established. In this study, the content of complete documents concerning sustainable development was the topic of discussion and the selected phrases regarding sustainable development in general documents. Code categories were also adopted, namely 17 SDGs and ESG elements with its 14 factors.

# 4. Results

## 4.1. Key SDGs for the chemical companies in Poland

The first research question concerned key SDGs for chemical enterprises. The 2030 Agenda for Sustainable Development (United Nations, 2015), shows that all goals have the same importance in the pursuit of sustainable development. However, specific organizations adopt in their strategies selected SDGs that are closest to the profile of their business activities. Since the chemical sector is one of the most diversified and complex of all industries, large integrated chemical groups often contribute to all SDGs. For example, due to the wide scope of multi-utility ORLEN Group's activities, mainly in the area of energy and fuel, all 17 SDGs are being supported (ORLEN Group Sustainable Development Strategy for 2021-2023, 2021), but a particular emphasis is on key goals for the fuel and energy industry.

To identify the key SDGs for the chemical industry, the strategic documents of seven chemical entities were examined, namely business strategies, CSR strategies, ESG strategies and, where strategies were unavailable, other relevant documents, as policies. It was assumed that the key SDGs are those that have been referred to directly or indirectly in the strategies and policies of the companies under study. As a result of the analyzes carried out, it was observed that in the documents of integrated groups there are direct references to key SDGs. While other companies indirectly refer to the SDGs. They present the plans for sustainable development activities, which comply with the description of the specific SDGs, but they do not indicate them. For other companies, the key SDGs were identified based on the content analysis applied to the accessible documents (Table 2).

**Table 2.**
*Key SDGs in the analyzed documents of the chemical companies*

| COMPANY NAME / SDGS | CIECH | AZOTY | ORLEN | BASF | ROKITA | PETRO | SYNTHOS | TOTAL |
|---|---|---|---|---|---|---|---|---|
| SDG 1 | | | | | | | | 0 |
| SDG 2 | ✓ | ✓ | | | | | | 2 |
| SDG 3 | ✓ | | ✓ | ✓ | | | | 3 |
| SDG 4 | ✓ | ✓ | | ✓ | | | | 3 |
| SDG 5 | ✓ | | | ✓ | | | | 2 |
| SDG 6 | ✓ | ✓ | | | | | | 2 |
| SDG 7 | ✓ | | ✓ | | | | ✓ | 3 |
| SDG 8 | ✓ | ✓ | | | ✓ | | ✓ | 4 |
| SDG 9 | ✓ | ✓ | ✓ | | | | ✓ | 4 |
| SDG 10 | | | | | | | | 0 |
| SDG 11 | ✓ | | ✓ | | | | | 2 |

Cont. table 2.

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| **SDG 12** | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | ✓ | **7** |
| SDG 13 | ✓ | ✓ | ✓ | | | | ✓ | 4 |
| SDG 14 | | | | | | | | 0 |
| SDG 15 | ✓ | | | | | | | 1 |
| SDG 16 | | | | | | | | 0 |
| SDG 17 | ✓ | | | | ✓ | | ✓ | 3 |
| **TOTAL** | **13** | **7** | **6** | **4** | **3** | **1** | **6** | **40** |

Note. Abbreviations used in the table: CIECH = CIECH Group, AZOTY = AZOTY Group, ORLEN = ORLEN Group, BASF = BASF Polska Sp. z o.o., ROKITA = PCC ROKITA S.A., PETRO = PETROCHEMIA-BLACHOWNIA S.A., SYNTHOS = SYNTHOS S.A.

✓ means that, in the entity's document, there is a direct reference to SDG or there is an indirect reference to SDG (the general notation refers to a specific SDG).

Source: own study based on the documents of the analyzed chemical companies.

The analysis of strategies and policies of the chemical companies allowed to identify 13 key SDGs. All seven studied entities considered SDG 12 Responsible consumption and production, therefore the SDG 12 seems to be the most important for the chemical industry.

Integrated groups contribute to SDG 12 Responsible consumption and production by planning numerous activities in their strategies. In the responsible consumption category, the AZOTY Group's priorities refer to reduction of coal consumption and to incorporating gas-fired sources into the energy mix. The CIECH Group declares using less raw materials. The AZOTY Group and the CIECH Group will use less energy per unit of production. The ORLEN Group plans significant pro-ecological investments and using hydrogen technologies in transport and hydrogen-based energy consumption. It is also important for the integrated groups to consider responsible production. For example, the AZOTY Group's intends to recover waste energy from chemical processes and to implement recycling technology in production. Its priorities refer to decarbonization of production and to the reduction in CO2 emissions. The CIECH Group declares reducing waste in production processes. The ORLEN Group's strategy incorporates a commitment to CO2 reduction targets, less emissions from its existing refining and petrochemical assets and basing power generation business mainly on renewables and gas-fired sources.

Other companies also refer to SDG 12 Responsible consumption and production, but indirectly. Planned contribution of SYNTHOS S.A. to responsible consumption consists in using ecological and carbon-free energy sources. All examined companies, i.e. BASF Polska Sp. z o.o., PCC ROKITA S.A., PETROCHEMIA-BLACHOWNIA S.A. and SYNTHOS S.A., present the aims in the responsible production category. They all anticipate reduction of: waste, wastewater, CO2 emissions and pollutants. Some of the companies foresee monitoring of the carbon footprint. Additionally, BASF Polska Sp. z o. o. intends to improve the energy result and implement sustainable energy management.

Taking into account the frequency of indicated SDGs, mention should be made of SDG 8 Decent work and economic growth, SDG 9 Industry, innovation and infrastructure and SDG 13 Climate action, which were indicated four times each. Interestingly, no references to

SDG 1 No poverty, SDG 10 Reduced inequalities, SDG 14 Life below water and 16 Peace, justice and strong institutions were found in the analyzed documents.

The analysis also shows that the entity that mentions the most key SDGs in its strategy, as many as 13, is the CIECH Group. The presence of so many SDGs in the CIECH Group's ESG Strategy is probably due to the wide range of products offered, that is: soda ash, baking soda, salt, polyester and epoxy resins, crop protection products, glass products, silicates and other chemicals (CIECH Group). These products are used in the production of countless articles necessary in the everyday life of people, hence the CIECH Group contributes to many SDGs. Indirect reference to only one SDG is included in the Integrated Management System Policy of the PETROCHEMIA-BLACHOWNIA S.A. It may result from a narrow range of products compared to other enterprises.

### 4.2. ESG activities of the Polish chemical companies

The second research question involved the activities carried out within each of the three ESG elements in the chemical companies. To identify these activities, various reports of the chemical entities were investigated. In the case of the integrated groups, these were integrated reports and non-financial reports. These documents contain sections in which environmental, social and governance activities are presented directly. In the case of the other companies, only one enterprise posted a report on the website, i.e. PETROCHEMIA-BLACHOWNIA S.A. posted the Environmental and Health and Safety Report. In the process of analyzing reports, categories of ESG factors compatible with the sustainability reporting standards were applied (Directive (EU) 2022/2464) (Table 3).

**Table 3.**
*ESG activities in the analyzed documents of the chemical companies*

| ESG FACTORS \ COMPANY NAME | | CIECH | AZOTY | ORLEN | PETRO |
|---|---|---|---|---|---|
| Environmental factors | 1. Climate change mitigation | ✓ | ✓ | ✓ | ✓ |
| | 2. Climate change adaptation | ✓ | ✓ | ✓ | |
| | 3. Water resources | ✓ | ✓ | ✓ | ✓ |
| | 4. Resource use and the circular economy | ✓ | ✓ | ✓ | |
| | 5. Pollution | ✓ | ✓ | ✓ | ✓ |
| | 6. Biodiversity and ecosystems | | ✓ | ✓ | |
| Social factors | 7. Equal treatment and opportunities for all | ✓ | ✓ | ✓ | |
| | 8. Working conditions | ✓ | ✓ | ✓ | ✓ |
| | 9. Respect | ✓ | ✓ | ✓ | |
| Governance factors | 10. Sustainability matters in management | ✓ | ✓ | ✓ | |
| | 11. Internal control and risk management | ✓ | ✓ | ✓ | |
| | 12. Business ethics | ✓ | ✓ | ✓ | |
| | 13. Exerting political influence | ✓ | | ✓ | |
| | 14. Relationships with stakeholders | ✓ | ✓ | ✓ | |

Note. Abbreviations used in the table: CIECH = CIECH Group, AZOTY = AZOTY Group, ORLEN = ORLEN Group, PETRO = PETROCHEMIA-BLACHOWNIA S.A.

✓ means that, in the entity's document ESG activity has been identified.

Source: own study based on the documents of the analyzed chemical companies.

The analysis of the reports allowed to identify countless activities of the chemical entities carried out within environmental, social and governance elements.

Table 3 clearly shows, that in 2021, studied integrated groups implemented activities related to three ESG elements. The ORLEN Group disclosed information on all 14 ESG factors in the report, while the other two entities referred to 13 factors each. The CIECH Group did not disclose data on biodiversity and ecosystems, while the AZOTY Group omitted its activities and obligations related to exerting political influence, including lobbying.

The first group of six factors concerns the environmental element. As part of climate change mitigation (1), integrated groups reduced the consumption of hard coal, reduced greenhouse gas emissions into the atmosphere and made significant investments in the best available environmental techniques and innovative, low-emission technologies. Two entities reduced their carbon footprint and invested in the development of renewable energy sources and emission-free sources. All integrated groups have also taken action to adapt to climate change (2). Primarily, they analyzed the risks and opportunities related to climate change, in accordance with the recommendations of the Task Force on Climate-related Financial Disclosures (TCFD). Another factor concerns water resources (3). In this case, all enterprises reduced water consumption in the plants, e.g. as a result of using closed water circuits. In addition, wastewater in the ORLEN Group is directed to industrial and rainwater sewage systems, and then subjected to treatment processes. Resource use and the circular economy (4) is the next factor. All companies operated in accordance with the principles of the circular economy and reduced electricity consumption. The CIECH Group reduced energy intensity, which was measured by the amount of energy consumed per unit of revenue, reduced the amount of waste and used less raw materials. All integrated groups have also reduced pollution (5). They reduced emissions of pollutants into the atmosphere, water and soil, conducted rational waste management and maintained the highest possible ecological neutrality of production processes. They have made significant investments to eliminate pollution. For example, the CIECH Group started the construction of a thermal waste processing installation, modernized electrostatic precipitators, built a flue gas denitrification installation and a flue gas desulfurization installation in several plants. the AZOTY Group continued work on developing an environmentally friendly technology for the production of succinic acid. The ORLEN Group carried out a series of investments in the area of wastewater management, moreover, a modern flue gas desulfurization installation was built, an exhaust gas monitoring system was installed, just to name a few. The sixth factor relates to the biodiversity and ecosystems (6). The CIECH Group, unlike other companies, did not include this issue in the report. The AZOTY Group constantly cares about the protection of ecosystems and natural resources. In 2021, it took numerous preventive and compensatory measures for the negative impact on nature. The ORLEN Group continually pays attention to the natural environment, protects biodiversity and develops ecological sensitivity.

The second group of factors concerns the social element. As part of equal treatment and opportunities for all (7) the CIECH Group eliminated disproportions in the remuneration of women and men in the same positions. The AZOTY Group did not allow discrimination in employment and did not differentiate salaries based on gender. Particularly, in 2021, 31% of women in the AZOTY Group held managerial positions and the average number of training hours per employee was 6.6 for women and 7.0 for men. It is important for the ORLEN Group to give employment opportunities to people with disabilities. In the ORLEN Group a number of projects were implemented to educate managers and employees in counteracting discrimination and managing diversity. Information campaigns were also carried out to raise awareness of disability in the workplace. The next factor relates to working conditions (8). In all investigated entities the highest safety standards were implemented, preventive measures were developed to reduce the accident rate, information on incidents was analyzed and safety risks were assessed. In the CIECH Group, as part of Performance Management, objectives related to safety were included in the process of evaluating managers. The issue of working conditions also includes the professional development of employees. Numerous training sessions were conducted in all studied organizations. Other examples of implemented activities include: development of e-learning and language platforms, employee engagement and satisfaction surveys, implementation of programs promoting a healthy lifestyle. The last social factor is the respect for human rights and fundamental freedoms (9). The studied entities ensure that in the analyzed period they attached importance to caring for the dignity of each employee, showing them due respect, regardless of, among others, religion, skin colour, beliefs, sex or age. Training courses were also conducted in this area, e.g. in the ORLEN Group, 67% of employees were trained in the subject of respect for human rights.

Finally, the third group of governance factors is opened by the component concerning sustainability matters in management (10). In all reports, the description of the role of the organization's bodies with regard to sustainability matters and their composition, was not given due attention. Only designated persons on the boards responsible for sustainability issues were indicated. But, the ORLEN Group reported that ESG management structures were strengthened in the analyzed period. In terms of the subsequent factor, main features of the organization's internal control and risk management systems (11), all entities reported the implementation of risk management systems, and interestingly, in the ORLEN Group this system was integrated with climate risks. In addition, the AZOTY Group conducted a review of ESG factors. The ORLEN Group's report mentioned that the internal audit function was performed by an independent Audit Office. Business ethics (12) is the following factor described in the studied reports. It is worth noting, that the codes of ethical conduct have been implemented in all integrated groups. The CIECH Group signed a declaration of adoption of the Standard of the United Nations Global Compact. Risks in the area of counteracting corruption and bribery, embezzlement and abuse were identified and assessed in the ORLEN Group and a number of projects were implemented to educate managers and employees in the field of ethics. Unlike

the business ethics, not much space was devoted in the reports to the problems of exerting political influence, including lobbying (13). The CIECH Group emphasized that it did not carry out lobbying activities other than as part of participation in national and international industry organizations, while the ORLEN Group stressed that it did not make donations to political parties, politicians and institutions of a similar nature. Finally, the last factor concerned the management and quality of relationships with stakeholders (14). The scale of the activities of the studied entities makes them cooperate with many groups of stakeholders. All integrated groups identify stakeholders and work with them for sustainable development. The ORLEN Group and the AZOTY Group presented stakeholder maps in their reports. The CIECH Group constantly operates on the basis of the CIECH Group Code of Conduct and the Business Partner Code, and additionally, in 2021, it started analyzing the ESG level among its suppliers.

Table 3 shows, that only one enterprise belonging to the category other companies posted a report on its website, i.e. PETROCHEMIA-BLACHOWNIA S.A. and only this report was subject to analysis. It does not mean, that the remaining companies belonging to the other companies group have not implemented activities in the ESG areas, quite the contrary. The information available on their websites proves that many such projects have been realized. However, in this study it was assumed that reports posted on websites were analyzed.

PETROCHEMIA-BLACHOWNIA S.A. disclosed information on three environmental factors and one social factor. The analyzed report shows activities related to climate change mitigation (1). The company constantly monitors the volume of carbon dioxide emissions, and in the period under review, it achieved a significant decrease in the volume of these emissions. PETROCHEMIA-BLACHOWNIA S.A. also monitors the condition of the water resources, which falls within the range of water resources factor (3). The condition of groundwater did not deteriorate in the reporting period. The studied entity is constantly improving technological solutions that contribute to reduced pollution (5). It modernized its production installations, thanks to which the emission of gaseous and dust pollutants into the air was reduced. In the analyzed document, the company referred to working conditions (8) as the only factor within the social element. The records show, that great importance was attached to the issue of safety and protection of health and life of the employees.

### 4.3. The links between SDGs and ESG elements in the Polish chemical companies

The third research question referred linking specific SDGs and ESG elements in the case of the chemical industry. The analysis of the sustainable development documents of the CIECH Group, the AZOTY Group and the ORLEN Group allowed to present these linkages in Table 4.

**Table 4.**
*The links between SDGs and ESG elements in the chemical companies*

| COMPANY NAME / ESG ELEMENTS | CIECH | AZOTY | ORLEN |
|---|---|---|---|
| Environmental | SDG 12 Responsible consumption and production<br>SDG 13 Climate action<br>SDG 15 Life on land | SDG 12 Responsible consumption and production<br>SDG 13 Climate action | SDG 12 Responsible consumption and production<br>SDG 13 Climate action |
| Social | SDG 2 Zero hunger<br>SDG 3 Good health and well-being<br>SDG 4 Quality education<br>SDG 5 Gender equality<br>SDG 6 Clean water and sanitation<br>SDG 7 Affordable and clean energy<br>SDG 8 Decent work and economic growth<br>SDG 9 Industry, innovation and infrastructure<br>SDG 11 Sustainable cities and communities | SDG 2 Zero hunger<br>SDG 4 Quality education<br>SDG 6 Clean water and sanitation<br>SDG 8 Decent work and economic growth<br>SDG 9 Industry, innovation and infrastructure | SDG 3 Good health and well-being<br>SDG 7 Affordable and clean energy<br>SDG 9 Industry, innovation and infrastructure<br>SDG 11 Sustainable cities and communities |
| Governance | SDG 17 Partnerships for the goals | - | - |
| **TOTAL** | **13** | **7** | **6** |

Note. Abbreviations used in the table: CIECH = CIECH Group, AZOTY = AZOTY Group, ORLEN = ORLEN Group.

Source: own study based on the documents of the analyzed chemical companies.

Table 4 presents specific SDGs in connection with three ESG elements according to the opinion of the author of the article. First of all, SDGs were assigned to the social element. But also many of them are related in scope to the environmental area. Only one SDG has been allocated to the governance element. Most SDGs have been identified in the CHECH Group documents. Other entities did not indicate goals other than the CIECH Group.

## 5. Discussion

This study contributes to the literature on sustainable development activities undertaken in companies and focuses on the chemical industry in Poland. The article presents answers to three research questions, one of which is about the key SDGs for the chemical companies, the other is about the ESG activities of the chemical companies, and the last one concerns the links between SDGs and ESG elements in the chemical companies.

The analysis of strategies and policies of the Polish chemical companies allowed to identify 13 key SDGs. All studied entities considered SDG 12 Responsible consumption and production. This is a goal closely related to the chemical industry, because it includes target 12.4, concerning the achievement of "the environmentally sound management of chemicals and

all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water and soil in order to minimize their adverse impacts on human health and the environment" (United Nations, 2015, p. 22). The great importance of SDG 12 in the chemical industry was also noticed in Nechita et al. (2020) research. Beyond the SDG 12, the following goals were also identified in this investigation among the key SDGs: SDG 2 Zero hunger, SDG 3 Good health and well-being, SDG 4 Quality education, SDG 5 Gender equality, SDG 6 Clean water and sanitation, SDG 7 Affordable and clean energy, SDG 8 Decent work and economic growth, SDG 9 Industry, innovation and infrastructure, SDG 11 Sustainable cities and communities, SDG 13 Climate action, SDG 15 Life on land and SDG 17 Partnerships for the goals. The list of 13 key SDGs is largely in line with ten priority SDGs for the chemical sector which were identified by the World Business Council for Sustainable Development (WBCSD, 2018). The main difference is that more SDGs have been identified in this study. However, the chemical sector, being one of the most diversified and complex of all industries, interacts with a wide number of SDGs. For example, the largest companies in the in the world, e.g. the BASF Group, or in Poland, e.g. the ORLEN Group, declare meeting all 17 goals, although only some are a priority for them. The results of this study are also in line with the studies of Mhlanga et al. (2018). Namely, they observed lack of consistency in how companies determine which SDGs to prioritize, e.g. some companies take an approach by prioritizing two or three SDGs, while others decide to engage with most of the goals (Mhlanga et al., 2018).

The analysis of reports of the Polish chemical companies allowed the discovery of countless activities related to three ESG elements and its 14 factors. However, there is a noticeable difference between the analyzed medium size company and other large integrated groups. Integrated groups disclosed information on all 14 ESG factors in their reports, while the smaller enterprise disclosed information on four factors, including three environmental and one social factor. In the analyzed period, most activities were observed in the environmental and social area. Noteworthy is the fact that, among the governance factors, integrated groups strengthened their ESG management structures, conducted a review of ESG factors or started analyzing the ESG level among the suppliers. This indicates an increased interest in ESG issues, which is consistent with the research by the Polish Chamber of Chemical Industry (PCCI, 2022). According to the PCCI publication, 71% of the surveyed chemical companies in Poland indicated that their business partners pay attention and put pressure on adaptation of ESG elements into the various documents (PCCI, 2022).

The results of the analysis of sustainable development documents, made it possible to find the links between specific SDGs and ESG elements in the chemical companies in Poland. Most SDGs were assigned to social and environmental areas. Only one SDG has been allocated to the governance element. The proposed links are largely consistent with the research results of Rockström and Sukhdev (2016), especially in the case of social and environmental elements. Both proposals, by Rockström and Sukhdev as well as by the author of this article, suggest

connecting the social area with the following SDGs: SDG 2 Zero hunger, SDG 3 Good health and well-being, SDG 4 Quality education, SDG 5 Gender equality and SDG 7 Affordable and clean energy. In turn, the environmental field was linked with SDG 13 Climate action and SDG 15 Life on land. Minor differences between the linkages proposed in this article and in the approach of Rockström and Sukhdev may result from the specificity of the chemical industry and from including the economic perspective by Rockström and Sukhdev.

## 6. Summary

In recent years, Poland has made progress in the field of sustainable development. For example, in 2020 Poland achieved a reduction of 35% in the emission of greenhouse gases, in relation to the base year level, what exceeded the level required under the Kyoto Protocol (GUS, 2022). Companies representing the chemical sector contributed to a large extent to this result. Therefore, it is justified to explore sustainable development activities undertaken in the chemical industry enterprises in Poland. Especially in the context of the new Corporate Sustainability Reporting Directive (Directive (EU) 2022/2464) that obliges some companies to report on sustainability. Through those reports, organizations provide a clear picture of undertaken sustainable development activities to the stakeholders. Among stakeholders there are investors for whom reports relating to ESG issues are becoming more and more important (PwC, 2022).

Firstly, the analysis of strategies and policies allowed to identify 13 key SDGs, wherein SDG 12 Responsible consumption and production, seems to be the most important for the Polish chemical companies. Secondly, analysis of the reports, allowed the discovery of numerous activities, undertaken by the studied entities, in the environmental, social and governance areas. Research has shown that large integrated entities develop ESG strategies and disclose ESG data in the reports, but this is still a challenge for smaller chemical companies, in Poland. Finally, the links between specific SDGs and ESG elements in the chemical sector were presented.

The paper contributes to the better understanding of the chemical companies' sustainable development activities, thus offering findings that are potentially useful for both theory and practice. From the point of view of the theory, the results provide a more complete view about the priority SDGs, ESG elements and links between them, in the context of the chemical industry. In terms of practical implications, the results could guide chemical companies in the development of their ESG strategies.

The article is not free from limitations. One of them concerns the research method used. The content analysis was limited to examining the strategies, policies and reports available on the websites of the studied chemical companies. The records contained therein certainly do not

show all the sustainable development activities carried out by the chemical industry enterprises in Poland. In future research, other materials published on websites, such as information on current events, could be analyzed. It would be also interesting for the author to extend the scope of the analysis to other industries, as it may provide a deeper understanding of the sustainable development activities.

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# CRITICAL SUCCESS FACTORS AFFECTING EFFICIENT MANAGEMENT OF THE NEW PRODUCT IMPLEMENTATION PROCESS AT RESEARCH ORGANISATIONS

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**Purpose:** Identification and selection of a set of critical success factors for a research organisation based on the evaluation conducted by managers of new product development processes at such organisations. Determination of factors that are of the utmost importance at the pre-development stage (so-called fuzzy front-end stage) and verification of the obtained results based on the case study of a successful new product implementation.
**Design/method/approach:** First, desk research was conducted, followed by a survey and a case study analysis.
**Conclusions:** The adequacy of the identified set of factors was confirmed (applicability of 90% of the selected factors was recognised). A number of additional success determinants of the new product development (NPD) process were specified. The importance of planning, tactical and organisational measures taken at the fuzzy front-end stage of the NPD process was confirmed. The crucial importance of identifying and verifying NPD process critical success factors was demonstrated.
**Research limitations/implications:** Possibility to expand the set of critical success factors for a research organisation, verification of the adequacy of the developed set based on other cases and types of technological solutions.
**Practical implications:** The study can serve as a reference for research organisations that want to verify the reasons for the success or failure of their implementation processes.
**Social implications:** The study can contribute to the implementation of standards and good practices concerning the NPD process implementation, which are directed at social participation and consideration of social needs during the processes of innovation development and implementation.
**Originality/value:** The study addresses the needs of teams involved in NPD processes, both at research organisations and in companies. The article provides important guidance to managers of NPD processes. It offers a comprehensive overview of critical success factors and identifies a set of good practices to improve the efficiency of the NPD process.

