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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 41 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: marketing, Industry 4.0, production management, sustainability, logistics, safety management, finances, management systems, environmental management, human resources management, quality management, project management, public management, innovation management, technology management, impact of COVID-19 pandemic on management, business analytics, Smart City and cross-cultural management.

*Radosław Wolniak*





## THE COMPARABILITY OF NON-FINANCIAL INFORMATION IN INSURANCE COMPANIES

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**Purpose:** The paper aims to assess the comparability of non-financial information disclosed in the annual reports of insurance companies.

**Design/methodology/approach:** This study applies to the Polish insurance market. The reports of the following insurance companies have been evaluated: PZU, Ergo Hestia, and UNIQA. The methodology is based on the NiCE index of financial reporting quality assessment, though it's original. The authors have developed a method of evaluation suited to the specific nature of non-financial information. A set of six areas is prepared and a five-point Likert's scale is applied to assess how the criteria defined for these areas are fulfilled.

**Findings:** The comparability of non-financial information across insurance companies is a very difficult and subjective process. This is first of all due to the fact this information is not measurable and the structures of non-financial reporting by the particular companies are not formalised. The reports disclose some varied extents of details, not only for the particular undertakings, but even over years. This requires some systematic standards of non-financial reporting to be compiled and assessment indicators for the positions of insurance companies to be standardised in future.

**Research limitations/implications** Since the research sample was limited, the study should be treated as a pilot and its results as an introduction to further, more in-depth empirical research.

**Social implications:** Non-financial information relates to the realisation of sustainable development strategies, in particular, the ESG (Environment Social Governance) issues, and forms a major area of assessment of an economic undertaking's reliability. It's therefore important that it shows certain useful characteristics, in particular, comparability, especially important to decision-making processes. This study identifies some areas for improvement and thus contributes to the improvement and restricts the risk of the decision-making process in both insurance companies and organisations that constitute their social and economic environment.

**Originality/value:** This research extends the knowledge concerning the assessment of non-financial reporting quality and fills a gap in research into its comparability in insurance companies.

**Keywords:** insurance companies, non-financial information, ESG (Environment Social Governance) reporting, comparability of information.

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

## 1. Introduction

The comparability of information is expected to facilitate its utility and faithful representation of a business undertaking and its financial position. Information is considered more useful if it can be compared with other, similar information. The similarity of information relates to information arising from financial reporting by both various undertakings (comparability in space) and by a single undertaking compiled in different periods (comparability in time). Comparability is a most desirable feature of reliable reporting information, which also includes non-financial information, since it is part of the reporting systems of economic undertakings, including insurance companies. The comparability of non-financial information in insurance companies is important in the perspective of its utility as it provides foundations for a variety of assessments and managerial decisions, both operational, strategic, and investment. It should be noted, too, insurance companies are among public trust institutions, where the care for their image and financial situation is particularly important. The utility and especially the comparability of information is undoubtedly its essential feature whose presence helps to maintain the good image of a public trust institution, namely, an insurance company.

Insurance companies have been obliged to compile non-financial information covering environmental, social, and corporate governance issues since 01.01.2017. This arises from the provisions of the Directive 2014/95/EU concerning the disclosure of non-financial and diversity information by certain large undertakings and groups (Non-financial Reporting Directive, NFRD) and from the amended Accounting Act of 15 December 2016, which is adapted to that Directive. The Directive 2022/2464/EU with regard to corporate sustainability reporting (Corporate Sustainability Reporting Directive, CSRD) was accepted on 10 November 2022. It introduces some more detailed reporting requirements concerning the impact of economic undertakings on the environment, human rights, and society.

This study is therefore undertaken for the following reasons:

- The comparability of non-financial information in insurance companies is important in the perspective of its utility as it provides foundations for a variety of assessments and managerial decisions, both operational, strategic, and investment.

- The new ESG (Environmental Social Governance) regulations in connection with the European Green Deal – the Directive 2022/2464/EU with regard to corporate sustainability reporting (Corporate Sustainability Reporting Directive - CSRD), which changes the rules of reporting non-financial information.
- A research gap in respect of the comparability of insurance companies' non-financial information.

An assessment of the comparability of non-financial information disclosed by insurance companies in their annual reports is the purpose of this study.

The methodology is based on the NiCE index of financial reporting quality assessment, described by F. Beest and B. Geert (2009). Similar research has been conducted by Yurisandi, Puspitasari (2015) and Almehairi et al. (2021), among others. These evaluations have referred to financial information, thus the novelty value of this paper consists in adapting the methods applied to the evaluations of financial information to analysing the quality of non-financial information. This methodology is novel as it's suited to the unique nature of non-financial information. What's more, the earlier studies have not covered insurance companies.