**Keywords:** critical success factors, CSF, new product development, NPD, commercialisation, research organisation.

**Category:** scientific article, case study.

## 1. Introduction

The generation of innovation ideas, i.e. the invention of new or improved solutions or discovery of alternative fields of use, may seem to be a crucial element of all new product development (NPD) processes at research organisations. However, in practice, this is only one of many milestones an organisation must reach to successfully commercialise its solutions. Research organisations that wish to maintain their competitive advantage and actively market innovations must be properly equipped to identify and verify critical success factors (CSFs) throughout the product development life cycle. The knowledge of the NPD process success factors may be particularly useful for R&D project managers and it can help them effectively plan the work of individual teams and make the right decisions about the implementation of innovative undertakings (even at an early stage), which are often crucial to the success of the entire project.

The literature discusses many impediments to the new product development process. The development of new innovations is most frequently hampered by technological barriers (Mazurkiewicz, Poteralska, 2016) and barriers of tactical nature (Mazurkiewicz et al., 2022) that adversely affect the cooperation between research organisations and end users of technological solutions as well as success of new product/technology implementation processes. However, many authors acknowledge that, in addition to identifying barriers to the NPD process, it is also possible to identify its critical success factors (Müller, Jugdev, 2012). The implementation of the NPD process may vary across industries and sectors. This is confirmed by relative abundance of publications centred around the identification of critical success factors for NPD processes per sector or product type (Almeida et al., 2020). This stems not only from external conditions (surrounding), but also from differences in the implementation of projects concerning development of new products based (to a greater or lesser extent) on new technologies. Additionally, there is a significant research gap – authors and practitioner fail to identify critical success factors for NPD processes at research organisations. This article assumes that critical success factors for NPD processes at research organisations and other entities differ due to the specificity of research organisations' operations and high innovativeness of the products they develop. Therefore, the article aims to select a set of critical success factors for research organisations, based on the evaluation conducted by managers of new product development processes at such organisations (institutes affiliated under the Łukasiewicz Research Network in Poland).

## 2. Method

For the purpose of this article, in order to determine critical success factors for NPD processes at research organisations, the "NPD process success" is defined as a full and timely implementation of a project, while maintaining at least minimum profitability (min. 5% gross margin).

To identify the set of CSFs for NPD processes, the authors conducted a literature review that covered articles published between 2010 and 2022 (they were selected using Google Scholar and Science Direct), as a result of which 35 most commonly discussed factors were indicated. The authors paid particular attention to the importance attached to each factor in individual market sectors. Factors selected as a result of the literature review were grouped and then assessed by 18 implementation project managers at research organisations. The survey (Google Forms) included factors of a universal nature (i.e. those that were most frequently listed with reference to the cases described) and factors indicated in the literature as crucial to the implementation of new technology-based products. The respondents represented 15 research organisations in Poland, including institutes affiliated under the Łukasiewicz Research Network. The survey was conducted with a view to selecting a final set of 10 critical success factors for NPD projects implemented by research organisations. The survey also included an additional question to identify those success factors that seem crucial, particularly with reference to the product pre-development stage, i.e. the fuzzy front-end stage. The selected success factor sets were then verified as part of the NPD process at a research organisation that ended with a successful implementation of a new product.

## 3. Literature review

New product development (NPD) can be defined as a set of measures taken by an organisation to develop a new, distinctive product tailored to the needs of end users. The NPD process is successful if end users want to try a new product and buy it again. Therefore, a team working on the development of an innovative product should check and consider how the market assesses the value offered by the product (Grunert, Trijp, 2014). The NPD process may be divided into three phases: fuzzy front-end (or project planning), product development, and commercialisation. (Gwo-Tsuen, Yuan, 2016). As regards practical implementation of NPD projects, a set of critical success factors (CSFs) is usually defined – critical success factors are considered the key elements an organisation needs to achieve certain goals (Pieterson, ICF, 2019). Critical success factors are also presented in the literature as conditions or variables that have a significant impact on the success of the project and real

impact on the success of the implementation of a product, provided that the measures taken by managers properly address such factors and ensure that they are present (Almeida et al., 2020).

Major NPD process success factors may be divided into the following three groups of factors: (1) technological factors (technology added value, cost reduction through technology use), (2) marketing factors (response to customers' needs, production time, profit, market share) as well as (3) management and commercialisation-related factors (price and margin management, additional investments in business model adaptation) (Walasik, 2013). Using the above-mentioned grouping, the factors are further classified in this article as technological, management and organisational (including marketing) factors.

The determination of critical success factors for an implementation project should also consider interdependencies between the factors identified. It is worth noting that the success of the NPD process depends on a number of factors, which can be interlinked, and that the evaluation of their importance should be holistic (Clarke, 1999).

The concept of the application of critical success factors for an NPD process at a research organisation is presented in Figure 1 below.

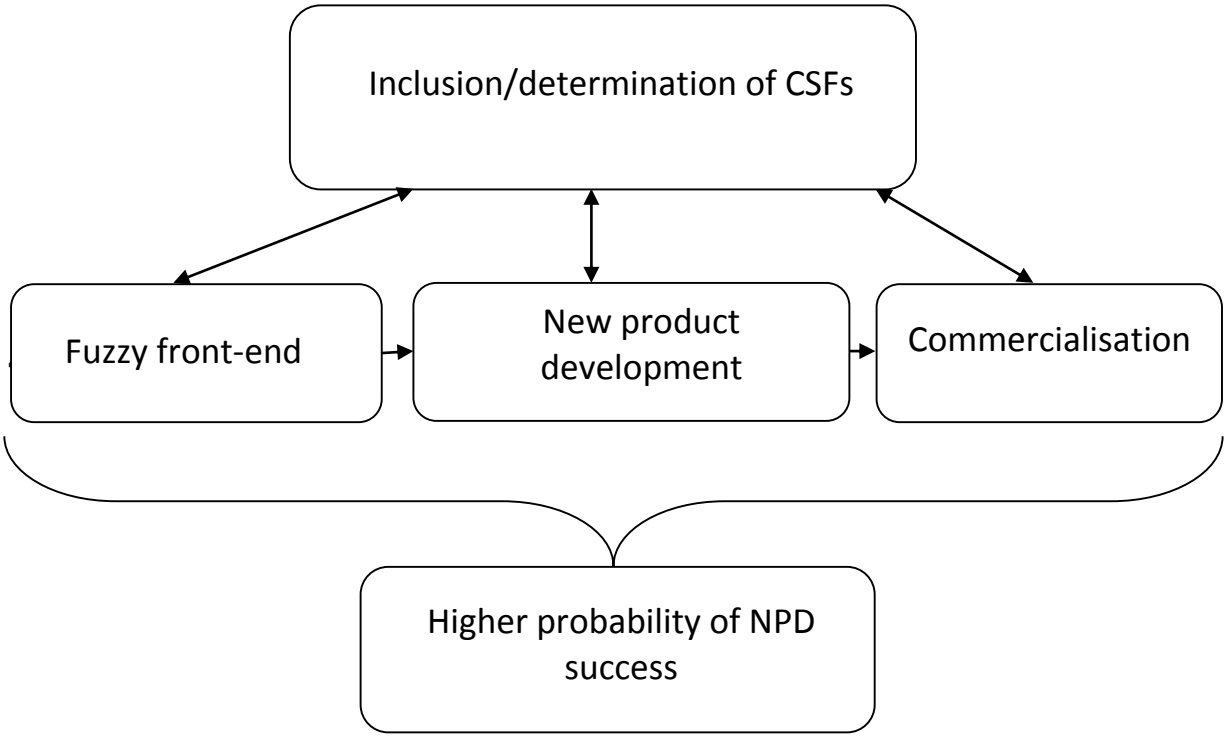


**Figure 1.** Visualised concept of increasing the probability of the NPD success by identifying and determining CSFs.

Source: Authors.

It should be noted that, while the correct identification of success factors at various stages of the NPD process can be crucial to the success of the implementation, the managers' impact on the creation of drivers may be limited; these factors may sometimes be completely beyond the control of the project team.

Table 1 presents the list of critical success factors identified through literature review per factor type.

**Table 1.**
*Critical success factors in the NPD process identified in the literature*

| Factor type | CSF | Source |
|---|---|---|
| organisational | team experienced in NPD project implementation | Florén et al., 2018 |
| | NPD process agility | Markham, Lee, 2013 |
| | provision of effective communication channels | Lindhard, Larsen, 2016 |
| | ensured flow of information in the IT system | Gal, Hadas, 2015 |
| | structured process of new product development | Markham, Lee, 2013 |
| | consideration of the risk and opportunity assessment at the planning stage | Dinu, 2016 |
| | consideration of lessons learned in the planning phase | Lindhard, Larsen, 2016 |
| | clearly specified roles and responsibilities | Dinu, 2016 |
| | market analysis | Cooper, 2011 |
| | creation of a business plan | Kornish, Hutchison-Krupat, 2017 |
| | application of verified project and risk management methods | Stanley, Uden, 2013 |
| | fixed priorities and resource allocation plans throughout the project | Buys, Stander, 2010 |
| | establishment of focus groups to validate ideas | Cooper, 2011 |
| | monitoring of financial and key performance indicators throughout the NPD process | De Souza, Lunkes, 2016 |
| | ongoing monitoring of progress vs. budget | Frow, Marginson, Ogden, 2010 |
| | product tailoring to individual needs of groups of customers | Walasik, 2013 |
| management | engagement of mangers | Dwivedi, Karim, 2021 |
| | compatibility of the project objective with the main objectives of the organisation | Florén et al., 2018 |
| | clearly set goals and measurable milestones | Dwivedi, Karim, 2021 |
| | engagement of experienced managers | Markham, Lee, 2013 |
| | effective product portfolio management | Kester et al., 2011 |
| | maintenance of reasonable headcount proportions in relation to the number of ongoing projects | Buys, Stander, 2010 |
| | compliance with codes of ethics throughout the NPD process | Gal, Hadas, 2015 |
| | motivating teams involved in the NPD process | PMBOK ,2013 |
| | enabling team competence development in line with the project requirements | PMBOK, 2013 |
| | evaluation of project-related benefits in relation to the organisation's strategic objectives | Breese, 2012 |
| | provision of funds in relation to the individual elements of the business plan | Serra, Kunc, 2015 |
| | periodic task progress reviews | Musawir et al., 2017 |
| | implementation of the marketing strategy based on market segmentation | Walasik, 2013 |
| | monitoring customer satisfaction throughout the NPD process | Walasik, 2013 |
| technological | application of new IT achievements to collect and verify ideas from groups/communities | Cooper, 2011 |
| | fair valuation of the benefits achieved through the use of technologies | Walasik, 2013 |
| | application of modern Big Data analysis methods in the commercialisation process | Gunasekaran, 2017 |
| | use of latest technological achievements to generate new product ideas | Wang, Zhang, 2020 |
| | modification of business models with new technologies | Walasik, 2013 |

Source: Authors.

The literature review enabled the authors to identify a set of CSFs for the NPD process (Table 1). The articles reviewed discuss various NPD success factors, and, while most of them are of a universal nature and can be used with reference to many products and technologies, their importance differs depending on the project or market sector. To identify a set of critical success factors for NPD processes at research organisations, the authors used a survey method. The questionnaire was sent out to implementation project managers at Polish research organisations. The survey was conducted to identify a set of 10 CSFs of the utmost importance to the success of the NPD process and 5 most important factors that are essential at the fuzzy front-end stage of the NPD process.

## 5. Discussion of survey results

The respondents were asked to evaluate the importance of the 35 selected factors with reference to the NPD process at their organisations, and based on their feedback a list of 10 CSFs with the highest level of importance to the NPD process was complied. The respondents most frequently identified the following factors as important:

Organisational factors:

- clearly specified roles and responsibilities,
- creation of a business plan,
- monitoring of financial and key performance indicators throughout the NPD process; and
- product tailoring to individual needs of groups of customers.

Management factors:

- clearly set goals and measurable milestones,
- maintenance of reasonable headcount proportions in relation to the number of ongoing projects,
- provision of funds in relation to the individual elements of the business plan; and
- periodic task progress reviews.

Technological factors:

- fair valuation of the benefits achieved through the use of technologies; and
- use of latest technological achievements to generate new product ideas.

The compiled list was sent out to the respondents who were asked to identify factors that, in their opinion, are crucial at the fuzzy front-end stage of the NPD process. The respondents indicated the following factors:

Organisational factors:

- consideration of the risk and opportunity assessment at the planning stage,
- creation of a business plan; and
- product tailoring to individual needs of groups of customers.

Technological factors:

- application of new IT achievements to collect and verify ideas from groups/ communities; and
- use of latest technological achievements to generate new product ideas.

From the survey results it follows that the respondents indicated three factors most crucial, in their opinion, to the success of the entire project and its fuzzy front-end stage. They are as follows: (1) creation of a business plan, (2) product tailoring to individual needs of groups of customers, and (3) use of latest technological achievements to generate new product ideas. Additionally, the respondents identified factors falling into all of the above-mentioned categories (Table 1) – organisational, management, and technological – as crucial to the success of the entire implementation project. However, it is apparent that the organisational and technological factors outweigh the management factors in the context of the fuzzy front-end stage of the NPD process.

The obtained results show that all above-listed categories of factors (i.e. organisational, management, and technological) are crucial to the success of the NPD process. In turn, failure to consider the indicated factors in the NPD process may delay project implementation, increase its total cost or ultimately lead to project failure. Additionally, the CSFs indicated as crucial to the success of the NPD process are largely dependent on the measures taken by managers and project teams.

The obtained results also confirm the paramount importance of the organisational, planning and strategic activities to be taken at the fuzzy front-end stage of the NPD process, in the case of which particularly crucial are the factors of an organisational nature as well as the very conceptualisation of the new product. The respondents appreciated the great possibilities new technologies offer with reference to the formulation and validation of new product concepts at the initial stages of the NPD process.

The analysis also allowed the authors to conclude that the effectiveness of any NPD process depends not only on the use of an appropriate implementation model, but also on the identification of relevant CSFs – in the form of conditions and practices facilitating successful implementation of a new product. The CSFs may vary from process to process and their importance may depend on the specificity of a given sector, industry or environment in which the organisation operates. However, a set of universal factors may be identified based on the case study analysis of successful implementation projects in a specific market sector or industry. Moreover, many analysed CSFs are dependent on the adopted management and organisational standards. This means that organisations can acquire certain universal skills with reference to the identification and creation of conditions conducive to successful and agile implementation

of NPD processes. The fact that some organisations are characterised by greater agility and capability as regards new product implementation seems to confirm this. The analysis allowed the authors to conclude that organisations' agility in conducting NPD processes depends on the competences of managers as well as on the ability of teams to verify and create factors facilitating successful implementation of NPD projects (i.e. critical success factors).

The authors decided to verify the adequacy of the selected set of critical success factors on the basis of the implementation by a research organisation of a new product employing membrane technologies.

## 6. Case study-based verification of selected CSFs Implementation of products employing innovative membrane technologies

Membrane technologies allow the design and manufacture of filtration materials tailored to a manufacturing entity's specific needs and filtration conditions. The use of unique filtration materials characterised by resistance to the deposition of biological, organic and inorganic contaminants present in the filtered media helps increase the efficiency of wastewater treatment processes, reduce the cost of regeneration of used operating fluids, and extend the service life of filtration materials.

Membrane techniques include microfiltration, ultrafiltration, nanofiltration, and reverse osmosis. Solutions employing membrane technologies are scalable – the use of a modular system facilitates the expansion of a membrane filtration station, ensures continuity of the process, and makes it possible to automate the operation of the membrane filtration station and to connect the station with other machines included in the manufacturer's machine park. Membranes' life is short due to chemical and thermal impacts and, once worn out, membranes need to be replaced to ensure continuity of the process. Innovative membranes were developed at a research organisation to increase the effectiveness of the regeneration of wastewater generated by various industries. The concept of innovative filtration materials was developed by a team of researchers that verified and tested existing materials, technologies and their fields of use.

For the solution developed, a sales model (traditional model, including membrane production and provision of the design, testing, construction, assembly, and material replacement services) was identified as the preferred model of commercialisation. A licensing model was identified as a second possible model of commercialisation (applicable to potential breakthroughs as regards operating features or methods of filtration material regeneration). In the course of the NPD process, CSFs were identified as part of the developed go-to-market strategy.

**Table 2.**
*Go-to-market plan for innovative products employing membrane technologies*

| Industries using membrane technologies | Manufacturers: Food industry | | | Coal mining industry | Tanneries |
|---|---|---|---|---|---|
| | Beverage manufacturers | Dairies | Manufacturers of other types of food | | |
| **Milestones** | • reaching potential interested end users<br>• need for filtration material regeneration/replacement<br>• little experience in working on commissioned projects<br>• no market recognition<br>• competitors – monopolistic market | | | | |
| **Critical success factors:** | **Measures taken – good practices:** | | | | |
| **OBJECTIVE 1. Comprehensive action plan** | • development of business model canvas<br>• schedule approval (in cooperation with employees)<br>• determination of milestones and KPIs<br>• determination of sources of financing for individual phases | | | | |
| **OBJECTIVE 2. Offer tailored to customers' needs** | • compilation of a list of potential clients<br>• interviews to determine whether the problem is significant enough for entrepreneurs to incur costs<br>• consideration of the profitability of the subcontractor's market position – contacts with the existing supplier of solutions<br>• determination of the preferred business models: design of solutions, development, subcontracting, projects | | | | |
| **OBJECTIVE 3. Information dissemination/educational activities** | • development of promotional materials<br>• traditional direct marketing methods (email, telephone, fairs)<br>• launching a campaign that will help reach specific businesses (at a national level) through various communication channels<br>• short educational video recording | | | | |
| **OBJECTIVE 4. Beating the competition** | • analysis of competitors' offers, determination of price ranges<br>• estimation of cost thresholds for standard undertakings (services price list) | | | | |
| **OBJECTIVE 5. Effective use of technologies** | • determination of technological challenges – search for and investment in further technology development<br>• search for inspiration (participation in industry events, membership of clusters, etc.)<br>• patent applications for new technological solutions (protection of intellectual property) | | | | |

Source: Reports by the Commercialisation Department at Łukasiewicz Research Network – Institute for Sustainable Technologies.

## 7. Benchmarking conclusions

As part of the analysis of the case study of a successful implementation of the NPD process at a research organisation, the authors identified all three (3) factors indicated by the respondents as crucial to the entire process and to the fuzzy front-stage, i.e.: (1) creation of a business plan, (2) product tailoring to individual needs of groups of customers, and (3) use of latest technological achievements to generate new product ideas. The first stage of implementation was centred around organisational (preparing and approving, in consultation with employees, a detailed schedule) and planning (defining milestones and KPIs) tasks and around the preparation of business model canvas. This also means the identification of the

following success factors: (1) clearly set goals and measurable milestones, (2) monitoring of financial and key performance indicators throughout the NPD process, and (3) clearly specified roles and responsibilities. Additionally, sources of financing were identified for individual stages of the schedule implementation (KPI: provision of funds in relation to the individual elements of the business plan). This was followed by the verification of the final product concept and possible business models (as a result of market consultations and contact with a competitor). The authors also determined the profitability of the selected commercialisation/implementation models, indicated risks, and proposed mitigating measures (KPI: consideration of the risk and opportunity assessment at the planning stage).

In line with the generally applicable management standards, the implementation project progress was monitored on an ongoing basis – weekly team meetings and quarterly reports reviewed by a relevant Director for Research Development. (KPI: periodic task progress reviews). The implementation process was monitored continuously to identify potential issues and shortages of resources (also human resources) – appropriate corrective measures were taken (KPI: maintenance of reasonable headcount proportions in relation to the number of ongoing projects – here work planned in the project). The developed solutions were valuated and contracts were reviewed in cooperation with the Commercialisation Department, and then approved by the Managing Director (KPI: fair valuation of the benefits achieved through the use of technologies).

Therefore, it can be stated that in the case analysed, most KPIs determined in the survey as crucial to the implementation project were identified. Only the "application of new IT achievements to collect and verify ideas from groups/communities" factor relating to the use of online solutions (forum, digital platform) and possibilities offered by Big Data analytical tools with reference to the verification of potential customers' needs was not identified. Therefore, in the case analysed it seems that end users of the developed solution are clearly specified, which means that membership of industry clusters, participation in thematic events, and the use of account-based marketing are far more effective to reach relevant market segments than market consultations. A comprehensive look at the implementation methods also allowed the authors to identify success factors other than those selected during the survey: (1) implementation of the marketing strategy based on market segmentation, (2) engagement of experienced managers, (3) engagement of mangers, (4) consideration of lessons learned in the planning phase, and (4) team experienced in NPD project implementation.

## 8. Summary

The analysis allowed the identification and verification of a set of 10 critical success factors (CSFs) for NPD processes at research organisations. CSFs indicated by the survey respondents proved adequate in the case of the implementation of products employing innovative membrane technologies (9 out of the 10 CSFs indicated by the respondents were identified). The study can serve as a reference for research organisations that want to verify the reasons for the success or failure of their implementation processes. The survey also confirmed the cardinal importance of planning, tactical and organisational measures taken at the fuzzy front-end stage of the NPD process and the significance of the identification and verification of critical success factors for NPD processes at research organisations, which – based on the collected data – can develop standards, good practices, and relevant project implementation methods. The analysis may also provide the basis for future studies directed, for example, at expanding the set of critical success factors or verifying the adequacy of the presented set for various cases and types of technological solutions.

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# INNOVATION PROCESS AT LOGISTICS SERVICES PROVIDERS: BARRIERS AND STIMULATION FACTORS

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**Purpose:** Dynamic changes in the logistics services industry are forcing Logistics service providers (LSPs) to implement innovations. In this area, there is a need for a better understanding of the process and the factors behind the successful implementation of innovations at LSPs. This study aims to discover stages in the innovation process at Logistics service providers and identify drivers for innovation implementation at LSPs.
**Design/methodology/approach**: The study used a two-step approach. The first stage is a systematic literature review following the procedure proposed by Tranfield, Denyer, and Smart (2003). The second stage was carried out using the Delphi research method.
**Findings:** The survey results show that the LSP innovation process consists of 8 steps. At each stage of the innovation process, undertaken activities were identified that were not recorded in the literature. A list of factors (barriers and stimulators) determining the process of implementing LSPs innovations was identified.
**Research limitations/implications**: Despite the value of research results and their contribution to knowledge, this research has some limitations. The limitation of this study is that it included experts from Poland. Therefore, it is recommended to repeat the survey with experts from different geographical locations, which will include experts from other countries and even continents, to obtain more general conclusions.
**Practical implications:** The results of the research can be used as a contribution to the improvement of activities in the field of implementation of the innovation process for companies from the logistics services industry willing to enter a higher level of implementation and offering of services.
**Originality/value:** The findings presented in this area can be treated as new research findings, thus a voice in the discussion that opens the possibility of further deeper exploration and inference.

**Keywords:** Innovation process, Logistics service providers (LSPs).

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

## 1. Introduction

Growing customer requirements, the struggle to gain a competitive advantage, continuous improvement of processes (e.g. inventory management process), or the search for cost reductions seem to stimulate the implementation by operators (3PL) and logistic integrators (4PL) of innovations and innovative solutions in the logistics service provided. According to Flint, Larsson, Gammelgaard, and Mentzer, knowledge about innovation in logistics is relatively small, hence we know little about the innovation of logistics service providers and innovation itself (Flint, Larsson, Gammelgaard, Mentzer, 2005). The authors state that logistics innovation is "all logistics-related services, from basic to comprehensive, which are perceived as new and helpful for a specific group of recipients (business partners or internal recipients)". They also point out that logistics innovations can be very simple or complex and can refer to small improvements to processes or services and the development of new services (Grawe, 2009). Similarly, Wallenburg and Lukassen point to the need for more intensive research in this area (Wallenburg, Lukassen, 2011).

On the other hand, Wagner and Sutter (Wagner and Sutter, 2012) emphasize that research into innovation in logistics services is still at an early stage of its recognition. Undoubtedly, a critical topic in innovation research, specifically innovation management, is the process of creating innovation by 3PL operators and 4PL integrators. The logistics industry includes many logistics service providers (LSPs) that provide logistics services to their customers (Delfmann et al., 2002). Globalizationa, outsourcing influenced the development of the logistics services industry, initially offering simple logistics services, for example, transport or warehousing services, to this day offering a wide range of services through logistics operators (3PL) offering combined and more complex logistics services (Selviaridis, Spring, 2007; Wagner, Sutter, 2012) and subcontracting and coordination by external LSPs (4PL) to other service providers (Win, 2008; Zacharia et al., 2011) (Cichosz, Wallenburg, Knemeyer, 2020).

The article aims to present the issue relating to the process of shaping innovation by logistics service providers in the logistics service of supply chains. The article presents selected results of the Delphi study covering the identified stages of the process of shaping innovation by logistics service providers (3PL, 4PL) and determinants stimulating and limiting the shaping of innovation by logistics service providers. The article is organized as follows. The first part describes the research methodology. Then the results of a systematic literature review and the Delphi study results were presented. The last part of the article summarizes the results and discusses the direction of future research.

## 2. Literature Review

### 2.1. Logistics innovations process

Undoubtedly, creating (shaping) innovations is important in the context of research related to innovation management. This process has become the subject of consideration of many researchers. Hence the literature offers various, often different views or interpretations of the concept of the process of innovation. For example, Griffin describes the process of innovation as "the process of developing, applying, activating, developing a creative idea and managing its maturation and decline (Griffin, 2004). A slightly different perspective of defining the concept of the process of innovation can be seen in the proposal of McGowan (McGowan, 1994), signalling that it is ”a continuous process that begins with noticing an opportunity, the need to satisfy it or a problem to be solved that aims to completion when a decision is made to implement a specific idea, selected from among many considered, and proceed to implementation”. The author proposed twelve stages that make up the innovative process, it is also worth mentioning that the author indicates the last stage as optional, and it does not mean resignation from starting works aimed at improvement. When considering the innovative processes presented in the literature, described as models, it should be emphasized that from the historical perspective, the first models characterizing the innovation process appeared in the early 1950s. The evolution of the innovation process models was presented in his concept by R. Rothwell (Rothwell, 1994).

However, concerning the research on the issue of the process of shaping innovation and its stages in logistics services provided by 3PL operators and 4PL logistics integrators, it should be emphasized that this issue appears exceptionally rare in the literature (da Mota Pedrosa, Blazevic, Jasmand, 2015). This sporadic research on this subject is clearly emphasized by Busse and Wallenburg (2011, pp. 187-218). Flint et al. focus on generating innovation by 3PL logistics operators from a process perspective (Busse, Wallenburg, 2011). Based on the systematic literature review, a small number of publications relating to the process of shaping innovation by logistics service providers were selected. Although the time range in the systematic literature review covered a longer period, the results of the query correspond to the conclusions of Buss and Wallenburg and are presented in Table 1.

**Table 1.**
*Stages of the innovation process (innovative forms of logistics services) by logistics service providers - results of a systematic literature review*

| Publication record<br>Author/s, year, keywords, country, geographic area of research | Proposed stages of the innovation process |
|---|---|
| Flint,<br>Larsson,<br>Gammelgaard,<br>Mentzer<br>2005<br>No keywords<br>Sweden, UK, USA | Four stages (phases):<br>- setting the stage activities (collecting ideas)<br>- customer clue-gathering activities<br>- negotiating, clarifying, and reflecting<br>- inter-organizational learning |
| de Mota Pedrosa,<br>Blazevic,<br>Jasmand<br>2015<br>Keywords:<br>Logistics innovation,<br>Microfoundations,<br>Knowledge<br>acquisition,<br>Customer contact<br>employees, Boundary-<br>spanning, Broad<br>knowledge, Deep<br>knowledge | Four stages (phases):<br>- idea generation - deepening knowledge<br>- concept development<br>- business analysis<br>- implementation |
| Björklund,<br>Forslund<br>2018<br>Keywords: Sustainable logistics,<br>Innovation process, Case study, Innovation<br>management<br>Sweden | Five stages (phases):<br>- generating ideas, including proactive problem / needs search<br>- selection of ideas<br>- concept development<br>- developing a business case for sustainable development<br>(separate stage)<br>- implementation and learning |

Source: own study.

In exploring the research of Flint et al., it should be emphasized that the authors, when analyzing innovations in the logistic operator-customer relationship, focused on the stage of generating ideas and concepts (Flint, Larsson, Gammelgaard, Mentzer, 2005). They assumed that the key role in the creation process is played by the interaction between process participants (i.e. the logistics operator and his client) and the analysis of how innovation affects the organizational structure, processes, or market opportunities of the enterprise - logistics operator. Based on the research conducted, Flint et al. developed a process of cooperation between the operator and the customer on logistics innovation, in other words, they focused on the operator's interaction with the customer and analysis of how the innovation affects the organization of the operator's operations. The innovation process proposed by the authors includes four Stages, the graphic form of the process is illustrated in Figure 1. In the proposed process stages, the authors distinguish:

- *setting the stage activities*, i.e. activities aimed at creating a favorable environment interacting with and listening to customers, and being an inspirational organization includes the very activities of collecting or analyzing data. These are planning and training activities which precede the collection of clues, data analysis and interpretation (etc.),
- *customer clue gathering activities*, i.e. managing customer groups, activities related to collecting customer guidance, i.e. managing customer groups, engaging in in-depth interviews with individual customers, conducting joint strategic planning meetings and outsourcing customer surveys (etc.),
- *negotiating, clarifying, and reflecting activities*, among others: joint efforts to internally negotiate the interpretation and implications of the client's voice, constantly explaining what was heard, exchanging ideas; clear interpretation - understanding the needs of the new client. Internal negotiations included choosing what information to convert into known organizational terms and what to leave in its original form for internal recipients, rethinking the implications of customer data and internally selling customer-related innovations. Reflection on the data obtained from the client (etc.),
- *inter-organizational learning* , i.e. new perceptions and understanding (common to LSPs managers and clients), joint learning of the operator and the client from the perspective of presenting different interpretations of the same data, as well as differences complementing data to the process, social interaction across organizational and functional boundaries enables the emergence of new opportunities (ect.).

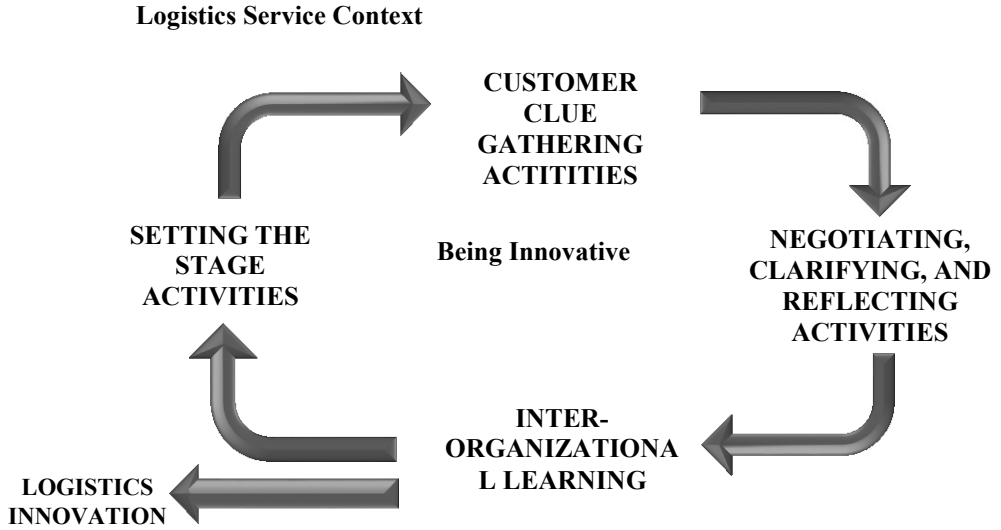


*Figure 1. A logistics innovation process.*

Source: own study based on: Flint, Larsson, Gammelgaard, Mentzer, 2005, pp. 113-147. https://doi.org/10.1002/j.2158-1592.2005.tb00196.x.

Therefore, the role of the logistics operator in the process of creating logistics innovation should focus on the use of own human resources (i.e. knowledge and skills), financial resources, and technical preparation in cooperation with the customer of a logistics innovation generating value for this customer (Flint, Larsson, Gammelgaard, Mentzer, 2005).

On the other hand, da Mota Pedrosa et al., Studied the actions and behavior of employees of 3PL logistics operators who have contact with the client in order to deepen and expand their knowledge about the future needs and expectations of clients, but also to engage clients in the development of innovation (da Mota Pedrosa, Blazevic, Jasmand, 2015). As a result, researchers identified key differences in the underlying patterns of customer-facing employees' acquisition of customer knowledge, suggesting that logistics service providers are able to find different ways to develop individualized and standard logistics innovations effectively. As a result of the research, the authors distinguished four Stages of the process of creating innovation, in which they mention (da Mota Pedrosa, Blazevic, Jasmand, 2015):

- *idea generation* – is one of the key stages in the authors' opinion. Meetings with customers' top managers enabled the identification of a logistics innovation need and prompted representatives of LSPs to perform activities that deepened customer knowledge during the idea generation stage;
- *business analysis* is a stage aimed at analyzing the potential success of innovation and deciding whether a change should be introduced; it included statistical analyzes carried out by the logistics operator, hence at this stage the surveyed companies resigned from engaging customers for active participation;
- *implementation*, the last stage involving the introduction of innovation and development of additional functions in order to improve it, thus improving.

Although the study covered a small research sample (six logistics service providers), the authors captured the perspective of different sequences in which employees engage in deepening and expanding knowledge about the customer depending on whether individualized or standard logistics innovations are developed. In conclusion, they emphasize that extensive research on the development of logistics innovations confirms that gaining knowledge about the customer is of key importance for successful logistics innovations (da Mota Pedrosa, Blazevic, Jasmand, 2015).

From a slightly different perspective, Björklund and Forslund (Björklund, Forslund, 2018, pp. 204-217) analyzed the aspects relating to the innovation process. The authors focused on researching the innovation process in sustainable logistics. According to the authors, describing the process with an indication of the stages provides a clear and sequential structure of the actions taking place, and forms a kind of "backbone" that plays an important structural role. Björklund and Forslund examined three logistic operators and three companies from various industries in the adopted method of multiple case studies. Based on the research, the authors distinguished the following five phases in the process of shaping innovation in sustainable logistics (Björklund, Forslund, 2018):

- *generating ideas* - including proactive searching for problems/needs of clients, interactions with clients play a key role in this phase, hence many internal stakeholders are involved,
- *selection of ideas* - important activities in this phase: speed, clearly selected criteria for choosing concepts and ideas,
- *concept development* - in this phase, the following activities and challenges were identified: first of all, the correct selection of teams, building trust with the logistics operator, as well as the development of simple concepts,
- *developing a business case* - this is a separate phase; it includes the following challenges: assessment of the economic, environmental, and social consequences of the innovation process in sustainable logistics, this stage is critical from the perspective of competing with other enterprises. Hence an important role is played by the assessment of financing and profitability of the implemented innovation,
- *implementation and learning* - sharing knowledge - in this phase, the speed of actions taken, and learning of the organization is emphasized, it is equally important to choose places for testing the developed process, i.e. companies can describe the diffusion of innovation, e.g. test them in the organization's departments or sister companies.

The authors conclude that the management of the innovation process in sustainable logistics may, on the one hand, contribute to reducing costs, but also to generating income. In addition, they indicate certain managerial challenges that need to be addressed. They are, among others involving customers to a greater extent and in several stages, more clearly informing about the selection criteria and conducting business case studies related to the issue of sustainable development in logistics. As the authors emphasize, the obvious direction of further research is to check the results of this study by replication on a larger sample. The study did not include producers, which, in the authors' opinion, seems to be an interesting area for further research (Björklund, Forslund, 2018).

Summing up the considerations about the process of shaping innovation by logistics service providers, it should also be emphasized that due to the nature of logistics services, innovation in logistics often arises not because of a formal plan or process, but as an "ad hoc" response to the customer's request (Wagner, Franklin, 2008). Moreover, the development of logistics innovations is a dynamic process that develops over time and requires companies to engage in various activities at different stages (Busse, Wallenburg, 2011).

As a result of the conducted systematic review of the literature, no studies dealing with the issues of the process of shaping innovation by enterprises operating in the form of a 4PL logistics integrator were identified in any of the selected publications. The author completed this research gap in the conducted empirical research.

After analyzing the above-specified scope of publications, for the purposes of the research carried out following DJ Flint et al., the concept *of the process of shaping innovation/innovative forms of logistics service of supply chains was adopted by 3PL operators and 4PL logistics integrators,* interpreting it as *a response to the customer's needs resulting from interaction with*

*the customer (group of customers) or identified own needs of the 3PL operator/4PL logistics integrator, covering a sequence of phases over time aimed at the implementation of innovation that generates value for the client (s) and/or the logistics service provider.*

Moreover, based on the results of research by Flint et al., Björklund, Forslund, and da Mota Pedrosa et al., In *the process of shaping innovation/innovative forms of logistics service of supply chains by 3PL operators and 4PL logistics integrators*, the following sequence:

- Stage 1 - preparation of an innovation implementation plan by the operator (3PL)/ logistics integrator (4PL),
- Stage 2 - collecting ideas,
- Stage 3 - choosing ideas,
- Stage 4 - sharing knowledge,
- Stage 5 - planning activities and resource use - concept development,
- Stage 6 - implementation of innovation - implementation - testing,
- Stage 7 - identification of gaps, planning, and implementation of improvement actions,
- Stage 8 - verification and evaluation of the achieved results of the implemented innovation.

The adopted definition and the distinguished stages of the process of shaping innovation/ innovative forms of logistics service of supply chains by 3PL operators and 4PL logistics integrators were the basis for designing a research tool and correct conclusions about its results.

### 2.2. Barriers and Drivers of Innovation in LSPs

The implementation of innovation (innovation process) at logistics service providers may be determined by numerous stimulating (motivating) factors or barriers limiting its success The issue of barriers and factors stimulating the implementation of innovations in the logistics services industry has already been raised by researchers. For example, Kandampully, in his research, analyzes the factors underlying the growth of logistics services and the emerging views on what constitutes a "resource" for service organizations (Kandampully, 2002). To this end, technology, knowledge, and relationship networks are examined as interdependent factors. The researcher argues that today's "resources" are the culmination of various advances in knowledge. The role of technology makes it easier to maintain a network of relationships with customers and partners inside and outside the company. The network of relationships makes the company's capabilities "amorphous" in nature. Chapman et al. in the conducted research, using industry examples, indicated factors supporting innovation in logistics services (Chapman et al., 2002). Researchers are looking for imperatives for innovation, and claim that: innovation is essential for logistics providers serving the market in the new economy, which they believe can be examined on the basis of three determinants of innovation in services. These factors, the authors, based on earlier research by Kandampully, describe them as "imperatives for innovation" in logistics services, identifying them as:

- technology,
- knowledge,
- relationship networks.

Table 2 presents the drivers of innovation and barriers to innovation in the logistics services sector (LPSs) identified during the systematic literature review.

**Table 2.**
*Factors and barriers determining the implementation of innovations in logistics services - selected results of a systematic literature review*

| **Factors driving innovation** | | **Barriers to innovation** | |
|---|---|---|---|
| **Author** | **Factor (s)** | **Author** | **Barriers/Limitations** |
| W. Zinn (1996) | • growing competition | A.J. Gellman (1986) | • legal regulations - ordinances<br>• impact of work - lack of human resourcesbrak innowacji wśród uczestników kanałów |
| R.L. Chapman et al. (2002) | • knowledge<br>• technology<br>• relationship networks | | |
| H. Håkansson G. Persson (2004) | • pooling resources in supply chains | | |
| **P.M. Panayides, M. So (2005)** | • learning the organization<br>• relationship orientation | A. Oke (2004, 2008) | • reactive versus proactive innovation<br>• specific clients<br>• ineffective knowledge transfer<br>• Inability to protect innovation with patents<br>• technology as the main source of innovation<br>• no effective development processes |
| D.J. Flint et al. (2005, 2008) | • learning the organization<br>• scope of teaching supply chain management<br>• scope of innovation management | | |
| S.M. Wagner (2008) | • training and education<br>• gaining of knowledge | B. Gammelgaard (2008) | • no long-term relationship<br>• information misuse and consumption of resources due to information sharing<br>• improper cooperation,<br>• no openness |
| C.W. Autry, S.E. Griffis (2008) | • structural capital<br>• relational capital<br>• the development of knowledge about the supply chain | | |
| S.J. Grawe et al. (2009) | • customer orientation<br>• focus on competition | A.V. Razzera, M.A. Machado (2017) | • bureaucracy, consensus, customs, culture, cost, adaptation without customer expectations, resistance to change, cooperation, sharing information, networking with partners, reducing costs, establishing relationships, customer knowledge, avoiding negotiations<br>• institutional work,<br>• budget and financial resources<br>• lack of understanding of the existing needs in terms of innovation |
| P. Daugherty et al. (2011) | • decentralization<br>• formalization | | |
| A.V. Razzera, M.A. Machado (2017) | • openness, communication, commitment, maturity, innovation profile, perseverance, planning, relationships<br>• information, networking with supply chain partners, crises, insight<br>• adjusting expectations, transparency | | |

Source: own study based on the results of a systematic literature review.

## 3. Methodology

The Delphi study is part of a research project carried out by the author, including research within the framework of a prepared doctoral dissertation. The research was carried out following the principle of triangulation and included a quantitative study (CATI, N = 201, preceded by a pilot study) and qualitative research, i.e. a case study and a Delphi study. A systematic review of the literature preceded empirical research according to the procedure proposed by Tranfield, Denyer, and Smart (Tranfield, Denyer, Smart, 2003), who indicate its three basic stages. In the first stage, a detailed literature review plan was defined, the aim of the research was determined and research questions were formulated. The second stage included the selection of primary literature, the selection of publications for analysis, and the development of the publication database. The second stage of the systematic literature review focused on the following activities: selecting digital full-text databases and defining the scope of database searches (full-text databases such as DOAJ, Emerald Insight, JSTOR, ScienceDirect, Scopus® were selected. , Springer Nature Journals and Wiley). The publications available in the Polish BazEkon and CeOn database were also analyzed, and the EBSCO Discovery Service tool was used to search for publications in order to improve the research process). The bibliometric analysis stage, including publication count analysis and citation analysis, was performed using tools available in the following selected full-text databases: Springer (Citations.Springer.com), Scopus® (CiteScore), and scholar.google.com databases. The third step is to present the results of the review (treated as a report). In the systematic literature review, the time range for the analysis of publications from 1990-2021 was adopted.

The Delphi method was used considering that it consists of structuring the process of group communication, which enables a group of independent people to jointly solve a complex problem (Linstone, Turoff, 1975). It can be used to estimate the time interval of events, phenomena, or states and to analyze and study the existing reality. The universal nature of the Delphi method favors its use both for research in the field of social and economic life, as well as in science and technology (Sudoł, 2016). The Delphi study has already been used in similar research, for example, research on creating innovation in third-party logistics (TPL) provider–customer relationships Stephan M. Wagner, Reto Sutter (2012) or research by Gossler, T., Falagara Sigala et al. (2019) presenting best practices of aid agencies for outsourcing logistics to commercial logistics service providers (LSPs) in disaster relief. In the Delphi study, a sequence of six steps was adopted (following the sequence proposed by Matejun, 2012). In the first stage, the concept of the Delphi study was developed. The first step at this stage was to formulate the research problem and adopt the research objectives, which were, among others:

- *characterizing the process of shaping innovative forms of logistics service for supply chains by operators (3PL) and logistic integrators (4PL),*
- *identifying and classifying determinants of the process of creating innovative forms of logistics services in modern supply chains.*

In the second stage, the study was prepared, with the following planned: time frame of the study, rules of communication with experts, sending invitations to participate in the study, and selecting a group of experts. The Delphi study was conducted from May 2021 to mid-June 2021. The experts were contacted by electronic means (e-mail) when sending invitations to participate in the study and in the actual study. Following experts' anonymity rules, correspondence was sent individually to the e-mail address of each expert. Although there are no specific criteria for selecting experts in the Delphi study (Hasson, Keeney, 2011; McKenna, 1994), it seems obvious that the knowledge and experience of the participants in the study determine the credibility of the results of the Delphi study (Hasson, Keeney, 2011). Experts are people working (scientists, representatives of business practice) in a given field (area) and having significant knowledge of the studied issue (McKenna, 1994, Powell). The selection of the expert group was preceded by establishing the selection criteria (K), which were formulated as follows:

- K1: scientists recognized as authorities, deliberately selected for their expertise related to the topic under study,
- K2: managing managers in enterprises from the logistics sector in Poland,
- K3: supply chain managers, especially responsible for outsourcing logistics services,
- K4: specialists who are members of an organization associating forwarders and logistics specialists (PISIL, The Polish International Freight Forwarders Association) and/or the Polish Logistics Association (PTL).

Based on the adopted criteria, a list of 15 experts who were invited to participate in the study was prepared. In response, consent was obtained for participation in the study from 11 experts, who were: representatives of the world of science - eminent experts on the issues discussed, representatives of practice - occupying the highest and managerial positions in enterprises providing logistics services for supply chains (who are also members of organizations indicated in the selection criteria), as well as logistics customer service specialists. The final list of experts participating in the study was drawn up on this basis. The structure of the division into groups of experts is presented in Figure 2. The first group includes representatives of the world of science, they accounted for 54.5% of the respondents. The second group consisted of business community representatives (45.5%).

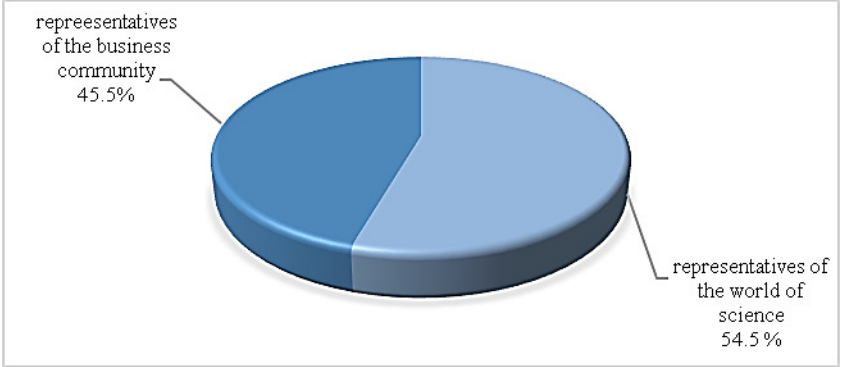


**Figure 2.** Structure of the expert group in the Delphi study.

Source: own study based on the results of the Delphi study.

This division made it possible not only to capture opinions from different perspectives but also to confront the views of two circles, leading to the development of a consensus on the phenomena studied.

As Hogarth (Hogarth, 1978) signals, the number of 6 to 12 expert group members is optimal for implementing the Delphi method. It should also be emphasized that the literature also indicates that 11 to 50 experts most often participate in the Delphi research, such a position is expressed by Diamond, Grant Feldman, Pencharz, Ling, Moore, Wales (2014).

The third stage covered the research in the first round, in which the Delphi questionnaire was sent to selected experts. As mentioned earlier, in order to preserve the anonymity and sovereignty of the opinions expressed by experts, individual contact with each of the experts was used via electronic means (e-mail).

Then, in the fourth stage, initial conclusions were drawn after receiving the experts' responses. Preliminary results of the analysis of the received responses (opinions) of the experts were prepared, which were included in the developed second questionnaire of the Delphi study (feedback) so that in the second iteration, each of the experts again referred to the studied issues. The literature selected in the systematic literature review was again used in order to develop the second-round Delphi questionnaire properly.

The fifth stage was focused on commencing activities in the next iteration - the implementation of the second round of the study. Another questionnaire (the second) was sent, and as a result, experts' responses were obtained, which allowed for obtaining convergent opinions (consensus). Hence the number of iterations has been exhausted. Obtaining a consensus with this number of rounds would be impossible if the proper selection of experts was neglected. It seems important to signal that we will not find a unified position among researchers regarding the number of rounds in the Delphi study. Most Delphi studies consist of two or three rounds (Diamond et al.). Hence, it was assumed that two rounds will be carried out in the study.

In the sixth stage, the responses received from experts participating in the second round of the study were analyzed. They formed the basis for the smooth implementation of the seventh stage. The seventh, and last stage focused on developing the final analysis of the results, which was prepared using the Microsoft Excel 2019 spreadsheet. Based on the analysis, conclusions were drawn and the completed Delphi study was summarized.