In the first section of the paper, specialist literature on the comparability of non-financial information is reviewed; in the second part, the methodology is presented; the results of the authors' research are discussed in the third section, while these results are referred to similar research and conclusions are formulated in the final section.

This research extends the knowledge concerning the assessment of non-financial reporting quality and fills a gap in research into its comparability in insurance companies.

## **2. The comparability of non-financial information – literature review**

The comparability of reporting information is an important qualitative characteristic of statements and reporting.

Its preponderance over other qualitative features of financial reporting has been stressed by, among others, Hope (2004), Riahi-Belkaoui (2004), Skinner (2005), Sunder (2007), Cole et al. (2010, 2011).

The principle of comparability is realised as (IAS 1 Presentation of *Financial Statements*):

1. comparability over time – the financials of a given organisation from different periods are compared,
2. comparability in space – the financials of different economic undertakings are compared as part of sectoral, national or international comparisons.

It should be pointed out the drive towards the comparability of reporting information for successive periods can't be seen as a ban on the introduction of new, improved solutions. An organisation may change its existing solutions insofar as it serves the purpose of a clear and

reliable presentation of its position. Reasons for such a change must be identified then, their numerical impact on the financial result must be determined, and the comparability of financial statement for the year prior to the year of these changes must be assured. In effect of applying the comparability principle, the financial statement users must be informed about:

1. the accounting principles applied,
2. any changes of these principles,
3. any effects of such changes.

The literature review shows the following benefits can be identified of the realisation of the principle of reporting information comparability:

1. investors are able to identify and understand similarities and differences in financial statements - Chauhan, Kumar (2019),
2. a positive correlation with the precision and accuracy of managers' forecasts - Chen, Gong (2019),
3. the costs of obtaining financial information are reduced - De Franco, Kothari, Verdi (2011),
4. the uncertainty of assessment is reduced - Majeed, Chao (2022),
5. the level and quality of information disclosed are improved - Almehairi et al. (2021), Jibril (2019),
6. the asymmetry of information is reduced as the quality of financial statements is improved - Almehairi et al. (2021), Daske et al. (2008).

Non-financial information is part of the financial reporting system. Under the prevailing regulations (Article 49b of the amended Accounting Act dated 15 December 2016), it can be presented as a declaration of non-financial information or a separate statement on non-financial information from a single organisation or capital group, to be published at the website within 6 months of the balance closing date.

In line with Article 49b Section 2 of the Accounting Act, a non-financial information declaration should include a description of:

1. the business model of an organisation,
2. policies applied by an organisation with regard to social and labour risks, natural environment, respect for human rights, counteracting corruption, and of the results of these policies,
3. due diligence procedures,
4. major types of risks connected to an organisation's activities and the principles of their management.

As part of a financial statement, non-financial information should also exhibit utility, including comparability. Research in this respect commonly refers to:

- the quality of non-financial information – e.g., Szadziewska (2015), Krasodomska, Cho (2017),

- the standardisation of reporting - including Breijer, Orij (2022), Waniek-Michalak (2017), Krištofik et al. (2016),
- the impact of Corporate Social Responsibility actions on business image – for example, Axjonow et al. (2018),
- the impact of Corporate Social Responsibility actions on the financial results of reporting organisations – for instance, Crous et al. (2022), Lament, Bukowski (2022), Winman (2021).

Research into insurance companies' non-financial reporting, in particular, the quality and comparability of non-financial information, is not common, like the studies of insurers' accounting and its unique nature. Examples include Lament, Piątek (2023), Jonas (2020), Chmielowiec-Lewczuk (2018), Hołda, Staszal (2014), Karmańska et al. (2003). The literature review discovers the following assessments of non-financial information quality in insurance companies:

- K. Bauer, M. Chmielowiec-Lewczuk, M. Lament, E. Spigarska (2021) – a study of the quality of non-financial statements of selected insurance companies in the Polish market – it shows their varied quality.
- M. Lament (2017) – a study of the quality of non-financial statements drafted in 2001-2015 by insurance companies operating in Poland – it demonstrates their varying quality.
- K. Jonas (2017) – insurance and reinsurance companies active in Poland as of 31.12.2015 were examined. A review of the results points to a variety of ways non-financial information is presented.
- N.V. Kavitha, T. Anuradha (2016) – a study of good practices in Corporate Social Responsibility.
- M.M. Simona (2013) – 16 insurance companies operating in Romania were studied. Non-financial reports published in 2011 were covered. A variety of non-financial reporting principles was found. Only 2 companies prepared their non-financial reports in line with the GRI (Global Reporting Initiative) standard.
- Lock, P. Seele (2013) – 473 non-financial statements from chemical and finance (banks and insurance) businesses were reviewed. Economic undertakings active in Germany and Switzerland were analysed. The research concludes insurance companies have no standard ways of compiling non-financial reporting.
- B. Wieteska-Rosiak (2012) – a study of some social and environmental actions by selected insurance companies, i.e., PZU SA, STU Ergo Hestia SA, TU Allianz SA, ING Życie SA, TUiR Warta SA. The level of reporting on those Corporate Social Responsibility initiatives is very low.
- B. Scholtens (2011) – 153 insurance companies from 20 countries active in 2007 were examined. The analysis demonstrates social and ethical aspects are integrated into insurance activities better than environment issues. 25% of the insurance companies address all the categories involved in their reporting.