## 4. The process and determinants of shaping innovation by logistics service providers - results of the Delphi study

The study focused on obtaining expert opinions on achieving the goal, which was to *characterize the process of shaping innovative forms of logistics service for supply chains by operators (3PL) and logistics integrators (4PL)*. Hence, taking into account the views of experts obtained in the first iteration (first round), in the last round of experts, the opinions were asked to obtain a consensus on this area. Experts gave their opinion on which of the indicated stages should be considered a necessary and therefore extremely important stage, which can be indicated as optional, and which of them should be indicated as redundant. The results of the analysis, including the collected views of experts, therefore the consensus in this area is presented in Table 3.

**Table 3.**
*Stages of the process of shaping innovative forms of logistics service for supply chains*

| **(The process of shaping innovative forms/services/solutions in the field of logistics services)** | | | |
|---|---|---|---|
| **Stages of the process of shaping innovative forms in logistics services** | **Number of expert opinions** | | |
| | **Essential stage** | **Optional stage** | **Stage redundant** |
| Stage 1 - Preparation of a plan (project/concept) for the implementation of innovation by the operator (3PL) and logistics integrator (4PL) (problem identification; identification of stakeholders (recipients/recipients) of the innovation - internal or/and external innovation (related to the client/clients); identification of "drivers" - stimulators of innovation implementation. involvement of the top management from the planning stage (design) to implementation and scaling; involvement of human resources, the appointment of divisions/departments/employees for the implementation of planned activities) | 10 | 1 | 0 |
| Stage 2 - Generating ideas (collecting ideas within the organization, i.e. at the 3PL operator and 4PL logistics integrator; identification of the needs of stakeholders; characterization of the producer's needs; analysis of customer / s expectations; analysis of the competition's offer, industrial and/or development research; participation in conferences; membership in research consortia (networks); searching for available solutions, collecting data) | 7 | 4 | 0 |

Cont. table 3.

| | | | |
|---|---|---|---|
| Stage 3 - Specifying and selecting innovations/ideas for innovations (analysis of the collected ideas; analysis of the collected data; analysis and risk assessment; selection of innovation - meetings, and involvement of appointed teams/departments - stakeholder parties, determination of an acceptable level of investment in innovation; determination of the time frame to implemented innovations; personalization of comprehensive logistics services (taking into account changes taking place on the TSL market) | *8* | *3* | *0* |
| Stage 4 - Knowledge sharing (inter-organizational learning - i.e. using the customer's perspective to jointly learn from the logistics operator (3PL) / integrator (4PL) and the customer; knowledge transfer both between organizations and within the operator and customer organization; sharing good practices and previous experience in implementing innovations) | 7 | 4 | 0 |
| Stage 5 - Planning activities and use of resources (meetings and involvement of appointed teams/departments - stakeholder parties; identification of possessed and necessary resources to use: human (knowledge and skills), financial, infrastructural, IT, ICT; matching own capabilities to the needs (e.g. . IT system, technical possibilities; planning the schedule of activities carried out in the implemented innovation) | 10 | 1 | 0 |
| Stage 6 - Implementation of innovation (implementation of activities according to the adopted schedule; monitoring of activities and activities undertaken, implementation of innovation) | 7 | 4 | 0 |
| Stage 7 - Gap identification, planning, and implementation of improvement actions (meetings of appointed teams, meetings, and involvement of appointed teams/departments - stakeholder parties in order to identify existing / possible gaps/problems; controlling, improving the idea, improving) | 10 | 1 | 0 |
| Stage 8 - Verification and evaluation of the achieved results of the implemented innovation (s) (monitoring; data collection: parties - stakeholders; meetings and involvement of appointed teams/departments - stakeholder parties in order to summarize and verify the achieved results, involvement of the top management; analysis of the actual effects (including financial) by the parties involved) | 7 | 4 | 0 |

Source: own study based on the results of the Delphi study.

Referring to the expert opinion results presented in the table above, it should be noted that the vast majority of experts agreed in expressing their views on the sequence of stages in the process of shaping innovation, innovative solutions, solutions in logistics services. In the opinion of experts, each of the stages is necessary or slightly assessed as optional. Moreover, the experts did not indicate that any stage could be considered redundant. It is also worth adding that in this respect, there were slight differences in views between the opinions of experts representing the world of science and the opinions of representatives of business practice. These differences were related to the expressed views on the *optional stages*, which were indicated in the vast majority of economic practice representatives, except for the first stage assessed as *optional* by an expert representing the world of science.

Then, the focus was on achieving another goal of the Delphi study, which was to *identify and classify the determinants of creating innovative logistics services in modern supply chains*. In this area, experts were asked for opinions on the extent to which the indicated factors stimulate and limit 3PL operators and 4PL logistics integrators in implementing innovations

(innovative services/solutions) in the logistics service of supply chains. A scale from 0% to 100% was adopted for individual factors, where 0% - does not stimulate at all, and 100% - stimulates the maximum. A strong, and thus considered significant, level of the impact of individual factors indicated by experts was adopted according to criteria including the scale of the impact degree from 50% to 100%. The stimulating and limiting factors groups are divided into internal and external factors. Table 4 presents groups of factors stimulating operators and logistic integrators in implementing innovations.

**Table 4.**
*Determinants stimulating operators (3PLs) and logistic integrators (4PLs) to implement innovations (innovative services/solutions) in the logistics service of supply chains*

| **A group of stimulating factors** | | |
|---|---|---|
| **Category of factors**<br>**Internal factors** | **%**<br>**experts** | **The degree of influence (%) in the opinion of experts** |
| Organization level | **45.45%** | 90% |
| | **36.36%** | 80% |
| | 18.18% | 70% |
| Structural changes | **45.45%** | 90% |
| | **18.18%** | 80% |
| | **18.18%** | 70% |
| | 9.09% | 60% |
| | 9.09% | 50% |
| Financial conditions | **36.36%** | 90% |
| | **36.36%** | 80% |
| | 18.18% | 50% |
| | 9.09% | 60% |
| Resources owned | **18.18%** | 100% |
| | **27.27%** | 90% |
| | **18.18%** | 80% |
| | **36.36%** | 70% |
| Learning between organizations | 9.09% | 100% |
| | 9.09% | 90% |
| | 9.09% | 80% |
| | 9.09% | 70% |
| | **18.18%** | 60% |
| | **36.36%** | 50% |
| **External factors** | **% of experts** | **The degree of influence (%) in the opinion of experts** |
| Customer requirements | **27.27%** | 100% |
| | **45.45%** | 90% |
| | 9.09% | 80% |
| | 18.18% | 70% |
| Industry requirements | **18.18%** | 100% |
| | **36.36%** | 90% |
| | **18.18%** | 80% |
| | 9.09% | 70% |
| | 18.18% | 60% |
| Globalization and internationalization | 9.09% | 100% |
| | **18.18%** | 90% |
| | **54.55%** | 80% |
| | 9.09% | 70% |
| | 9.09% | 60% |

Cont. table 4.

| | | |
|---|---|---|
| Requirements of suppliers - cooperators | 9.09% | 100% |
| | **36.36%** | 90% |
| | **27.27%** | 80% |
| | **27.27%** | 60% |
| Pro-ecological requirements | 9.09% | 100% |
| | **36.36%** | 90% |
| | **27.27%** | 70% |
| | **27.27%** | 60% |
| Political conditions | 9.09% | 100% |
| | **18.18%** | 90% |
| | 9.09% | 80% |
| | 9.09% | 70% |
| | **18.18%** | 60% |
| | **27.27%** | 50% |
| | 9.09% | 20% |
| The growing role and pace of process (technological) and product innovations | 9.09% | 100% |
| | **36.36%** | 80% |
| | **36.36%** | 70% |
| | 18.18% | 60% |
| Competition | **18.18%** | 90% |
| | **63.64%** | 80% |
| | 9.09% | 60% |
| | 9.09% | 50% |
| Availability of financial support | **54.55%** | 80% |
| | **45.45%** | 70% |
| Increased interest in sustainable development | 9.09% | 90% |
| | **18.18%** | 80% |
| | **18.18%** | 60% |
| | **27.27%** | 50% |
| | **27.27%** | 40% |

Source: own study based on the results of the Delphi study.

Considering the expert opinions, the conclusion can be drawn to the most important internal and external factors motivating 3PL operators and 4PL logistics integrators to create and implement innovations. In the group of internal factors, the following factors should be distinguished:

- related to *the level of organization* - understood as the adopted assumptions, goals for further development, as well as openness to the adaptation and implementation of innovative solutions, for example, personalized services, or new services for the markets or industries served, etc. (from 36% to 45% of experts indicated the degree of impact in the range between 80% and 90%),
- *structure change* - read in a positive sense (decentralization, centralization, mergers, acquisitions, strategic alliances) (from over 18% to over 45% of experts indicated the degree of influence from 70% to 90%),
- *financial conditions* - own financial resources, as well as the possibility of obtaining support from financing institutions, is an internal stimulating factor, the degree of impact of which at the highest level of 80% and 90% was indicated by over 36% of experts.

- *resources* - technological resources (technology and information flow, including the availability of IT and ICT solutions and openness to sharing information) as well as human resources (human resources, personnel qualifications), as well as knowledge and experience (also certificates, licenses, " know-how ") (the degree of impact at the level of 70% was assessed by over 36% of experts, the level of 100% of the impact was indicated by over 18% of experts),
- *learning between organizations* - interpreted as organizational learning, relationship orientation, openness to learning of both top management and lower-level employees, as well as openness in establishing partnerships (cooperation - relationship networks) (over 36% indicated the degree of impact at the level of 50%, over 18% of experts assessed the degree of impact at the level of 60%, the highest level of impact from 70% to 100% was emphasized by almost 10% of experts). It is also worth mentioning that the experts did not indicate the lowest thresholds for the level of influence (from 0% to 40%) for any internal factor.

The most important in the group of external factors stimulating 3PL operators and 4PL logistics integrators in creating innovations (innovative forms, services) in logistics services, experts indicated *competition*. Competition is understood as activities of other competitive enterprises on the local, regional, and industry market, as well as new trends and solutions appearing on the market, as well as striving to achieve a competitive advantage (and focusing on the high quality of services provided). Over 63% of experts indicated this factor's impact at 80%, and almost 19% of experts assessed its stimulating effect at the level of 90%. Interestingly, a slightly smaller group of experts, i.e. about 10%, assessed the motivating influence of *the competition factor* at the level of 50% and 60%.

A significant external factor indicated by a group of over 54% of experts is the factor related to *globalization and internationalization,* the impact of which was assessed by experts at the level of 80%. A smaller group of experts (over 18%) indicated the motivating impact *of globalization of internationalization* at 90%.

Equally high, almost similar, indications of experts can be observed in assessing the impact of factors such as customer and *industry requirements*. Almost 30% of experts indicated the highest degree of impact of the *customer requirements factor expressed at the level of 100%.* A much larger group of experts, over 45%, assessed the impact of this factor at the level of 90%, and less than 10% of experts indicated the 80% level of impact. In turn, the impact of the factor *industry requirements* was assessed by 18.8% of experts at the level of 100% and 80%. On the other hand, the most numerous group of experts (36.6%) indicated the stimulating effect of this factor at the level of 90%.

*Availability of financial support* is another external factor stimulating the innovative activities of 3PL operators and 4PL logistics integrators, indicated by a large group of experts. The impact of this factor was assessed by over 54% of experts at the level of 80%. On the other hand, the level of 70% of the impact in relation to this factor was indicated by almost 46% of experts.

As shown by the results of the study, equally important external factors inspiring to innovation, in the opinion of experts, are also:

- *pro-ecological requirements* (the growing importance and awareness of the implementation of pro-ecological actions by 3PL operators and 4PL logistics integrators, as well as pro-ecological policy (legislation and policy in the field of safety and environmental protection of the EU) (over 36% of experts indicated the impact at the level of 90%, over 27%, impact at the level of 60% and 70%),
- *political conditions* (over 18% of experts indicated the impact at the level of 90% and 60%),
- *the growing role and pace of process (technological) and product innovations* (strong impact at the level of 70%, 80%, and 100%),
- *increased interest in sustainable development* (over 27% of experts indicated the impact at the level of 50% and 40%).

When examining the group of limiting factors and their impact on implementing innovations by 3PL operators and 4PL logistics integrators, they were also divided into two categories, internal and external factors. The results of the analysis of the collected opinions of experts in the area of identified key internal factors (including their impact) are presented in Table 5.

**Table 5.**

*Restrictive external and internal factors and their negative impact in shaping innovation by 3PL operators and 4PL logistics integrators*

| External factor (restrictive) | The degree of influence of the factor | | | | | | | | | Internal (limiting) factor | The degree of influence of the factor | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 100% | 90% | 80% | 70% | 60% | 50% | 40% | 30% | 20% | | 100% | 90% | 80% | 70% | 60% | 50% |
| | % of expert opinions | | | | | | | | | | % of expert opinions | | | | | |
| Customer requirements | **36%** | **18%** | **9%** | **18%** | **9%** | 0% | 0% | 9% | 0% | Organization structure | 9% | **27%** | 0% | 9% | 9% | **45%** |
| Crises: Epidemiological | **18%** | **27%** | **36%** | 0% | 0% | 9% | 9% | 0% | 0% | | | | | | | |
| Legal conditions | **18%** | **27%** | **27%** | **9%** | **9%** | 0% | 0% | 9% | 0% | | | | | | | |
| Unstable political and economic situation | **18%** | **18%** | **18%** | **18%** | **18%** | 0% | 9% | 0% | 0% | | | | | | | |
| Cyber attacks; terrorist attacks | **9%** | **18%** | **9%** | **36%** | **18%** | 0% | 0% | 9% | 0% | Related to resources | 0% | **27%** | **45%** | 9% | 0% | 0% |
| Global market requirements | **18%** | **9%** | **18%** | **27%** | **9%** | **18%** | 0% | 0% | 0% | | | | | | | |
| Related to the attitude of logistics service providers - subcontractors | **9%** | **27%** | 0% | **27%** | 9% | **27%** | 0% | 0% | 0% | | | | | | | |
| Diversified access to resources | 0% | **18%** | **36%** | **36%** | 9% | 0% | 0% | 0% | 0% | Economic/financial conditions | 0% | **36%** | **27%** | 9% | 0% | 0% |
| Ecological requirements | 0% | **18%** | **9%** | **18%** | **36%** | **9%** | 0% | 0% | 9% | | | | | | | |
| Intercultural aspects | 0% | **9%** | **9%** | 0% | **27%** | **27%** | 18% | 9% | 0% | | | | | | | |

Source: own study based on the results of the Delphi study.

The highest indications of experts in relation to the group of internal factors limiting the development of innovations (innovative forms, solutions) by 3PL operators and 4PL logistics integrators, according to experts, are:

- conditions *related to resources (impact at the level of 80%)*, more specifically human resources, including the lack of qualified staff, the reluctance of employees to self-improve, or the growing costs of employee maintenance, etc.,
- *economic/financial conditions* - according to experts, these conditions should be associated with the lack of financial resources of 3PL operators and 4PL integrators, thus the lack of the possibility of financing innovations/innovative solutions and investing in research and development. In this aspect, experts also indicated high costs of searching for and implementing innovations (impact at the level of 90%),
- *organizational structure* - defined by experts as "rigid" structures, centralization, and the inability to individualize activities and development of a branch/sector (limiting impact at the level of branch/unit).

In the group of external factors, experts distinguished a much larger spectrum of barriers, also pointing to their limiting influence in shaping innovation by 3PL operators and 4PL logistics integrators. The factor related to customer requirements is the first factor indicated by experts with a high degree of influence (adequately in terms of the degree of influence at the level from 60% to 100%). In the group of external factors limiting innovative activities with a strong level of influence (the percentage of indications of the degree of influence on a scale from 60% to 100%), the experts distinguished the following factors:

- *legal conditions* relating to tax and fiscal changes; differences in regulations/legal directives in different countries and regions (e.g. EU); changes in customs law (including Brexit),
- *epidemiological crises,* including historical and contemporary crises (in the opinion of experts, e.g. swine flu, avian flu, SARS-CoV-2 pandemic, etc.; economic; migration; natural disasters, natural disasters),
- *unstable political and economic situation, requirements of the global market, and cyber attacks - terrorist attacks.*

Moreover, among the equally important external factors, the following determinants were indicated in the opinions of experts that have an extremely destimulating effect on the creation of innovative initiatives by 3PL operators and 4PL logistics integrators:

- *the attitude of logistics service providers - subcontractors,* therefore, in the opinion of experts, means resistance to change, to sharing information, creating networks with partners, to establishing relationships, sharing knowledge with clients/partners, avoiding negotiations (lack of openness, reluctance to establish long-term relationships; inappropriate cooperation),

- *diversified access to resources,* meaning, in the opinion of experts, human resources, IT resources, technical and technological resources - IT gap - a gap in access to IT/ICT solutions in different regions, countries, etc.),
- *intercultural aspects*, interpreted as multiculturalism, different customs on domestic and international markets,
- *environmental requirements*, commented by experts as restrictions on the introduction of innovations related to environmental protection as a barrier, including differentiation in terms of national, and international legal regulations in the field of environmental protection.

Summing up, it should be noted that the vast majority of experts indicated a more substantial influence of external factors, both stimulating and limiting the innovative activity of 3PL operators and 4PL logistics integrators. The spectrum of factors indicated by experts representing the scientific community and business practice, therefore from the perspective of two environments, is an extremely valuable contribution to the theoretical research conducted so far, the results may also be of interest to representatives of business practice.

## 5. Discussion and conclusions

The identified and classified list of factors determining the process of creating and implementing innovations and innovative forms (solutions, services) by 3PL operators and 4PL logistics integrators in the logistics service of supply chains will undoubtedly change. Hence, the catalog of identified and classified determinants should be treated as open. The shape of the list, including the emergence of new factors or the exclusion of individual factors, will most likely be influenced by globalization and internationalization, as well as progressing digitization (including the development of new technologies). It should also be assumed that the strength and direction of the impact of individual factors will also change. It is worth noting that this area is still valid and is a valuable insight for science, knowledge, and practice in general.

Based on the results of the study, activities in the process of shaping innovative logistics services were identified, and its stages were characterized. As indicated earlier in the research results published so far, fragmentary and often selective discussion on the implementation of the process of shaping innovation by logistics service providers (for example the previously mentioned research by Björklund and Forslund) was noted. Hence, the findings presented in this area can be treated as new research findings, thus a voice in the discussion that opens the possibility of further deeper exploration and inference.

The results and conclusions from the conducted research lead to the formulation of implications for economic practice. The research conclusions confirm that logistics service providers should demonstrate a high level of awareness that today's customers are increasingly demanding. Logistics service providers should be aware that customers expect proper logistics service and that logistics companies will follow the dominant trends in technology, pro-ecological activities, and the scale of services provided. Logistics service providers should be open to the "voice of the customer" and its role in creating innovation to obtain information on customer needs and preferences and their opinions on the services and solutions offered. In this way, logistics service providers will obtain key information in creating various types of innovations, including, in particular, the directions of improving the services offered.

Despite the value of the research results and their contribution to knowledge, the research has some limitations. The limitation of this study is that it covered experts from Poland. Hence, the direction of further research is recommended to repeat or even extend the research in new contexts. For example, they can be experts from various geographic locations that will cover other countries and even continents to produce more generalized conclusions.

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# FUNCTIONING OF REAL-TIME ANALYTICS IN BUSINESS

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**Purpose:** The goal of the paper is to analyze the main features, benefits and problems with the real-time analytics usage.
**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 paper focus on the advantages and disadvantages of real-time analytics. The ability to process and analyze data in real-time allows organizations to quickly identify trends and patterns, optimize their operations, and allocate resources more efficiently. Additionally, real-time analytics helps businesses identify new revenue opportunities and optimize their pricing strategies, monitor user behavior, detect security threats, and react without delay. However, real-time analytics can be expensive to implement, require technical expertise, and generate false positives. Proper data quality, security measures, and system scaling are also essential for effective implementation. The vague definition of real-time and the requirement to collect detailed requirements from all stakeholders can also present challenges to businesses.
**Originality/value**: Detailed analysis of all subjects related to the problems connected with the real-time analytics.

**Keywords:** Industry 4.0; business analytics, data analysis, real-time analytics, predictive analytics.

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

## 1. Introduction

Real-time analytics refers to the practice of collecting and analyzing data in real-time or near real-time, as it is generated. This approach enables organizations to monitor and respond to events as they occur, allowing for faster and more informed decision-making.

Real-time analytics typically involves the use of advanced technologies such as high-speed data processing, complex event processing (CEP), machine learning algorithms, and artificial intelligence (AI) to collect, process, and analyze data as quickly as possible. The approach

enables organizations to gain insights faster, respond to events more quickly, and make better decisions based on the most up-to-date data available.

The goal of the paper is to analyze the main features, benefits and problems with the real-time analytics usage.

## 2. Descriptive analytics - definitions

Real-time analytics has become an increasingly important tool for organizations across industries, as it enables them to quickly and efficiently process and analyze large amounts of data as it is generated. This approach has numerous benefits, including faster and more informed decision-making, improved operational efficiency, and the ability to monitor and respond to events in real-time (Hwang et al., 2017).

Real-time analytics can also help organizations improve their operational efficiency. By monitoring and analyzing data in real-time, organizations can identify areas where they can optimize their operations, reduce waste, and improve overall efficiency. For example, a logistics company might use real-time analytics to track the movements of its vehicles, enabling it to optimize delivery routes and reduce fuel costs (Hurwitz et al., 2015).

The real time-analytics can be defined as follows (Patanjali, 2018; Nourani, 2021; Sharma et al., 2020):

- Real-time analytics refers to the use of data analytics to analyze data in real-time or near real-time, allowing organizations to make decisions and take actions quickly based on current data.
- Real-time analytics is a form of data analysis that enables the processing and analysis of data as soon as it is generated, allowing for immediate insights and action.
- Real-time analytics is the practice of analyzing and interpreting data as it is generated, allowing for immediate responses to changing conditions or events.
- Real-time analytics involves using sophisticated algorithms and advanced computing technologies to process and analyze data in real-time, providing instant insights into business operations and customer behavior.

Real-time analytics is useful to enable organizations to monitor and respond to events as they occur. This is particularly useful in industries such as healthcare, where real-time monitoring of patient data can help medical professionals identify potential health issues and respond to them quickly. Real-time analytics can also be used to detect and respond to security threats in real-time, helping organizations prevent data breaches and other cybersecurity incidents (Cam et al., 2021).

To implement real-time analytics effectively, organizations must have the right tools and infrastructure in place. This includes high-speed data processing systems, complex event processing (CEP) tools, and machine learning algorithms. Organizations must also have a solid understanding of their data and be able to identify the key insights that they need to monitor in.

Described method is a powerful tool that can help organizations across industries gain valuable insights, improve operational efficiency, and respond to events more quickly. By leveraging the latest technologies and best practices in data analysis, organizations can use real-time analytics to stay ahead of the competition and achieve their goals more effectively (Greasley, 2019).

When an organization want to implement real-time analytics it can be done according to following steps (Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023):

- Data collection: Real-time analytics requires collecting data from various sources in real-time or near real-time. This data can come from IoT sensors, social media feeds, website interactions, or other sources.
- Data processing: Once data is collected, it must be processed and cleaned to remove any noise or errors. This can involve data cleansing, normalization, and transformation to ensure the data is accurate and consistent.
- Real-time data analysis: With the clean data, real-time analytics algorithms and models can be applied to the data to generate insights and predictions. These insights can be used to make decisions or trigger automated actions in real-time.
- Visualization and reporting: The insights generated by real-time analytics need to be presented in an easy-to-understand format for decision-makers. This can involve creating visualizations, dashboards, or reports that display the most relevant information and KPIs.
- Actionable insights: The final step in real-time analytics is taking action based on the insights generated by the analysis. This can involve making changes to business operations, customer interactions, or other areas of the organization to improve outcomes and achieve business objectives.

It is also worth to mention about main differences between real-time analytics and more advances method of business analytics which calls predictive analytics (table 1). The main important differences between them are (Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023):

- Timing: Real-time analytics focuses on analyzing data in real-time or near real-time, while predictive analytics uses historical data to make predictions about future outcomes.

- Purpose: Real-time analytics is typically used to monitor and optimize ongoing operations in real-time, while predictive analytics is used to forecast future outcomes and make strategic decisions.
- Data sources: Real-time analytics relies on data from real-time or near real-time sources such as sensors or social media feeds, while predictive analytics uses historical data to make predictions about future outcomes.
- Analytical techniques: Real-time analytics relies on techniques such as streaming analytics, complex event processing, and machine learning to analyze data in real-time, while predictive analytics uses statistical and machine learning models to analyze historical data and make predictions.
- Outputs: Real-time analytics produces immediate insights and alerts based on real-time data, while predictive analytics produces forecasts, scenarios, and models that can be used to make strategic decisions.

Real-time analytics and predictive analytics are complementary techniques that can be used together to provide a comprehensive view of business operations. Real-time analytics provides insights into ongoing operations in real-time, while predictive analytics provides strategic insights and forecasts based on historical data. Both techniques are important for organizations looking to optimize operations, improve outcomes, and stay ahead of the competition.

**Table 1.**
*Comparison of real-time analytics and predictive analytics*

| | Real-time analytics | Predictive analytics |
|---|---|---|
| Timing | Real-time or near real-time | Historical |
| Purpose | Monitor and optimize ongoing operations | Forecast future outcomes and make strategic decisions |
| Data sources | Real-time or near real-time sources such as sensors or social media feeds | Historical data |
| Analytical techniques | Streaming analytics, complex event processing, machine learning | Statistical and machine learning models |
| Outputs | Immediate insights and alerts based on real-time data | Forecasts, scenarios, and models based on historical data |

Source: Authors own work on the basis of: (Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023).

Real-time analytics plays a critical role in Industry 4.0, which is characterized by the increasing digitization and automation of industrial processes (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023). We can distinguish some methods real-time analytics can be used in Industry 4.0 (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021):

- Predictive maintenance: Real-time analytics can be used to monitor machines and equipment in real-time, allowing organizations to identify potential issues before they become major problems. By collecting and analyzing data on machine performance, organizations can identify patterns and anomalies that may indicate impending failures or maintenance needs.
- Quality control: Real-time analytics can be used to monitor and analyze production processes in real-time, allowing organizations to quickly detect and address quality issues. By analyzing data on product quality and production parameters, organizations can identify patterns and trends that may indicate quality issues, allowing them to take corrective action before products are shipped (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).
- Supply chain optimization: Real-time analytics can be used to monitor and optimize supply chain processes, allowing organizations to respond quickly to changes in demand and supply. By analyzing data on inventory levels, production schedules, and customer demand, organizations can identify potential bottlenecks or supply chain disruptions and take corrective action in real-time.
- Energy management: Real-time analytics can be used to monitor and optimize energy consumption in industrial processes, allowing organizations to reduce energy costs and improve sustainability. By analyzing data on energy consumption and production processes, organizations can identify opportunities to optimize energy use and reduce waste (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021).
- Safety and security: Real-time analytics can be used to monitor and detect potential safety and security threats in industrial processes. By analyzing data on machine performance, employee behavior, and environmental conditions, organizations can identify potential safety or security issues and take corrective action in real-time.

Real-time analytics is a key enabler of Industry 4.0, allowing organizations to optimize industrial processes, improve efficiency, and reduce costs. By leveraging the latest technologies and best practices in data analysis, organizations can use real-time analytics to gain valuable insights and achieve their goals more effectively.

## 3. Benefits and problems of descriptive analytics usage

Very important advantages of real-time analytics is its ability to provide organizations with up-to-date insights into their operations. By collecting and processing data in real-time, organizations can quickly identify trends and patterns, allowing them to respond to events more quickly and effectively. This is particularly useful in industries such as finance, where even small delays in decision-making can have significant consequences Sharma et al., 2020, Wolniak, 2013, 2016; Hys, Wolniak, 2018). Real-time analytics offers numerous benefits to organizations across industries. By leveraging the latest technologies and best practices in data analysis, organizations can use real-time analytics to gain valuable insights, improve efficiency, and achieve their goals more effectively.

On the basis of the literature analysis following advantages of real-time analytics can be distinguished (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023; Tucci, 2019):

- Real-time analytics allows organizations to process and analyze data as it is generated, providing them with up-to-date insights into their operations. This enables faster and more informed decision-making, allowing organizations to respond to events more quickly and effectively.
- Described approach can help organizations identify areas where they can optimize their operations, reduce waste, and improve overall efficiency. For example, a manufacturing company might use real-time analytics to monitor the performance of its machines, enabling it to identify potential issues and make adjustments in real-time.
- Real-time analytics can help organizations better understand their customers and their needs, enabling them to provide more personalized and effective service. For example, an e-commerce company might use real-time analytics to track customer behavior on its website, enabling it to provide targeted recommendations and promotions based on their interests and preferences.
- Method described in the paper can help organizations identify new revenue opportunities and optimize their pricing strategies. For example, a retailer might use real-time analytics to monitor demand for certain products and adjust prices in real-time to maximize revenue.
- This type of analytics can help organizations allocate resources more effectively, enabling them to make better use of their time, money, and personnel. For example, a healthcare provider might use real-time analytics to monitor patient data and allocate resources more efficiently based on patient needs.

- Real-time analytics can help organizations detect and respond to security threats in real-time, enabling them to prevent data breaches and other cybersecurity incidents. For example, a financial institution might use real-time analytics to monitor transactions and detect potential fraud in real-time.
- Real-time analytics enables businesses to react without delay, quickly detect and respond to patterns in user behavior, take advantage of opportunities that could otherwise be missed and prevent problems before they arise.
- Businesses that utilize real-time analytics greatly reduce risk throughout their company since the system uses data to predict outcomes and suggest alternatives rather than relying on the collection of speculations based on past events or recent scans - as is the case with historical data analytics.
- Real-time analytics provides insights into what is going on in the moment.
- Data visualization. Real-time data can be visualized and reflects occurrences throughout the company as they occur, whereas historical data can only be placed into a chart in order to communicate an overall idea.
- Improved competitiveness. Businesses that use real-time analytics can identify trends and benchmarks faster than their competitors who are still using historical data. Real-time analytics also allows businesses to evaluate their partners' and competitors' performance reports instantaneously.
- Precise information. Real-time analytics focuses on instant analyses that are consistently useful in the creation of focused outcomes, helping ensure time is not wasted on the collection of useless data.
- Lower costs. While real-time technologies can be expensive, their multiple and constant benefits make them more profitable when used long term. Furthermore, the technologies help avoid delays in using resources or receiving information.
- Faster results. The ability to instantly classify raw data allows queries to more efficiently collect the appropriate data and sort through it quickly. This, in turn, allows for faster and more efficient trend prediction and decision making

Besides many advantages the real-time analytics usage has also some disadvantages and problems. Among them the most important are (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023; Tucci, 2019):

- Real-time analytics can be expensive to implement, as it requires specialized hardware and software, as well as highly skilled data scientists and engineers. Organizations must be willing to invest in these resources to achieve the benefits of real-time analytics.
- Real-time analytics requires a high level of technical expertise, as it involves complex data processing and analysis. Organizations must have the right skills and resources in place to effectively implement and maintain real-time analytics This method relies on accurate and reliable data, and if data quality is poor, it can lead to inaccurate insights

and decisions. Organizations must have processes in place to ensure that data is accurate and up-to-date, and that data sources are properly integrated.

- Real-time analytics systems must be able to scale to handle large volumes of data and users. Organizations must have a plan in place for scaling their systems as their needs grow, to ensure that they can continue to support real-time analytics effectively.
- When we used described type of analytics systems must be properly secured to prevent data breaches and other cybersecurity incidents. Organizations must implement appropriate security measures, such as encryption, access controls, and monitoring, to protect their data and systems.
- Real-time analytics systems can sometimes generate false positives, alerting users to potential issues that are not actually problematic. This can lead to wasted time and resources, as well as reduced trust in the system. Organizations must have processes in place to properly validate alerts and ensure that they are accurate before taking action.
- One major challenge faced in real-time analytics is the vague definition of real time and the inconsistent requirements that result from the various interpretations of the term.
- As a result, businesses must invest a significant amount of time and effort to collect specific and detailed requirements from all stakeholders in order to agree on a specific definition of real time, what is needed for it and what data sources should be used.
- The implementation of a real-time analytics system can also present a challenge to a business's internal processes.
- The technical tasks required to set up real-time analytics - such as creation of the architecture - often cause businesses to ignore changes that should be made to internal processes.
- Enterprises should view real-time analytics as a tool and starting point for improving internal processes rather than as the ultimate goal of the business.
- Companies may find that their employees are resistant to the change when implementing real-time analytics.

## 4. Example of descriptive analytics usage in business

Real-time analytics can be used in a variety of industries and use cases, such as (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023):

- E-commerce - real-time analytics is used in e-commerce to track website traffic, monitor purchasing behavior, and optimize promotions and pricing in real-time. For example, online retailers can use real-time analytics to monitor website traffic, analyze customer behavior, and make product recommendations based on their browsing history.
- Financial services - real-time analytics is used in financial services to monitor financial transactions, detect fraud, and identify anomalies in trading activity. For example, banks and other financial institutions can use real-time analytics to detect fraudulent transactions in real-time and respond to them quickly.
- Healthcare - real-time analytics is used in healthcare to monitor patient health data in real-time, alerting medical professionals to potential health issues and allowing for faster interventions. For example, hospitals can use real-time analytics to monitor patient vital signs and detect changes in health status, enabling them to provide timely interventions and improve patient outcomes.
- Transportation - real-time analytics is used in transportation to track vehicle movements, optimize route planning, and monitor driving behavior in real-time. For example, logistics companies can use real-time analytics to monitor the location of their vehicles, optimize delivery routes, and reduce fuel costs.
- Manufacturing - real-time analytics is used in manufacturing to monitor the performance of machines and optimize production processes. For example, factories can use real-time analytics to detect potential issues with their machines and make adjustments in real-time to minimize downtime and improve efficiency.
- Marketing - real-time analytics is used in marketing to track customer behavior and optimize advertising campaigns in real-time. For example, marketers can use real-time analytics to monitor the effectiveness of their campaigns and make adjustments in real-time to maximize ROI.
- Energy - real-time analytics is used in the energy sector to monitor energy consumption, predict demand, and optimize energy production. For example, utilities can use real-time analytics to monitor energy consumption in real-time and predict future demand based on historical data, weather patterns, and other factors.
- Sports - real-time analytics is used in sports to monitor player performance, track game statistics, and provide real-time insights to coaches and players. For example, sports teams can use real-time analytics to track player movements on the field, monitor their heart rate and other biometric data, and make adjustments in real-time to improve performance.
- Telecom - real-time analytics is used in the telecommunications industry to monitor network performance, detect anomalies, and optimize network capacity. For example, telecom companies can use real-time analytics to monitor network traffic and identify potential issues, such as dropped calls, before they affect customers.

- Agriculture - real-time analytics is used in agriculture to monitor crop health, predict yields, and optimize irrigation and fertilization. For example, farmers can use real-time analytics to monitor soil moisture levels, detect crop diseases, and adjust irrigation and fertilization in real-time to maximize crop yields.
- Gaming - real-time analytics is used in gaming to monitor player behavior, track game performance, and optimize in-game experiences. For example, game developers can use real-time analytics to monitor player behavior in real-time, adjust game difficulty levels, and provide personalized recommendations to improve player engagement.

The real-time analytics can be also used in many area of an organization. Especially there are many potential usages of this approach in quality management. We can mention about following potential usage of this types of analytics in quality management (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023; Cam et al., 2021):

- Real-time analytics is used in manufacturing to monitor product quality and detect defects as they occur. For example, sensors can be placed on production lines to monitor temperature, pressure, and other factors that can affect product quality. Real-time analytics can then be used to identify patterns in the data and alert quality control teams to potential issues.
- This type of analytics is used in the food and beverage industry to monitor product quality and safety. For example, temperature sensors can be used to monitor the temperature of food products during transportation and storage. Real-time analytics can then be used to identify potential quality issues and take corrective actions before products are shipped to customers.
- Real-time analytics is used in healthcare to monitor patient outcomes and improve the quality of care. For example, hospitals can use real-time analytics to monitor patient vital signs and detect changes in health status. Real-time analytics can then be used to alert medical teams to potential issues and provide timely interventions to improve patient outcomes.
- Real-time analytics is used in software development to monitor code quality and detect defects early in the development process. For example, software development teams can use real-time analytics to monitor code commits, track bug reports, and identify potential issues before they become larger problems.
- Described analytic method is used in retail to monitor product quality and customer satisfaction. For example, retailers can use real-time analytics to monitor customer feedback on social media and other channels, identify potential issues with products, and take corrective actions to improve customer satisfaction.

## 5. Conclusion

The paper discusses real-time analytics, which is a form of data analysis that allows organizations to process and analyze data as it is generated. It provides immediate insights, enables faster decision-making, improves operational efficiency, and helps in monitoring and responding to events in real-time. To implement real-time analytics, organizations need the right tools and infrastructure, including high-speed data processing systems, complex event processing tools, and machine learning algorithms. The process involves data collection, processing, real-time data analysis, visualization and reporting, and actionable insights. Real-time analytics is different from predictive analytics in terms of timing, purpose, data sources, analytical techniques, and outputs. Real-time analytics is used for ongoing operations, while predictive analytics is used for forecasting future outcomes and making strategic decisions. Both techniques are complementary and can be used together to provide a comprehensive view of business operations.

The paper also focus on the advantages and disadvantages of real-time analytics. The ability to process and analyze data in real-time allows organizations to quickly identify trends and patterns, optimize their operations, and allocate resources more efficiently. Additionally, real-time analytics helps businesses identify new revenue opportunities and optimize their pricing strategies, monitor user behavior, detect security threats, and react without delay. However, real-time analytics can be expensive to implement, require technical expertise, and generate false positives. Proper data quality, security measures, and system scaling are also essential for effective implementation. The vague definition of real-time and the requirement to collect detailed requirements from all stakeholders can also present challenges to businesses.

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# SMART MOBILITY IN SMART CITY – COPENHAGEN AND BARCELONA COMPARISION

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**Purpose:** The goal of the paper is to analyze the main differences between the smart mobility idea implementation in Copenhagen and Barcelona.
**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 papers compares the smart mobility solutions implemented in Copenhagen and Barcelona, two cities that have developed comprehensive and innovative transportation systems. While both cities have sustainable, efficient, and convenient transportation systems, they differ in their focus and governance structure. Copenhagen is a leading city in sustainable transportation, with a strong focus on cycling infrastructure and an integrated public transportation system. On the other hand, Barcelona focuses on reducing traffic congestion and improving air quality, with innovative solutions such as a low-emission zone and a smart parking system. Additionally, Copenhagen has a highly centralized governance structure, while Barcelona adopts a more decentralized approach, engaging citizens and stakeholders in transportation decision-making.
**Originality/value**: Detailed analysis of differences between Copenhagen and Barcelona in the case of smart mobility implementation.

**Keywords:** Smart City, smart mobility, smart biking, sustainability, cycling.

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

## 1. Introduction

Smart mobility plays a crucial role in smart cities by providing efficient and sustainable transportation solutions that meet the needs of residents and visitors while reducing congestion, improving air quality, and enhancing quality of life. Smart mobility solutions are designed to optimize the use of transportation infrastructure and resources through the use of technology and data.

One of the primary goals of smart mobility in a smart city is to promote sustainable transportation modes such as cycling, walking, and public transportation, and to reduce dependence on single-occupancy vehicles. This can be achieved through the development of cycling infrastructure, bike-sharing schemes, and integrated public transportation systems that make it easy for people to get around the city.

The goal of the paper is to analyze the main differences between the smart mobility idea implementation in Copenhagen and Barcelona.

## 2. Smart Mobility in Smart City

Smart mobility involves the use of technology to improve the efficiency of transportation systems. For example, smart traffic management systems can use real-time data to monitor traffic flow and adjust traffic lights to optimize traffic flow and reduce congestion (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023, Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). Similarly, smart parking systems can use sensors to detect available parking spaces and direct drivers to the nearest available spot, reducing the time spent looking for parking and minimizing congestion (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022; Wolniak, 2013, 2016; Hys, Wolniak, 2018).

In addition to improving transportation efficiency, smart mobility solutions can also enhance safety and accessibility (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021). For example, intelligent transportation systems can provide real-time information to pedestrians and cyclists about potential hazards or delays, while also providing real-time information to public transportation users about delays or service disruptions (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023).

## 3. Smart Mobility solutions in Copenhagen

Copenhagen is one of the leading cities in the world when it comes to smart mobility solutions. The city has a long-standing commitment to sustainable transportation and has implemented a range of innovative initiatives to promote cycling, walking, and public transportation while reducing car dependency and improving air quality (Bjørner, 2021).

One of the key smart mobility solutions used in Copenhagen is the development of cycling infrastructure. The city has invested heavily in building a network of dedicated bike lanes and cycle paths, making it easy and safe for cyclists to navigate the city. The city's bike-sharing scheme, which allows residents and visitors to rent bikes for a small fee, has also been hugely successful and has contributed to the growth of cycling as a primary mode of transportation in the city (Cenre, 2017).

Another smart mobility solution used in Copenhagen is the integration of public transportation systems. The city has a comprehensive network of buses, trains, and metro lines that are integrated into a single ticketing system, making it easy and convenient for residents and visitors to use public transportation. The city has also introduced real-time information displays at bus and train stops, allowing passengers to see exactly when the next bus or train is due (Eltved et al., 2021).

Copenhagen has also implemented a range of smart traffic management solutions to reduce congestion and improve traffic flow. The city's intelligent traffic management system uses real-time data to monitor traffic flow and adjust traffic lights to optimize traffic flow and reduce congestion. The city has also introduced a smart parking system that uses sensors to detect available parking spaces and directs drivers to the nearest available spot, reducing the time spent looking for parking and minimizing congestion (Doost, Rezaie, 2020).

In addition to these initiatives, Copenhagen has also introduced a range of smart mobility solutions to enhance safety and accessibility. The city has introduced pedestrian and cyclist detection systems at key intersections, alerting drivers to the presence of pedestrians and cyclists and reducing the risk of accidents. The city has also introduced a range of accessibility initiatives, including low-floor buses and tactile paving for visually impaired pedestrians (Bager, Mundaca, 2021).

Copenhagen's smart mobility solutions are focused on promoting sustainable transportation modes, improving transportation efficiency, and enhancing safety and accessibility. The city's commitment to sustainable transportation has not only improved the quality of life for residents, but it has also positioned Copenhagen as a leader in the global effort to reduce greenhouse gas emissions and combat climate change (Copenhages, 2020).

In the table 1 there is a description of realization of main factors of smart mobility concept realization in Copenhagen. The city's investment in cycling infrastructure has created a dedicated network of bike lanes and cycle paths, which has contributed to the growth of cycling as a primary mode of transportation in the city. The integration of public transportation systems has made it easy and convenient for residents and visitors to use public transportation,

and the use of real-time information displays has improved the user experience. The city's smart traffic management system and smart parking system have helped to reduce congestion and improve traffic flow, while the introduction of pedestrian and cyclist detection systems has enhanced safety and accessibility for vulnerable road users (Mortensen et al., 2020).

**Table 1.**
*Main factors of smart mobility in Copenhagen*

| Factor | Realization |
|---|---|
| **Cycling Infrastructure** | Copenhagen has invested heavily in building a network of dedicated bike lanes and cycle paths, making it easy and safe for cyclists to navigate the city. The city's bike-sharing scheme, which allows residents and visitors to rent bikes for a small fee, has also been hugely successful and has contributed to the growth of cycling as a primary mode of transportation in the city. |
| **Public Transportation Integration** | Copenhagen has a comprehensive network of buses, trains, and metro lines that are integrated into a single ticketing system, making it easy and convenient for residents and visitors to use public transportation. The city has also introduced real-time information displays at bus and train stops, allowing passengers to see exactly when the next bus or train is due. |
| **Smart Traffic Management** | Copenhagen's intelligent traffic management system uses real-time data to monitor traffic flow and adjust traffic lights to optimize traffic flow and reduce congestion. The city has also introduced a smart parking system that uses sensors to detect available parking spaces and directs drivers to the nearest available spot, reducing the time spent looking for parking and minimizing congestion. |
| **Safety and Accessibility** | Copenhagen has introduced pedestrian and cyclist detection systems at key intersections, alerting drivers to the presence of pedestrians and cyclists and reducing the risk of accidents. The city has also introduced a range of accessibility initiatives, including low-floor buses and tactile paving for visually impaired pedestrians. |
| **Sustainable Transportation Promotion** | Copenhagen's smart mobility solutions are focused on promoting sustainable transportation modes, including cycling, walking, and public transportation. The city has also introduced incentives for sustainable transportation, such as a congestion charge for drivers entering the city center, which has helped to reduce car dependency and improve air quality. |

Source: Authors own work on the basis of: (Bjørner, 2021; Cenre; 2017; Eltved et al., 2021; Doost, Rezaie, 2020; Bager et al., 2021; Copenhagen, 2020; Mortensen et al., 2020).

In the table 2 there is an analysis of main advantages and problems in implementation of smart mobility solutions in Copenhagen.

**Table 2.**
*Comparison of advantages and problems of implementing smart mobility in Kopenhagen*

| Advantages | Problems |
|---|---|
| Promotes sustainable transportation modes such as cycling, walking, and public transportation | Limited space for expanding cycling infrastructure and public transportation systems |
| Reduces car dependency and improves air quality | Resistance from some residents and businesses to changes in transportation infrastructure and systems |
| Increases transportation efficiency and reduces congestion | High cost of implementing smart mobility solutions |
| Enhances safety and accessibility for pedestrians and cyclists | Need for ongoing maintenance and upgrades to smart mobility systems |
| Positions Copenhagen as a leader in sustainable transportation and climate action | Limited resources and funding for implementing smart mobility solutions |

Source: Authors own work on the basis of: (Bjørner, 2021; Cenre; 2017; Eltved et al., 2021; Doost, Rezaie, 2020; Bager et al., 2021; Copenhagen, 2020; Mortensen et al., 2020).

## 4. Smart Mobility solutions in Barcelona

Barcelona is a city that has been at the forefront of innovation in smart mobility solutions. The city has implemented a range of initiatives aimed at promoting sustainable transportation and reducing congestion, including bike-sharing schemes, electric vehicles, and a network of smart parking systems (Eicher, 2020).

Barcelona has implemented a bike-sharing scheme, known as Bicing, which allows residents and visitors to rent bikes for a small fee. The scheme has been highly successful and has contributed to the growth of cycling as a primary mode of transportation in the city. Barcelona has also implemented a range of initiatives aimed at promoting cycling, including the creation of dedicated bike lanes and the introduction of bike-sharing schemes for tourists (Rueda Arsanaz, Grimaldi, 2017; Channock et al., 2021).

The analyzed city has invested heavily in electric vehicles, with a goal to make the city's entire fleet of buses and taxis electric by 2025. The city has also introduced a range of incentives for electric vehicle owners, including free parking and charging stations located throughout the city. Barcelona has introduced a network of smart parking systems that use sensors to detect available parking spaces and direct drivers to the nearest available spot. The system has helped to reduce the time spent looking for parking, minimizing congestion and reducing emissions (Eskhita et al., 2021, Smith, Martin, 2021).

Barcelona has a comprehensive network of public transportation, including buses, metro lines, and trams. The city has implemented a smart ticketing system that allows passengers to use a single ticket for all modes of transportation, making it easy and convenient to use public transportation. Barcelona has also introduced real-time information displays at bus and metro stops, allowing passengers to see exactly when the next bus or train is due (Di Martino et al., 2020).

Barcelona's intelligent traffic management system uses real-time data to monitor traffic flow and adjust traffic lights to optimize traffic flow and reduce congestion. The city has also implemented a range of measures aimed at reducing the number of cars on the road, including a congestion charge for drivers entering the city center. Analyzed Spanish city has implemented a range of shared mobility solutions, including car-sharing schemes and ride-sharing services. The city has also introduced a range of initiatives aimed at promoting shared mobility, including the creation of car-free zones and the promotion of carpooling (Bibri, Krogstie, 2020; Mann et al., 2020).

Barcelona has implemented a range of data collection and analysis tools to monitor transportation patterns and improve the efficiency of its transportation systems. The city has introduced a traffic data platform, which collects data from traffic sensors and provides real-time traffic updates to drivers. Barcelona has also introduced a range of initiatives aimed at reducing emissions and improving air quality, including the promotion of electric vehicles and the creation of low-emission zones (Noory et al., 2020).

On the basis of the analysis it can be stated that Barcelona's smart mobility solutions are focused on promoting sustainable transportation modes, including cycling, public transportation, electric vehicles, and shared mobility. The city has invested heavily in smart parking systems and intelligent traffic management to reduce congestion and emissions. Barcelona's data collection and analysis tools have helped to inform future investments in transportation infrastructure, ensuring that the city remains at the forefront of innovation in smart mobility solutions (Mancbo, 2020; Vasilenko, Mokhailova, 2019).

In the table 2 there is a description of realization of main factors of smart mobility concept realization in Barcelona. Barcelona's smart mobility solutions are focused on promoting sustainable transportation modes, reducing congestion, and improving air quality. The city has invested heavily in smart parking systems, intelligent traffic management, and data collection and analysis to improve the efficiency of its transportation systems. Barcelona has also implemented a range of pedestrian-friendly initiatives and green spaces to promote sustainable transportation options and improve air quality. The city's smart city initiatives have helped to integrate transportation systems with other city services, creating a more efficient and sustainable city (March, Ribera-Fumaz, 2018, Smart Mobility, 2018).

**Table 3.**
*Main factors of smart mobility in Barcelona*

| Factor | Realization |
|---|---|
| **Bike-Sharing Schemes** | Barcelona has implemented a successful bike-sharing scheme, known as Bicing, which allows residents and visitors to rent bikes for a small fee. The city has also created dedicated bike lanes and introduced bike-sharing schemes for tourists. |
| **Electric Vehicles** | Barcelona has invested heavily in electric vehicles, with a goal to make the city's entire fleet of buses and taxis electric by 2025. The city has also introduced a range of incentives for electric vehicle owners, including free parking and charging stations located throughout the city. |
| **Smart Parking Systems** | Barcelona has introduced a network of smart parking systems that use sensors to detect available parking spaces and direct drivers to the nearest available spot. The system has helped to reduce the time spent looking for parking, minimizing congestion and reducing emissions. |
| **Integrated Public Transportation** | Barcelona has a comprehensive network of public transportation, including buses, metro lines, and trams. The city has implemented a smart ticketing system that allows passengers to use a single ticket for all modes of transportation, making it easy and convenient to use public transportation. Barcelona has also introduced real-time information displays at bus and metro stops, allowing passengers to see exactly when the next bus or train is due. |
| **Smart Traffic Management** | Barcelona's intelligent traffic management system uses real-time data to monitor traffic flow and adjust traffic lights to optimize traffic flow and reduce congestion. The city has also implemented a range of measures aimed at reducing the number of cars on the road, including a congestion charge for drivers entering the city center. |
| **Shared Mobility** | Barcelona has implemented a range of shared mobility solutions, including car-sharing schemes and ride-sharing services. The city has also introduced a range of initiatives aimed at promoting shared mobility, including the creation of car-free zones and the promotion of carpooling. |

Cont. table 3.

| | |
|---|---|
| **Data Collection and Analysis** | Barcelona has implemented a range of data collection and analysis tools to monitor transportation patterns and improve the efficiency of its transportation systems. The city has introduced a traffic data platform, which collects data from traffic sensors and provides real-time traffic updates to drivers. Barcelona has also introduced a range of initiatives aimed at reducing emissions and improving air quality, including the promotion of electric vehicles and the creation of low-emission zones. |
| **Pedestrian-Friendly Design** | Barcelona has introduced a range of pedestrian-friendly initiatives, including the creation of pedestrian zones and the redesign of streets to prioritize walking and cycling over cars. The city has also implemented a "superblock" system, which creates a network of streets closed to cars, allowing for safe and sustainable transportation options. |
| **Green Spaces** | Barcelona has implemented a range of green spaces and park systems, including the creation of large pedestrian-friendly parks and green spaces throughout the city. These initiatives help to promote sustainable transportation options and improve air quality. |
| **Smart City Initiatives** | Barcelona has implemented a range of smart city initiatives, including the integration of transportation systems with other city services, such as waste management and public safety. The city has also introduced a range of innovative technology solutions, including smart traffic lights and autonomous vehicles |

Source: Authors own work on the basis of: (Eicher, 2020; Rueda Arsanaz, Grimaldi, 2017; Channock et al., 2021; Eskhita et al., 2021; Smith, Martin, 2021; Di Martino et al., 2020; Bibri, Krogstie, 2020; Mann et al., 2020; Noory et al., 2020; Mancbo, 2020; Vasilenko, Mokhailova, 2019; March, Ribera-Fumaz, 2018, Smart Mobility, 2018).

In the table 4 there is an analysis of main advantages and problems in implementation of smart mobility solutions in Barcelona.

**Table 4.**
*Comparison of advantages and problems of implementing smart mobility in Barcelona*

| Advantages | Problems |
|---|---|
| Reduces traffic congestion and emissions | High implementation costs |
| Improves air quality | Requires significant infrastructure upgrades |
| Enhances the quality of life for residents | Limited public acceptance |
| Promotes sustainable transportation options | Difficulty in changing established travel patterns |
| Increases access to transportation for all residents | Balancing the needs of different transportation modes |
| Creates economic opportunities | Requires significant coordination between different city departments |
| Improves transportation efficiency | Technical challenges in integrating different transportation systems |
| Improves public safety | Potential privacy concerns with data collection and analysis |

Source: Authors own work on the basis of: (Eicher, 2020; Rueda Arsanaz, Grimaldi, 2017; Channock et al., 2021; Eskhita et al., 2021; Smith, Martin, 2021; Di Martino et al., 2020; Bibri, Krogstie, 2020; Mann et al., 2020; Noory et al., 2020; Mancbo, 2020; Vasilenko, Mokhailova, 2019; March, Ribera-Fumaz, 2018, Smart Mobility, 2018).

## 5. Copenhagen and Barcelona comparison

Copenhagen and Barcelona are two cities that have implemented innovative smart mobility solutions to improve transportation in urban areas. Both cities have developed a comprehensive transportation system that is sustainable, efficient, and convenient. However, there are some differences in the smart mobility solutions used in these cities.

Copenhagen is a leading city in sustainable transportation, and it has invested heavily in cycling infrastructure. The city has developed a network of cycling lanes, bike-sharing schemes, and bicycle parking facilities. This has made cycling a popular and safe mode of transportation for the city's residents. In addition, Copenhagen has implemented an integrated public transportation system, which includes buses, metro, and trains. The city's transportation system is also designed to be accessible to all residents, including those with disabilities (Bjørner, 2021; Cenre; 2017; Eltved et al., 2021; Doost, Rezaie, 2020).

Barcelona, on the other hand, has developed a smart mobility system that is focused on reducing traffic congestion and improving air quality. The city has implemented a low-emission zone in the city center, which restricts the entry of high-polluting vehicles. Barcelona has also developed an innovative smart parking system, which uses sensors to detect available parking spaces in real-time. This has reduced the time drivers spend searching for parking and has also reduced traffic congestion (Bibri, Krogstie, 2020; Mann et al., 2020; Noory et al., 2020).

Another difference between the two cities is their approach to smart mobility governance. Copenhagen has a highly centralized governance structure, with a strong role for the city government in transportation planning and management (Bjørner, 2021; Cenre; 2017; Eltved et al., 2021; Doost, Rezaie, 2020). In contrast, Barcelona has adopted a more decentralized approach, with a focus on engaging citizens and stakeholders in transportation decision-making.

Cities analyzed in the paper have both implemented smart mobility solutions that have improved transportation in urban areas. However, their approaches differ in terms of the focus of their solutions and the governance structures used to implement them. Copenhagen has focused on sustainable transportation, while Barcelona has focused on reducing congestion and improving air quality. Additionally, Copenhagen has a highly centralized governance structure, while Barcelona has a more decentralized approach.

In the table 5 there is a comparison of smart mobility implementation in Copenhagen and Barcelona. The more extensive comparison was prepared in the table 6.

**Table 5.**
*Comparison of Copenhagen and Barcelona smart mobility solutions*

| Factor | Copenhagen | Barcelona |
|---|---|---|
| **Focus of smart mobility solutions** | Sustainable transportation, cycling infrastructure, integrated public transportation system | Reducing traffic congestion, improving air quality, smart parking system |
| **Cycling infrastructure** | Network of cycling lanes, bike-sharing schemes, and bicycle parking facilities | Developing cycling infrastructure as a priority |
| **Public transportation system** | Integrated system including buses, metro, and trains | Developing metro system as a priority |
| **Governance structure** | Highly centralized with strong role for city government | Decentralized with focus on engaging citizens and stakeholders |
| **Smart parking system** | Not a major focus | Innovative smart parking system using sensors to detect available parking spaces in real-time |
| **Low-emission zone** | Not implemented | Implemented in the city center |

Source: Authors own work on the basis of: (Eicher, 2020; Rueda Arsanaz, Grimaldi, 2017; Channock et al., 2021; Eskhita et al., 2021; Smith, Martin, 2021; Di Martino et al., 2020; Bibri, Krogstie, 2020; Mann et al., 2020; Noory et al., 2020; Mancbo, 2020; Vasilenko, Mokhailova, 2019; March, Ribera-Fumaz, 2018, Smart Mobility, 2018).

**Table 6.**
*Extensive analysis of differences between Copenhagen and Barcelona in smart mobility solutions implementation*

| Factor | Copenhagen | Barcelona |
|---|---|---|
| **Overview of Smart Mobility Solutions** | Copenhagen is a leading city in sustainable transportation and has invested heavily in cycling infrastructure. The city has developed a network of cycling lanes, bike-sharing schemes, and bicycle parking facilities. It has also implemented an integrated public transportation system, which includes buses, metro, and trains. | Barcelona has developed a smart mobility system that focuses on reducing traffic congestion and improving air quality. The city has implemented a low-emission zone in the city center, which restricts the entry of high-polluting vehicles. Barcelona has also developed an innovative smart parking system, which uses sensors to detect available parking spaces in real-time. |
| **Cycling infrastructure** | Copenhagen has developed a comprehensive cycling infrastructure that spans over 400 kilometers of cycle lanes, with a further 100 kilometers planned. The city also has a bike-sharing scheme called Bycyklen, with 1,860 bikes available for rental across 100 stations. Additionally, there are bicycle parking facilities across the city, including indoor parking facilities at train and metro stations. | Barcelona is developing its cycling infrastructure and has implemented a bike-sharing scheme called Bicing, with over 7,000 bicycles available for rental across 420 stations. The city is planning to add 200 kilometers of cycle lanes by 2024, with the aim of reducing the use of cars for short trips and improving air quality. |
| **Public transportation system** | Copenhagen's public transportation system is integrated, making it easy for residents and visitors to travel within the city. It includes buses, metro, and trains, and is operated by a single transport authority, Movia. The city has also implemented a smart ticketing system, which allows passengers to use a single ticket across all modes of transportation. Additionally, Copenhagen has a plan to introduce a driverless metro by 2025. | Barcelona's public transportation system includes buses, metro, and trains, and is operated by two transport authorities, TMB and FGC. The city has a comprehensive ticketing system that allows passengers to use a single ticket across all modes of transportation. Barcelona is also developing its metro system, with plans to add 30 kilometers of new lines and 50 new stations by 2026. |

Cont. table 6.

| | | |
|---|---|---|
| **Governance structure** | Copenhagen has a highly centralized governance structure, with a strong role for the city government in transportation planning and management. The city government sets policies and strategies for transportation, and is responsible for implementing and managing the transportation system. | Barcelona has a decentralized governance structure, with a focus on engaging citizens and stakeholders in transportation decision-making. The city government works closely with local communities and neighborhood associations to develop transportation policies and plans. There is also a strong emphasis on public participation and consultation in transportation projects. |
| **Smart parking system** | Copenhagen has not implemented a smart parking system on a city-wide basis, but it has introduced parking guidance systems in some areas. These systems use sensors to detect available parking spaces and display the information on electronic signs, making it easier for drivers to find parking. | Barcelona has developed an innovative smart parking system, which uses sensors to detect available parking spaces in real-time. The system is integrated with a mobile app, which allows drivers to find available parking spaces and pay for parking. This has reduced the time drivers spend searchi |

Source: Authors own work on the basis of: (Eicher, 2020; Rueda Arsanaz, Grimaldi, 2017; Channock et al., 2021; Eskhita et al., 2021; Smith, Martin, 2021; Di Martino et al., 2020; Bibri, Krogstie, 2020; Mann et al., 2020; Noory et al., 2020; Mancbo, 2020; Vasilenko, Mokhailova, 2019; March, Ribera-Fumaz, 2018, Smart Mobility, 2018).

## 6. Conclusion

The paper analyzes the smart mobility solutions implemented in Copenhagen and Barcelona to improve urban transportation. Both cities have developed a comprehensive transportation system that is sustainable, efficient, and convenient. However, there are differences in the smart mobility solutions used in these cities. Copenhagen has invested heavily in cycling infrastructure, making cycling a popular and safe mode of transportation. The city has also implemented an integrated public transportation system that is accessible to all residents, including those with disabilities.

On the other hand, Barcelona has focused on reducing traffic congestion and improving air quality by implementing a low-emission zone in the city center and an innovative smart parking system that uses sensors to detect available parking spaces in real-time. Additionally, Copenhagen has a highly centralized governance structure, while Barcelona has a decentralized approach. The paper includes a comparison table and an extensive analysis of the differences between the two cities' smart mobility solutions implementation.

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# THE CONCEPT OF DESCRIPTIVE ANALYTICS

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**Purpose:** The goal of the paper is to analyze the main features, benefits and problems with the descriptive analytics usage.
**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 paper discusses the concept of descriptive analytics, which involves collecting, cleaning, and summarizing historical data from various sources to provide a clear and concise summary that can aid in decision-making. The paper explains the importance of descriptive analytics as the foundation for other types of data analytics, and highlights the steps involved in its implementation, including data collection, cleaning and preparation, exploration and visualization, analysis, interpretation, and reporting. The paper also mentions the advantages of descriptive analytics, such as identifying trends and patterns, optimizing processes, improving decision-making, and simplifying communication, while cautioning businesses about the potential pitfalls and challenges of this approach, such as limited predictive power, incomplete data, data privacy concerns, biased results, and overreliance on historical data. The paper emphasizes the importance of understanding these issues to ensure that the insights generated are relevant, accurate, and useful.
**Originality/value**: Detailed analysis of all subjects related to the problems connected with the descriptive analytics.

**Keywords:** Industry 4.0; descriptive analytics, business analytics, data analysis, real-time analytics.

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

## 1. Introduction

Descriptive analytics is a branch of data analytics that deals with the examination and interpretation of past data to gain insights into what has happened in a business or organization. It involves collecting, summarizing, and presenting historical data in a way that enables businesses to understand patterns, trends, and relationships.

Descriptive analytics is a crucial aspect of data analysis that involves examining historical data to gain insights and identify trends, patterns, and relationships. This type of analysis is widely used in a range of industries, including finance, marketing, healthcare, and manufacturing. In this essay, we will explore the concept of descriptive analytics, its applications, and its benefits.

The goal of the paper is to analyze the main features, benefits and problems with the descriptive analytics usage.

## 2. Descriptive analytics - definitions

Descriptive analytics involves collecting, cleaning, and summarizing data from various sources. The goal is to provide a clear and concise summary of the data that can be used to inform decision-making. The data is then presented in a way that is easy to understand, using tools such as charts, tables, and graphs. This approach helps businesses to identify areas of strength and weakness, track progress over time, and make informed decisions based on historical data (Hurwitz et al., 2015).

Descriptive analytics involves the utilization of diverse statistical analysis methods to dissect raw data into a structure that enables individuals to detect patterns, anomalies, enhance planning, and make comparisons. Organizations can maximize the benefits of descriptive analytics by using it to compare different items over time or against each other (Hwang et al., 2017).

Descriptive analytics is a type of data analysis that involves examining historical data to understand past events, trends, and patterns. It is often the first stage of the data analytics process and is used to gain insights into what has happened in the past. Descriptive analytics helps businesses and organizations to understand what has happened, when it happened, and why it happened.

We can find in the literature following examples of descriptive analytics definitions (Patanjali, 2018; Nourani, 2021, Sharma et al., 2020):

- Descriptive analytics is the examination of data or content, usually manually performed, to answer the question 'What happened?
- Descriptive analytics examines data to describe what has happened in the past, providing context for understanding current operations and predicting future outcomes.
- Descriptive analytics provides insights into what has happened in the past, what is happening now, and what might happen in the future based on past performance.
- Descriptive analytics is a form of business intelligence that examines historical data to identify patterns and trends and to gain insights into what has happened in the past.

The goal of descriptive analytics is to provide a clear and concise summary of the data that can be used to inform decision-making. It involves using tools such as charts, tables, and graphs to visualize data and present it in a way that is easy to understand. This approach can help businesses to identify areas of strength and weakness, track progress over time, and make informed decisions based on historical data.

Descriptive analytics is concerned with answering questions such as (Cam et al., 2021):

- What happened?
- When did it happen?
- Where did it happen?
- How often did it happen?
- What were the main characteristics or features of what happened?

It can be stated that descriptive analytics provides a valuable foundation for other types of data analytics, such as predictive analytics and prescriptive analytics, which use historical data to make predictions about future events or prescribe actions to achieve specific outcomes.

Descriptive analytics is a valuable tool for businesses and organizations looking to gain insights into their operations, improve decision-making, and identify areas for improvement. By analyzing historical data, businesses can identify trends, patterns, and relationships that can be used to optimize processes, improve customer engagement, and increase profitability. With the right tools and techniques, descriptive analytics can help businesses to stay ahead of the competition and achieve long-term success (Greasley, 2019).

In the process of descriptive analytics implementation following steps should be used (Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023, Scappini, 2016, Peter et al., 2023):

- Data collection: Gather the data that you want to analyze from various sources, such as databases, spreadsheets, or other data repositories.
- Data cleaning and preparation: Clean the data by removing irrelevant or duplicated data, correcting errors, and ensuring that the data is in a format that can be analyzed.
- Data exploration and visualization: Explore the data to understand its characteristics, such as distributions, correlations, and outliers. Visualize the data using charts, graphs, or other visual aids to make it easier to understand.
- Data analysis: Apply statistical techniques to the data to identify patterns, trends, and relationships. Common techniques include mean, median, mode, standard deviation, and regression analysis.
- Interpretation and reporting: Analyze the results of the data analysis and interpret the findings in a way that is meaningful to stakeholders. Report the findings in a clear and concise manner using charts, graphs, or other visual aids.
- Very important thing is to differentiate the descriptive analytics and others types of analytics especially real-time analytics. The differences were summed up in the table 1. We can differentiate following main differences between them:

- Timeframe: Descriptive analytics is a type of data analysis that examines historical data to understand past events, trends, and patterns. Real-time analytics, on the other hand, involves analyzing data in real-time or near real-time as it is generated.
- Purpose: The purpose of descriptive analytics is to gain insights into what has happened in the past. It is often used to identify patterns and trends, and to provide context for understanding current operations and predicting future outcomes. Real-time analytics, on the other hand, is used to provide immediate insights into what is happening right now, and to enable real-time decision-making.
- Data sources: Descriptive analytics typically relies on structured data from databases, data warehouses, and other historical data sources. Real-time analytics, on the other hand, can analyze structured and unstructured data from a variety of sources, including sensors, social media, and other real-time data streams.
- Analytics tools: Descriptive analytics often involves the use of traditional analytics tools, such as business intelligence software, data visualization tools, and statistical analysis tools. Real-time analytics, on the other hand, often requires specialized tools and technologies that can process and analyze data in real-time, such as stream processing engines, complex event processing systems, and machine learning algorithms.
- Applications: Descriptive analytics is often used in applications such as sales analysis, customer segmentation, and supply chain management. Real-time analytics, on the other hand, is used in applications such as fraud detection, predictive maintenance, and real-time marketing.

**Table 1.**
*Comparison of descriptive analytics and real-time analytics*

| | **Descriptive Analytics** | **Real-time Analytics** |
|---|---|---|
| Timeframe | Examines historical data | Analyzes data in real-time or near real-time |
| Purpose | Gain insights into past events and identify patterns and trends | Provide immediate insights and enable real-time decision-making |
| Data Sources | Relies on structured data from databases and historical data sources | Analyzes structured and unstructured data from various sources, including sensors and real-time data streams |
| Analytics Tools | Uses traditional analytics tools such as business intelligence software and statistical analysis tools | Requires specialized tools such as stream processing engines and machine learning algorithms |
| Applications | Used in applications such as sales analysis, customer segmentation, and supply chain management | Used in applications such as fraud detection, predictive maintenance, and real-time marketing |

Source: Authors own work on the basis of: (Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023, Scappini, 2016, Peter et al., 2023).

Descriptive analytics is a type of data analytics that involves analyzing historical data to gain insights into past events and trends. Industry 4.0, on the other hand, refers to the current trend of using advanced technologies like artificial intelligence, the Internet of Things (IoT), and machine learning to create more intelligent and connected manufacturing processes (Jonek-

Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023, Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Steculа, Wolniak, 2022; Olkiewicz et al., 2021).

By analyzing historical data from production processes, businesses can identify patterns and trends that can inform decisions about optimizing manufacturing processes, reducing waste, improving quality control, and identifying areas for improvement (Sułkowski, Wolniak, 2015, 2016, 2018; Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023). For example, in a smart factory that utilizes Industry 4.0 technologies, data from IoT sensors on production lines can be analyzed using descriptive analytics to identify patterns in equipment performance or detect anomalies that could indicate a problem. This data can then be used to optimize production processes, reduce downtime, and improve product quality (Wolniak, Sułkowski, 2015, 2016; Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

Furthermore, descriptive analytics can also help industries to track and analyze key performance indicators (KPIs) such as production output, inventory levels, and customer demand. By using data analysis tools, businesses can gain a better understanding of how these factors are affecting their operations and make data-driven decisions to improve their processes (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021).

## 3. Benefits and problems of descriptive analytics usage

The significant benefits of descriptive analytics is its ability to help businesses identify areas of improvement. By analyzing historical data, businesses can identify areas where they are underperforming and take corrective action. For example, a business may identify a decline in sales in a particular region and adjust its marketing strategy to increase sales in that region. Descriptive analytics also helps businesses to track progress over time, providing a baseline for measuring success and identifying areas for improvement.

On the basis of literature analysis following benefits of descriptive analytics can be formulated (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023):

- Identifying trends and patterns: Descriptive analytics allows businesses to identify trends and patterns in historical data. This information can be used to understand customer behavior, sales performance, and market trends. Identifying these trends and patterns helps businesses to make informed decisions, optimize processes, and improve customer engagement.

- Measuring progress: By analyzing historical data, businesses can track progress over time. This provides a baseline for measuring success and identifying areas for improvement. Descriptive analytics helps businesses to set realistic goals and track progress towards those goals.
- Improving decision-making: Descriptive analytics provides businesses with valuable insights that can be used to make informed decisions. For example, businesses can use historical data to identify which products or services are selling well and which ones are not. This information can be used to adjust marketing strategies, optimize pricing, and improve customer satisfaction.
- Optimizing processes: Descriptive analytics helps businesses to identify areas where they are underperforming and take corrective action. By analyzing historical data, businesses can identify bottlenecks in their processes and take steps to improve efficiency and productivity.
- Increasing profitability: By using descriptive analytics to identify areas for improvement, businesses can increase profitability. For example, businesses can use historical data to identify which customers are most profitable and focus their marketing efforts on those customers.
- Preventing problems: Descriptive analytics can be used to identify potential problems before they occur. For example, businesses can use historical data to identify trends in customer complaints and take steps to address those complaints before they become a more significant issue.
- It can simplify communication about numerical data.
- It can improve understanding of complex situations.
- Companies can compare performance against the competition or across product lines.
- It can be used to help motivate teams to reach new goals.

The use of descriptive analytics provides several benefits to businesses and organizations. By analyzing historical data, businesses can identify trends and patterns, measure progress, improve decision-making, optimize processes, increase profitability, and prevent problems. With the right tools and techniques, businesses can use descriptive analytics to gain a competitive advantage and achieve long-term success (Sharma et al., 2020; Wolniak, 2013; 2016; Hys, Wolniak, 2018).

While there are several benefits to the use of descriptive analytics, there are also some potential disadvantages and problems that businesses and organizations should be aware of. Below are some of the key disadvantages and problems associated with the usage of descriptive analytics (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023):

- Limited predictive power: Descriptive analytics is focused on analyzing past data to identify trends and patterns. While this information can be useful for making informed decisions, it has limited predictive power. Descriptive analytics cannot predict future events or outcomes.
- Incomplete data: Descriptive analytics is only as good as the data that is used to analyze it. If the data is incomplete, inaccurate, or biased, the insights generated by descriptive analytics may be flawed or misleading.
- Data privacy concerns: The use of descriptive analytics may raise data privacy concerns. Businesses need to be mindful of the data they are collecting, how it is being used, and who has access to it. They must also ensure that they are compliant with relevant data privacy regulations.
- Difficulty in interpreting results: Descriptive analytics can generate a large amount of data that may be difficult to interpret. It can be challenging to identify which insights are most relevant and useful, particularly for businesses without an experienced data analytics team.
- Costly data storage and processing: Storing and processing large amounts of data can be costly. Businesses must invest in the necessary infrastructure, software, and personnel to collect, store, and process data effectively.
- Overreliance on historical data: Descriptive analytics is based on analyzing historical data. While this can be useful for identifying trends and patterns, it may lead to an overreliance on past data and an inability to adapt to changing market conditions or customer preferences.
- Existing biases can be amplified either accidentally or deliberately.
- Results can direct a company's focus to metrics that are not helpful, like sales versus profits.
- Motivational metrics can be gamed to encourage unintended behavior, such as mouse movers or sales fraud.
- Poorly chosen metrics can lead to a false sense of security.

While descriptive analytics can provide valuable insights into past trends and patterns, it has some potential disadvantages and problems that businesses and organizations should be aware of. These include limited predictive power, incomplete data, data privacy concerns, difficulty in interpreting results, costly data storage and processing, and overreliance on historical data. It is essential to understand these issues when implementing a descriptive analytics strategy to ensure that the insights generated are relevant, accurate, and useful.

## 4. Example of descriptive analytics usage in business

One of the primary applications of descriptive analytics is in business intelligence. Businesses use this approach to gain insights into their operations, including sales, marketing, and customer behavior. By analyzing historical data, businesses can identify trends and patterns in customer behavior, sales performance, and marketing campaigns. This information can be used to optimize business processes, improve customer engagement, and increase profitability.

The descriptive analytics is commonly used in following areas (Hwang et al., 2017; Hurwitz et al., 2015; Lawton, 2019; Charles et al., 2023; Scappini, 2016; Peter et al., 2023):

- financial reports,
- planning a new program,
- measuring effectiveness of a new program,
- understanding sales trends,
- comparing companies,
- motivating behavior with KPIs,
- recognizing anomalous behavior,
- interpreting survey results.

In sales analysis businesses can use descriptive analytics to examine sales data from the past to identify trends in sales volume, revenue, and customer behavior. By understanding past sales patterns, businesses can make informed decisions about inventory management, pricing strategies, and marketing campaigns (Cam et al., 2021).

Descriptive analytics can be used to segment customers based on their demographics, behaviors, and purchase history. This information can help businesses to better understand their customers and tailor their marketing and product offerings to meet their specific needs.

In finance, descriptive analytics is used to analyze financial statements, track investments, and identify trends in the stock market. By analyzing historical data, financial analysts can identify patterns in market trends and make informed decisions about investments. Descriptive analytics is also used in healthcare to analyze patient data, track disease outbreaks, and identify trends in patient health. This information is used to improve patient care, develop treatment plans, and prevent the spread of disease (Peter et al., 2023).

Descriptive analytics is also used to website traffic analysis. By analyzing website traffic data, businesses can identify which pages on their website are most popular, how long visitors stay on the site, and what actions they take. This information can help businesses to optimize their website design, content, and user experience to improve engagement and conversion rates.

Descriptive analytics can be used in logistic to analyze historical data on supply chain performance, such as lead times, inventory levels, and delivery times. This information can help businesses to identify bottlenecks in the supply chain and make data-driven decisions to optimize inventory management and reduce costs (Hurwitz et al., 2015).

By analyzing social media data, businesses can gain insights into customer sentiment, brand awareness, and engagement. This information can help businesses to adjust their marketing strategies and improve their social media presence.

Quality management is also an area were the descriptive analytics can be used in extensive way. Below are some of examples of usage of descriptive analytics in quality management (Hwang et al., 2017; 2015; Lawton, 2019; Charles et al., 2023, Scappini, 2016; Peter et al., 2023):

- Descriptive analytics can be used to analyze historical data on product defects to identify patterns and trends. By understanding the root causes of defects, businesses can make data-driven decisions to improve product quality and reduce waste.
- Descriptive analytics can be used to analyze customer complaints to identify the most common issues and areas for improvement. By addressing these issues, businesses can improve customer satisfaction and loyalty.
- The concept can be used to analyze data on process performance, such as cycle time, throughput, and yield. By understanding how processes perform over time, businesses can identify opportunities for improvement and make data-driven decisions to optimize operations.
- Descriptive analytics can be used to analyze data on supplier performance, such as delivery times, quality, and cost. By understanding supplier performance over time, businesses can identify opportunities to improve supplier relationships and reduce costs.
- This type of analytics can be used to analyze data from audits to identify areas of non-compliance and opportunities for improvement. By addressing these issues, businesses can reduce the risk of regulatory fines and improve overall compliance.

## 5. Conclusion

The paper describes descriptive analytics as a process of collecting, cleaning, and summarizing data from various sources to provide a clear and concise summary that can inform decision-making. It is the first stage of the data analytics process and involves examining historical data to understand past events, trends, and patterns. The goal is to identify areas of strength and weakness, track progress over time, and make informed decisions based on historical data. Descriptive analytics involves using tools such as charts, tables, and graphs to visualize data and present it in a way that is easy to understand. It can provide a valuable foundation for other types of data analytics, such as predictive and prescriptive analytics. The implementation of descriptive analytics involves several steps, including data collection, cleaning and preparation, data exploration and visualization, data analysis, interpretation and reporting.

Descriptive analytics allows businesses to analyze historical data to identify trends and patterns, measure progress, optimize processes, improve decision-making, increase profitability, prevent problems, and simplify communication about numerical data. However, businesses should be aware of its potential disadvantages and problems, including limited predictive power, incomplete data, data privacy concerns, difficulty in interpreting results, costly data storage and processing, overreliance on historical data, existing biases, the potential to direct focus to unhelpful metrics, gamification of motivational metrics, and the potential for a false sense of security. Businesses need to understand these issues to ensure that the insights generated are relevant, accurate, and useful.

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# RESPONSIBLE MANAGEMENT OF AGGREGATE WASTE TO IMPROVE THE PROPERTIES OF ANTI-CORROSION COATINGS

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**Purpose:** The aim of the study was to investigate the possibility of using engineering waste materials in the form of brick dust and volcanic tuff as corrosion inhibitors. The corrosion tests were carried out on the aluminium alloys against aggressive corrosive environments with acidic pH containing chlorine compounds.
**Design/methodology/approach:** The specimens for corrosion tests were cut from a sheet made of aluminium alloy EN AW-6060. In the first step the aluminium specimens was covered with a coating of clear alkyd varnish without any additives. In the next step used additives in the form of brick dust and vulcanic tuff were used. The tests were carried out using a RADWAG AS 310.R2 laboratory analytical balance to obtain the weight loss results for the specimens tested.
**Findings:** Brick dust used in concentrations of 10% to 40% by weight cannot be considered as a material that allows achieving satisfactory results. This is due to the absorption of the corrosive medium by the brick dust. On the other hand, the volcanic tuff addition of 30% by weight creates conditions that slow down the corrosion process in the long term.
**Research limitations/implications**: Consideration should be given to preparing all types of structural components for corrosion protection by blunting sharp edges for better adhesion of corrosion protection coatings. Therefore, further work should focus on obtaining a coating with an adequate adhesion as well as checking the action of volcanic tuff as an inhibitor in other corrosive media.
**Practical implications:** The introduction of appropriately prepared volcanic tuff additives into protective coatings is expected to increase the effectiveness of the protection of the metal substrate against the corrosion process. It is therefore important to manage and monitor the factors that affect the coating and occur during the painting process.
**Originality/value:** In tests confirmed the good properties of volcanic tuff, which slows down corrosion processes and preserves the uniform corrosion of aluminium. The result obtained has the lowest mass loss values of all the specimens prepared in the experiment, which proves the validity of using the volcanic tuff additive.

**Keywords:** waste management, brick dust, volcanic tuff, corrosion inhibitor.

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

## 1. Introduction

The economic development and the level and patterns of individual consumption are contributing to an increase in the amount of waste generated. The latest data show that 107,712,000 tonnes of waste (excluding municipal waste) were generated in Poland in 2021, from various branches of economic activity. The main sources of waste in 2021, as in previous years, were mining and the extractive industry (61.9% of total waste generated), industrial processing (22.0%) and electricity, gas, steam and hot water generation and supply (12.7%). As for the construction sector (3,504,000 tonnes of waste), it accounted for 3.3% of the waste generated. Of the total amount of waste generated in the period analysed, 48% of waste was recycled, 44% was disposed of by landfilling and 6% was disposed of by other means (GUS, 2022).

Therefore, proper waste management is an important link in the contemporary environmental policy of each member state of the European Union. In addition to introducing its own waste management regulations, Poland is also obliged to comply with and implement Community Regulations that ensure the even development of the natural economy (Żurawiecka, Kocia, 2019). Furthermore, waste management is an important component of sustainable development, according to which, the waste generated should have as little impact on the environment as possible. However, the main priority here will be waste prevention resulting from actions such as environmental education, waste prevention programmes, economic incentives for companies implementing recycling policies, and modelling of the waste management system based on quantitative, technical, economic and ecological criteria (Łagutko et al., 2018). On the other hand, a systemic understanding of our resources and waste systems reflects the challenges and compromises associated with the sustainable management of both resources and waste and their potential in a circular economy (Awasthi et al., 2021). And the latest research shows that the current way of managing waste needs to be significantly revised if closed-loop recycling is to be increased (Salmenperä et al., 2021).

Recently, environmental practices have resulted in a growing trend towards the use of recycled raw materials from recycled construction materials (Szafranko, Jaromińska, 2020, Huang et al., 2020, Bonoli et al., 2021, Oh et al., 2021). Waste from the construction industry is mainly concrete, asphalt, brick waste, ceramic waste, wood, metals, as well as plastics (Jura, 2017). The construction sector also accommodates the use of waste from other industries, e.g. waste from mines or steelworks (Wowkonowicz et al., 2018). On the other hand, in the case of extraction (mining) waste, the most popular method of managing it so far has been by dumping it in heaps or in mine workings. Increasingly, however, attempts are being made to process such materials, which not only promotes environmental protection, but also offers the possibility of recycling secondary raw materials (Jonczy et al., 2012).

An increasing number of companies and institutions see the need to use construction rubble as a substitute for natural aggregate in the production of concrete mixtures, which is due to economic and ecological reasons. By utilising construction rubble, the use of expensive natural aggregates is reduced, thereby also minimising the negative impact on the environment. A significant benefit is achieved when as much recycled aggregate as possible is used in the production of concrete. Among the fundamental reasons why recycling is becoming increasingly popular, the most important are the continuous increase in the amount of concrete waste and the steady increase in the use of concrete as a construction material (Sadowska-Buraczewska, 2014; Kalinowska-Wichrowska, 2018).

With the above in mind, new ways of using engineering waste materials, such as ground ceramic waste in the form of brick dust and volcanic tuff, which is treated as waste in quarries, are increasingly being sought. These materials are classified as lightweight aggregates suitable for concretes and mortars. The current standard for lightweight aggregates PN-EN 13055: 2016-07 divides the materials into four groups, i.e. natural, artificial, waste and recycled, where volcanic tuff is classified as a natural aggregate and brick dust being crushed ceramic rubble is classified as a recycled aggregate (Fig. 1). Another standard, EN 206+A2:2021-08, defines aggregate as a natural, artificial, recycled or reclaimed granular component suitable for use in concrete.

The first aggregate mentioned, i.e. brick dust, is a material derived from the crushing of bricks and has been successfully used for tennis court and running track surfaces, or as an ingredient in mixtures and grits for asphalt and concrete (Pluska, 2009; https://erobocze.pl/…, 2023). It is also widely used in the construction sector as an additive for mortar and concrete (Wild, 1996; Szwabowski et al., 1999; Dündar et al., 2020; Xue et al., 2021). In addition, brick dust has been used as a raw material for the preparation of geopolymer mixtures (Fořt et al., 2017) as well as a dusty material to enhance the sedimentation properties of activated sludge (Masłoń, 2015). Brick dust can also be a waste material from the production of hollow bricks (Fořt et al., 2017).

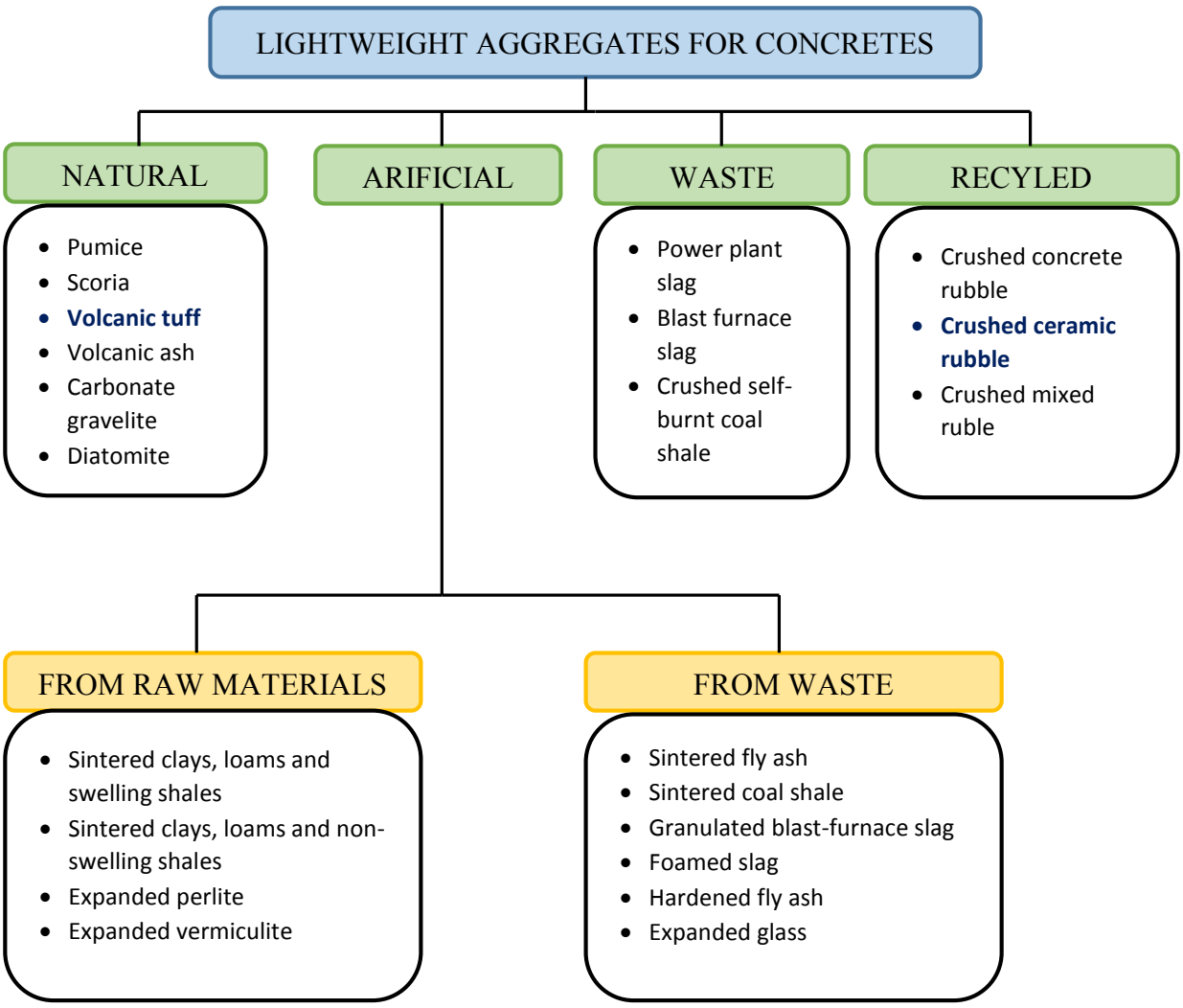


**Figure 1.** Classification of lightweight aggregates for concretes.

Source: Domagała, 2014.

As for the other waste material, i.e. volcanic tuff, it is a porous rock belonging to the clastic rocks and consists of pyroclastic material, often with the admixture of other clastic material, cemented with e.g. a silica or clay binder (http://swiat…, 2023). A characteristic feature of tuff is its high porosity which is associated with low specific gravity. Tuffs also include clay minerals and zeolites (Mikuła, Łach, 2012). The available literature contains many applications of volcanic tuffs, such as e.g. a raw material for the production of lightweight structural aggregates in the production of lightweight concrete, or for the production of rigid polyurethane-polyisocyanurate foams (Paciorek-Sadowska et al., 2016), a durable component for the production of cements, a mineral for the production of highly durable ceramic pigments and dyes, or a material for the production of geopolymer binders (Mikuła, Łach, 2012, 2014), and an attractive material for cosmetic preparations, such as e.g. scrubs (Mikuła, Łach, 2012). In addition, volcanic tuffs are an important tool in solving numerous environmental problems through their potential to remove ammonia, heavy metals (mainly lead) from municipal wastewater, and caesium and strontium from water from nuclear power plants (Grela et al.,

2013). It should be noted that a significant problem often encountered with the use of such materials is the variability of the mineral composition and characteristics depending on their place of occurrence. This affects the quality characteristics of cementitious materials in which volcanic tuff is used as a modifier. On the one hand, these materials may have a favourable chemical and mineralogical composition, but on the other hand, they may exhibit some not so good properties in the form of high water demand, and thus consistency of the concrete mixture (Shannag, Yeginobali, 1995; Pekmezci, Akyüz, 2004; Yılmaz, Ediz, 2008). It should also be emphasised that volcanic tuff particles can be successfully used as an additive for paints and varnishes due to their highly developed surface and sorption properties as well as abrasion resistance (Mikuła, Łach, 2012).

The aim of this paper is to investigate the possibility of using engineering waste materials, such as brick dust and volcanic tuff for corrosion protection of components made of aluminium alloys that come in contact with an aggressive acidic environment containing chlorine compounds. It should be emphasised in this context that it is a common belief that components made of aluminium do not corrode. The reason for this is usually the formation of an aluminium oxide film ($Al_2O_3$) which effectively protects the metal from the damaging effects of aqueous corrosive environments. This is evident from the potential-pH correlation for the Al-$H_2O$ pair shown (Fig. 2).

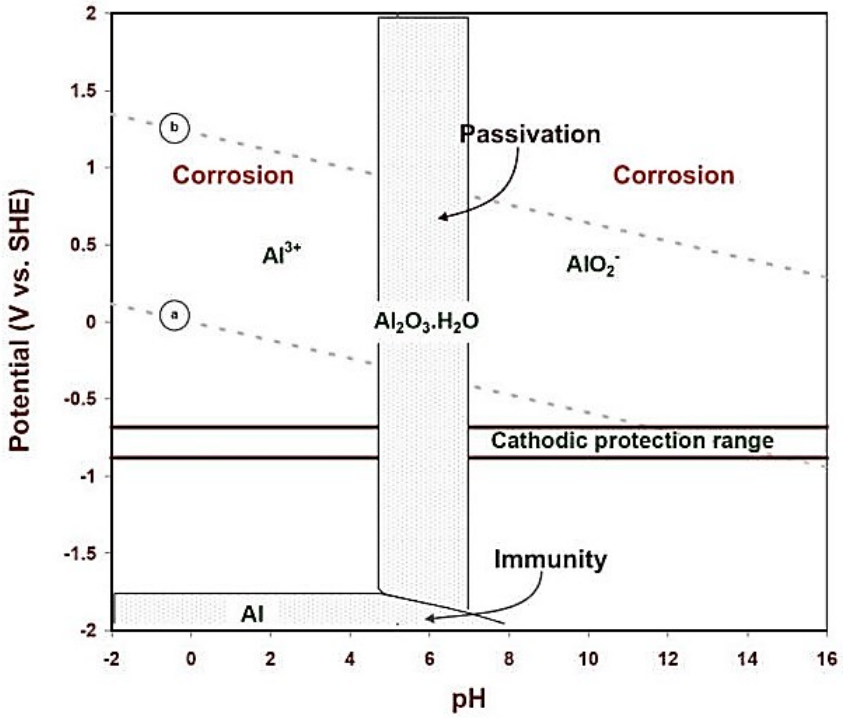


**Figure 2.** Potential-pH diagram of aluminium at 25°C.

Source: www.corrosion-doctors.org..., 2023.

From Figure 2, it is possible to determine the theoretical conditions under which aluminium should corrode or passivate due to the formation of gibbsite (hydrargyllite). This shows that for aqueous solutions with a pH in the range of 4.0 to 7.0, aluminium dissolution is not possible.

Thus, any cracks in the oxide coating, whether mechanical or chemical, will immediately seal themselves up. However, under conditions other than those indicated above, the aforementioned layer does not provide adequate protection (Shreir, 1976).

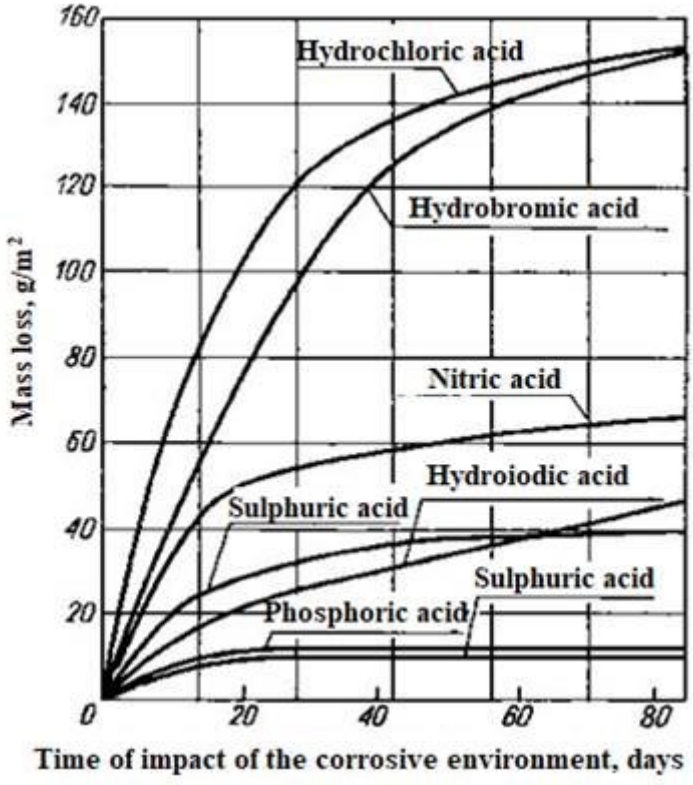


**Figure 3.** Diluted (0.1n) solutions of inorganic acids on commercial grade aluminium at 25°C.
Source: own work based on Shreir, 1976.

Particular attention should be paid to the corrosive effect of compounds in the form of inorganic acids (Fig. 3). The solution with the strongest impact on weight loss is hydrogen chloride (HCl). Chlorine is one of the main agents that act aggressively on components made of aluminium alloys. In practice, however, it is possible to distinguish a deliberate use of chlorine compounds in the food industry for preliminary digestion of fruit peels with hydrochloric acid, which peels are then subjected to a preservation process while it is of course necessary to make sure that suitable tools and containers are used to carry out this process so that the corrosion products are not processed together with the food. During winter periods, it is advisable to use an aqueous solution of sodium chloride (NaCl) with a concentration of 97% (Czarna, Kołodziejczyk, 2012) to remove hard-packed snow. A disadvantage is the corrosive effect of this compound on both motor vehicles (e.g. rims, heat shields, suspension components and bodywork) and urban infrastructure (e.g. pipelines, water pipes and other structural components) (Białobrzeski et al., 2002). Another example is the shipbuilding industry where it can be noticed that adequate protection against the effects of salty seawater is crucial for the service life of ships. In addition, the use of aluminium alloys for ship structures makes it possible, among other things, to reduce the final weight of the vessel by more than half, which

translates into operational capabilities such as increased cruising speed, manoeuvrability, stability conditions, etc. (Cudny, Puchaczewski, 1996; Jurczak, 2010).

It is also worth noting the high amount of chlorine in swimming pool water – provision should be made for the use of appropriate fittings so that sudden failures do not occur during use. Another industry where there is contact with an aggressive environment containing chlorine compounds is the mining industry. The method used here is that of borehole acidification. The reaction of hydrogen chloride with the rock intensifies and leads to the development of pores and fractures as well as the dissolution of the rock body (Fabia et al., 2011). During subsequent mining processes, parts of the machinery and equipment are exposed to the residues of the compounds used.

## 2. Materials and methods

Aluminium alloy EN AW-6060 was chosen for the experimental study. It is characterised by medium mechanical strength and impact strength, and good corrosion resistance. It is suitable for anodising and is amenable to polishing. It has average fatigue strength and is machinable (EN 573-3+A1:2022-11). The chemical composition of the material is shown in Table 1.

**Table 1.**
*EN AW-6060 chemical composition*

| | Fe [%] | Si [%] | Zn [%] | Ti [%] | Mg [%] | Mn [%] | Cu [%] | Cr [%] | Other [%] | Al [%] |
|---|---|---|---|---|---|---|---|---|---|---|
| min. | 0.10 | 0.30 | - | - | 0.35 | - | - | - | - | - |
| max. | 0.30 | 0.60 | 0.15 | 0.10 | 0.60 | 0.1 | 0.1 | 0.05 | 0.15 | rest |

Sources: PN-EN 573-3+A1:2022-11.

The material tested is characterised by an increased content of magnesium (Mg) and silicon (Si). According to A. Domony, the addition of magnesium increases the strength properties and corrosion resistance. On the other hand, the negative effect is a decrease in electrical conductivity. Furthermore, the addition of silicon as an alloying element increases the strength properties while decreasing the electrical conductivity. Also, with regard to its occurrence in the structural components, it does not affect the corrosion properties in solid solution, but it compromises corrosion resistance in a mixture (PN-EN 573-3+A1:2022-11).

Due to the silicon content in the chemical composition, a microstructure of the aluminium alloy indicated above was produced in the as-delivered condition to verify this information (Fig. 4). A sample of the material was embedded in a plastic and then subjected to grinding using abrasive grinding papers with decreasing grit coarseness. The surface was then polished until the scratches disappeared. The metallographic specimens were observed in the condition as-etched by 0.5% HF solution. The image was taken using a JEOL JSM 5510 LV Scanning Electron Microscope.

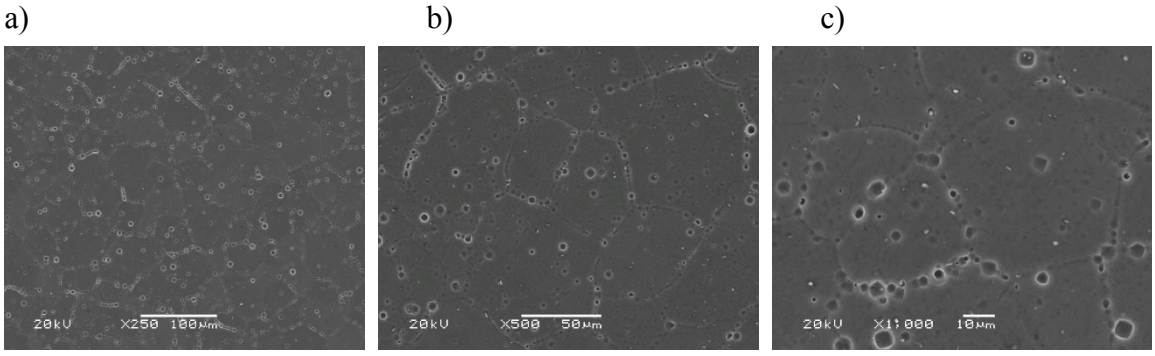


**Figure 4.** Microstructure of aluminium alloy AW-6060 (0.5% HF) as delivered – magnification: (a) 250x, (b) 500x, (c) 1000x.

Source: own work.

From the images obtained it appears that alloy 6060 has a single-phase structure with numerous precipitates (probably Mg2Si) at the grain boundaries indicating that it is in a precipitation-hardened condition. Thus, the information regarding the absence of a structural component in the mixture containing silicon is confirmed. This proves the absence of a negative effect of silicon on the corrosion properties.

The specimens for corrosion testing were cut from a sheet made of aluminium alloy EN AW-6060. The test specimens were prepared in accordance with EN/ISO 7384:2001 – the specimen geometry is presented in Fig. 5. The surface of the material in the as-delivered condition is shown in Fig. 6.

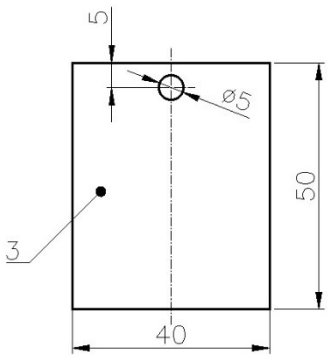


**Figure 5.** Dimensions of specimens for corrosion testing.

Source: PN-EN/ISO 7384:2001.

**Figure 6.** Surface of a raw aluminium specimen.

Source: own work.

Before proceeding, the specimens were prepared by roughening the surface with P120-grit sand paper and degreased to remove contaminants. Anti-corrosion coatings were applied onto the thus prepared surface. The primary protection was clear alkyd varnish for use on metals. The aluminium specimen was covered with a coating without any additives in order to identify the delay or acceleration of corrosion processes relative to the varnish with weight additives of the waste materials selected for testing. The waste material additives are either brick dust or volcanic tuff. The former is brick dust for which four different additives by weight were used

(+10%, +20%, +30% and +40%). The wide range of use of the additive is related to the lack of information on the use of the indicated waste material in this form as an additive for varnishes or other products. On the other hand, the use of volcanic tuff (aluminosilicates) is based on a literature analysis and the achievements of Prof. J. Mikuła's research team (Mikuła, Łach, 2012; Hebdowska-Krupa, Mikuła, 2006, 2007; Hebdowska-Krupa et al., 2016). This material has been shown to alter the nature of steel corrosion (Hebdowska-Krupa, Mikuła, 2007) and to slow down corrosion processes (Hebdowska-Krupa et al., 2016) thus being a corrosion inhibitor. The use of additives in the form of aluminosilicates for artificial materials can take values ranging from 10% to 30% (Mikuła, Łach, 2012). Therefore, the authors decided to apply in their investigation the indicated maximum limit value of the tuff additive to the alkyd varnish. For comparison purposes, an additional zinc coating was applied by spraying onto an aluminium specimen (double layer).

Following the application of the first layer, each specimen was subjected to a drying process at room temperature before the second layer was applied. The double application of the anti-corrosion coating is intended to thoroughly cover the surface of the protected metal in case of inaccuracies and discontinuities that may occur when only one layer is applied. The discontinuity of the anti-corrosion coating through the resulting defects allows the corrosion medium to contact the protected metal and initiate one of the types of corrosion, e.g.: sub-surface corrosion. A list of all types of specimens used for testing is shown in Table 2.

**Table 2.**
*Specimens used for corrosion testing in a 2% HCl solution*

| (1) | (2) | (3) | (4) | (5) | (6) | (7) | (8) |
|---|---|---|---|---|---|---|---|
| AW-6060 | AW-6060 + alkyd varnish | AW-6060 + alkyd varnish +10% dust | AW-6060 + alkyd varnish +20% dust | AW-6060 + alkyd varnish +30% dust | AW-6060 + alkyd varnish +40% dust | AW-6060 + alkyd varnish +30% tuff | AW-6060 + zinc coating |

Source: own work.

## 3. Analysis of the results

An aqueous solution environment containing 2% hydrochloric acid (HCl) was used to carry out the accelerated corrosion tests. The relatively low percentage concentration of the solution was chosen intentionally so that the corrosion process should take place relatively slowly. Rapid chemical reactions are associated with the release of a certain amount of heat and, consequently, with an increase in the temperature of the corrosive medium. This causes disturbances related to the rate of the corrosion process and inadequate practical conditions,

e.g. the corrosion of certain automotive components that are repeatedly exposed to chlorine, especially during the winter months.

The tests were carried out using a RADWAG AS 310.R2 laboratory analytical balance to obtain the weight loss results for the specimens tested. Each specimen was subjected to a drying process at room temperature for a period of 3-6 hours and then weighed. The results of the tests are presented in Tables 3-10.

**Table 3.**
*Examples of corrosion test data for AW-6060 in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (1) AW-6060 | 15.9345 | 29 | 15.697 | 0.2375 | 0.00819 |
| | | 60 | 15.5273 | 0.4072 | 0.00547 |
| | | 202 | 14.6364 | 1.2981 | 0.00627 |
| | | 322 | 14.1974 | 1.7371 | 0.00366 |
| | | 513 | 13.4357 | 2.4988 | 0.00399 |
| | | 630 | 13.0453 | 2.8892 | 0.00334 |

Source: own work.

**Table 4.**
*Examples of corrosion test data for AW-6060 with added alkyd varnish in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (2) AW-6060 + l alkyd varnish | 16.4472 | 29 | 16.439 | 0.0082 | 0.00028 |
| | | 60 | 16.432 | 0.0152 | 0.00023 |
| | | 202 | 16.1054 | 0.3418 | 0.00230 |
| | | 322 | 15.058 | 1.3892 | 0.00873 |
| | | 513 | 13.9834 | 2.4638 | 0.00563 |
| | | 630 | 13.4646 | 2.9826 | 0.00443 |

Source: own work.

**Table 5.**
*Examples of corrosion test data for AW-6060+alkyd varnish+10% brick dust in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (3) AW-6060 + alkyd varnish + 10% dust | 16.609 | 29 | 16.6014 | 0.0076 | 0.00026 |
| | | 60 | 16.5993 | 0.0097 | 0.00007 |
| | | 202 | 16.6141 | -0.0051 | -0.00010 |
| | | 322 | 16.2307 | 0.3783 | 0.00320 |
| | | 513 | 14.307 | 2.302 | 0.01007 |
| | | 630 | 13.5656 | 3.0434 | 0.00634 |

Source: own work.

**Table 6.**
*Examples of corrosion test data for AW-6060+alkyd varnish+20% brick dust in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (4) AW-6060 + alkyd varnish + 20% dust | 16.7335 | 29 | 16.7251 | 0.0084 | 0.00029 |
| | | 60 | 16.7214 | 0.0121 | 0.00020 |
| | | 202 | 16.5483 | 0.1852 | 0.00092 |
| | | 322 | 15.0826 | 1.6509 | 0.00513 |
| | | 513 | 14.0462 | 2.6873 | 0.00524 |
| | | 630 | 13.4588 | 3.2747 | 0.00520 |

Source: own work.

**Table 7.**
*Examples of corrosion test data for AW-6060+alkyd varnish+30% brick dust in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (5) AW-6060 + alkyd varnish + 30% dust | 16.6328 | 29 | 16.6244 | 0.0084 | 0.00029 |
| | | 60 | 16.6237 | 0.0091 | 0.00015 |
| | | 202 | 16.5943 | 0.0385 | 0.00019 |
| | | 322 | 16.2146 | 0.4182 | 0.00130 |
| | | 513 | 14.3806 | 2.2522 | 0.00439 |
| | | 630 | 13.3861 | 3.2467 | 0.00515 |

Source: own work.

**Table 8.**
*Examples of corrosion test data for AW-6060+alkyd varnish+40% brick dust in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (6) AW-6060 + alkyd varnish + 40% dust | 16.867 | 29 | 16.8605 | 0.0065 | 0.00022 |
| | | 60 | 16.8628 | 0.0042 | 0.00007 |
| | | 202 | 16.9792 | -0.1122 | -0.00056 |
| | | 322 | 16.6784 | 0.1886 | 0.00059 |
| | | 513 | 14.4452 | 2.4218 | 0.00472 |
| | | 630 | 13.656 | 3.211 | 0.00510 |

Source: own work.

**Table 9.**
*Examples of corrosion test data for AW-6060+alkyd varnish+30% volcanic tuff in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (7) AW-6060 + alkyd varnish + 30% tuff | 16.276 | 60 | 15.914 | 0.362 | 0.00603 |
| | | 202 | 16.155 | 0.121 | 0.00060 |
| | | 322 | 15.677 | 0.599 | 0.00186 |
| | | 513 | 15.34 | 0.936 | 0.00182 |
| | | 630 | 15.104 | 1.172 | 0.00186 |

Source: own work.

**Table 10.**
*Examples of corrosion test data for AW-6060+zinc coating in a 2% HCl solution*

| Specimen | Initial weight of the specimen [g] | Exposure time [h] | Weight measurement [g] | Weight loss [g] | Corrosion rate [g/h] |
|---|---|---|---|---|---|
| (8) AW-6060 + zinc coating | 16.146 | 60 | 15.88 | 0.266 | 0.00443 |
| | | 202 | 15.969 | 0.177 | 0.00088 |
| | | 322 | 15.372 | 0.774 | 0.00240 |
| | | 513 | 14.73 | 1.416 | 0.00276 |
| | | 630 | 14.303 | 1.843 | 0.00293 |

Source: own work.

A summary of the test results showing percentage of weight loss as a function of time is shown in Figure 7.

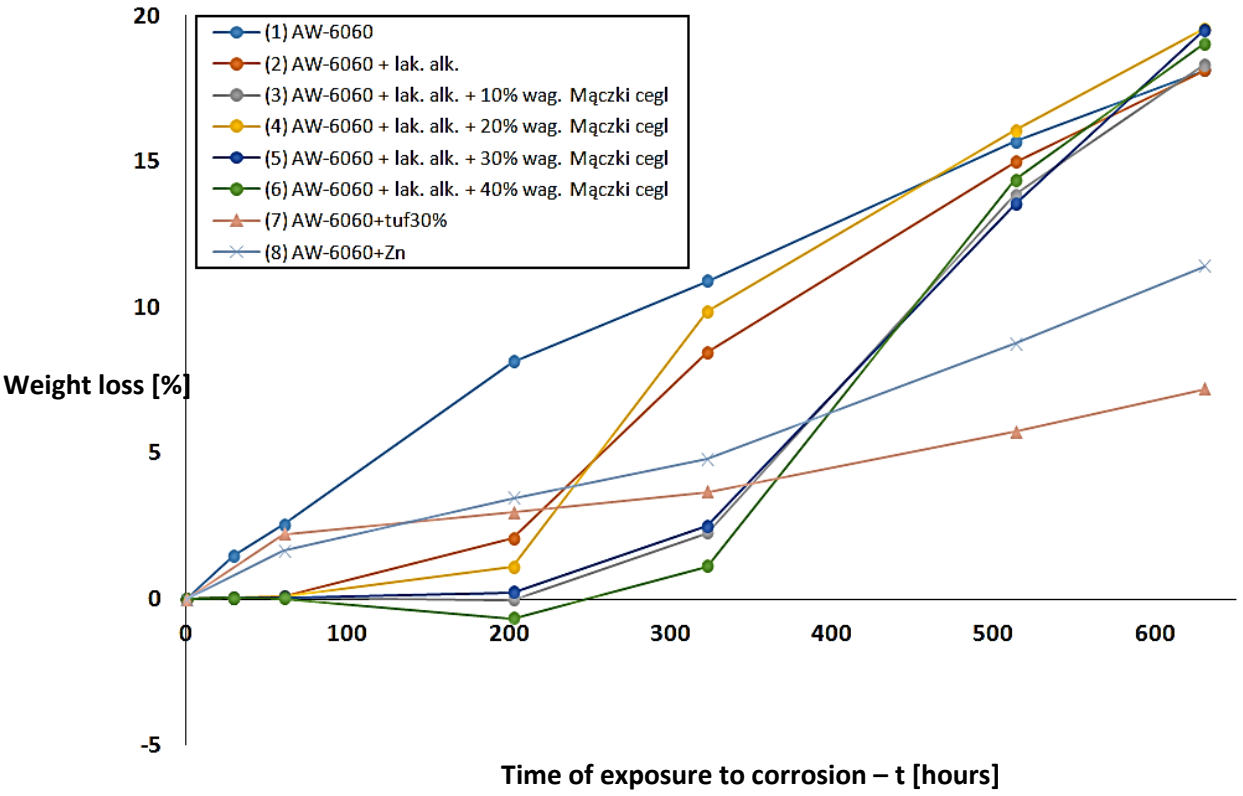


**Figure 7.** Percentage of weight loss for aluminium alloy AW-6060 in different configurations of corrosion protection layers as a function of time.

Source: own work.

During the study, photographs were taken of the specimens during the breaks when the specimens were weighed. A Levenhuk DTX 90 digital microscope was used to capture the changes in photographs. Figures 8-13 show a selection of the more interesting cases. The magnification of the images presented is 60x.

**Figure 8.** Specimen AW-6060 without corrosion protection coating – 630 hours.

Source: own work.

**Figure 9.** Specimen AW-6060 with alkyd varnish – 630 hours.

Source: own work.

**Figure 10.** Specimen AW-6060 with alkyd varnish +10% brick dust – 630 hours.

Source: own work.

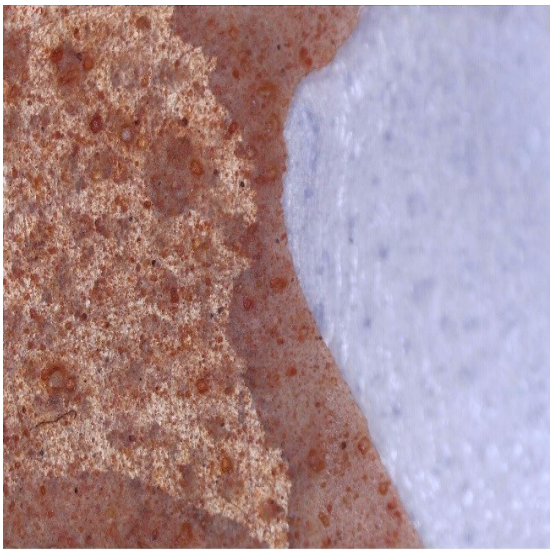

**Figure 11.** Specimen AW-6060 with alkyd varnish +20% brick dust – 630 hours.

Source: own work.

**Figure 12.** Specimen AW-6060 with alkyd varnish +40% brick dust – 630 hours.

Source: own work.

**Figure 13.** Specimen AW-6060 with alkyd varnish +30% volcanic tuff – 630 hours.

Source: own work.

The baseline specimen AW-6060 without a coating corroded in a manner close to rectilinear throughout the test range. Corrosion occurs in a uniform manner revealing the rolling direction (Fig. 8). This is the safest of all the possible types of corrosion due to its stability and predictability. Throughout the test period, hydrogen bubbles were present on the surface of the specimen indicating a process of progressive corrosion. This process took place without violent reactions. This therefore makes it possible to realistically estimate the service life of components exposed to a corrosive environment before they are replaced during maintenance. This type of assumption enables designing components with an additional allowance for excess material. The allowance is related to ensuring a safe cross-section over the entire range of use for the particular type and degree of load.

Alkyd varnish used as a varnish base in the initial phase of the process protects the metal from the corrosive environment. After approx. 200 hours this varnish peels off the surface at some spots where the target corrosion of the metal begins. Figure 9 shows a sample after 630 hours of testing. There are three zones visible on it. The first one is light grey with a well-adhered coating, the second one is in the form of a thin grey stripe indicating a lack of cohesion of the coating with the metal, and the third one is where the corrosion of the metal occurs. The weight loss relative to the base sample evens out after 630 hours of testing. To a large extent this is related to the peeling off of the coating which represents a sudden drop in the weight of the specimen. It can be assumed that the losses for both specimens will continue to be at a similar level.

Brick flour applied in weight concentrations of between 10% and 40% cannot be considered as a material that enables achieving satisfactory results (Fig. 10-12). This is related to the absorption of the corrosive medium by the brick dust. The absorption phenomenon allows the corrosive medium to penetrate and come into contact with the protected metal. The degree of

permeation depends on the percentage addition by weight – the higher the addition, the greater the absorption. This manifests itself as a swelling of the coating – without breaking the continuity of the coating. This is associated with an increase in weight – especially for the specimen with 40% addition of brick dust by weight (Fig. 7 – specimen (6) for test time t = 202 h). However, the process of corrosion does not occur instantaneously due to the preserved continuity of the coating. This significantly limits the exchange of the corrosive agent. It can be concluded that the flexibility of the coating is preserved. The acceleration of the corrosion process occurs due to a local break in the continuity of the coating at the sharp edges of the component (side edges). This results in a violent reaction in the form of the release of a significant amount of hydrogen bubbles over a relatively small area of the aluminium component. This causes dissolution of the metal and the formation of aluminium chlorides ($AlCl_3$). The process taking place is very unfavourable due to the change in the nature of the corrosion in relation to the baseline specimen (1) AW-6060 from uniform corrosion into uneven corrosion. If this is the case, estimation of the rate of the corrosion process and the effects that will arise becomes problematic. As a result of the observations, it should be noted that the coating (mainly for the 30% and 40% additive) does not degrade in the corrosive environment. For the purpose of photographing the metal surface, the protective coating was removed mechanically (Fig. 12). However, it retains its integrity by forming a permanent shell separated from the protected metal being an effect of subsurface corrosion. These coating discontinuities can be identified by the noticeable release of a significant quantity of hydrogen at the break points.

The volcanic tuff additive, 30% by weight, creates conditions that slow down the process of corrosion in the long term. In the first phase, small parts of the coating peel off (Fig. 13), which accounts for the initial increase in the percentage of weight loss. It can be concluded that although the coating itself does not perform its function sufficiently well, the volcanic tuff additive itself is a corrosion inhibitor. This effect was achieved and observed in the already mentioned studies conducted by Hebdowska M. & Mikuła J. for steel components. Our own investigation confirms the very good properties of volcanic tuff as it slows down corrosion processes and preserves the uniform corrosion of aluminium. The result obtained has the lowest weight loss values of all the specimens.

In the course of observing the specimens, it was noted that where the hole was made and its sharp edges were blunted, the degree of adhesion of the coatings was much higher than in the case of the sharp outer edges of the test pieces (Fig. 14).

**Figure 14.** Round hole in specimen AW-6060 with alkyd varnish +40% brick dust – 630 hours. Source: own work.

Due to structural considerations, a suitable method for preparing the components and blunting the sharp edges must be envisaged. It seems that the most sensible solution here is by rounding off sharp geometric transitions as this will increase the probability of maintaining the continuity of the corrosion protection coating over a wider range of time.

## 4. Summary

The revision of the so-called Waste Framework Directive (Directive (EU), 2018) introduces a new approach to waste management, moving away from thinking of waste in terms of an unwanted burden on the environment towards treating it as a valuable resource. This Directive primarily focuses on waste prevention and sets new targets that will help the EU achieve its overarching goal of becoming a recycling society.

The current approach to managing waste in the form of aggregates is mainly based on the construction sector. It should also be noted that construction and demolition waste is one of the most burdensome types of waste generated in the EU. It accounts for approx. 25-30% of all waste generated and consist of a wide range of materials, many of which can be recycled.

The investigation carried out by the authors of this paper was aimed at assessing the possibility of using engineering waste materials for corrosion protection of aluminium alloy components in contact with an aggressive corrosive environment with an acidic pH containing chlorine compounds. The varnish additives used in the tests were brick dust and volcanic tuff. Due to the lack of information regarding the possibility of using brick dust, different percentages of additives were used, ranging from 10% to 40% by weight. For the varnish-coated samples with volcanic tuff, the addition was 30% – this value is justified by research findings (Hebdowska-Krupa, Mikuła, 2006, 2007; Mikuła, Łach, 2012; Hebdowska-Krupa, M., Łach, M., Mikuła, 2016). The above studies show that the use of this additive does not adversely affect the properties of polymer products and it can be used successfully.

Based on the testing carried out in the form of weight loss measurements as well as observations of the processes taking place, the following conclusions can be drawn:

- In the context of the use of waste materials in the form of brick dust, the absorption (soaking) of the corrosive agent is a disqualifying factor.
- The addition of volcanic tuff to alkyd varnish has provided promising test results for components made of aluminium alloy.
- The preparation of all kinds of structural components for corrosion protection should include the blunting of sharp edges for better adhesion of corrosion protection coatings.

In accordance with the above, further work on volcanic tuff should focus on obtaining a coating with an adequate degree of adhesion as well as checking the action of tuff as an inhibitor in other corrosive media. In the case of brick dust, a desirable line of research would be to test the possibility of using it as a corrosion inhibitor in an atmosphere of different gases.

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