The results of the studies listed above show the quality of non-financial information from insurance companies is varied and requires improvements, e.g., in respect of comparability, a pre-requisite to the clarity and reliability of financial statements, necessary for the decision-making process to be realised. It needs to be noted all the research reviewed analyses the contents of non-financial statements as their methods and the techniques applied vary and basically involve a comparative analysis of some selected reporting areas and their contents. This means the methodology of studying the comparability of non-financial information requires improvements and some more standardised methods need to be found.

It should be stressed the comparability of non-financial information is important to both the undertakings drafting financial statements and to their environment, that is, it's crucial that the comparability of non-financial information be maintained both over reporting periods and between economic undertakings. Therefore, research into the comparability of non-financial information is topical as it helps to determine the weaknesses of existing solutions and identify some directions for their improvement, including also their methods.

### **3. A model for assessing the comparability of non-financial information in insurance companies**

The subject of comparability of insurance companies' non-financial statements is inspired by, among other motivations, an attempt at taking advantage of the insurance NiCE (*Nijmegen Centre for Economics*) model, encountered as part of the literature review. The model was developed by F. Beest and B. Geert (2009), then employed by T. Yurisandi and E. Puspitasari (2015) and M. N. Almehairi et al. (2021) to assess the quality of financial statements. The NiCE model is a comprehensive index for assessing the quality of financial reporting based on five qualitative characteristics, such as materiality, faithful representation, comprehensibility, comparability, and timeliness. These features were evaluated on a five-point Likert's scale. In the research mentioned above, the model serves the assessment of financial statements from all undertakings, not only financial institutions. The NiCE model allows for a comprehensive assessment of qualitative characteristics of a financial statement according to diverse criteria. In the case of comparability, it provides for an assessment both over time and in space. We believe it suffers from some limitations, too, first of all a subjective assessment of some factors.

Till now, the NiCE model has helped with assessing the quality of financial information and has inspired a proposal for a model that could be used to assess the comparability of non-financial information in insurance companies. The scope of information that must be presented by force of regulations became the starting point for the model. The scope of information itself

results from the regulatory requirements, however, the assessment of the accessibility and presentation of the information does not rely only on what is mandatory.

A universal tool is sought that could be modified and adapted to variable conditions, determined both by the regulations and the expectations of non-financial information users. It cannot rely on the regulatory requirements alone, therefore.

It can be concluded the scope of non-financial information under the model is a result of:

- the regulations of non-financial information reporting by insurance companies,
- the needs of stakeholders in non-financial information users.

In the event, the model identifies six areas that make up the objective scope of insurers' non-financial statements and should be assessed. These are (Bauer et al., 2021, pp. 129-131):

- business model,
- risk and the methods of risk management,
- environmental issues,
- social and labour issues,
- respect for human rights,
- counteracting bribery and corruption.

Likert's scale is used to assess non-financial information presented in the particular areas, just like in the NiCE model applied to financial information. The scale has five points, 1 to 5. The method of assigning scores is identical for all the six areas and covers:

1. organisational structure, including such detailed criteria as: the designation of affiliated organisations, the type and nature of their affiliations, relationships, both direct and indirect,
2. the environment, including such detailed criteria as: a description of market conditions, regulatory requirements, current situation in the market and competitors,
3. products, including such detailed criteria as: a description of product portfolio, identification of products key to a given insurance company that distinguish it, are innovative or have a large share in sales,
4. customer relationships, including such detailed criteria as: a description of customer service process, the characteristics of customer groups typical for a given insurance company.

The scopes of information to be assessed are not identical, on the other hand. They are more varied for the first two areas, i.e., business model and risk, and the same for the four remaining areas.

In all the areas, 1 is granted for the absence of any information about the area surveyed. A maximum of 4 can be awarded in the evaluation of key and detailed criteria. The latter, as highly varied, will be discussed for the particular areas to be assessed.

Table 1 lists the way non-financial information published by insurance companies about the business model is assessed.

**Table 1.***Scoring awarded for the evaluation of non-financial information about the business model*

Area	Assessment criterion/scoring
Business model	1 point - the absence of any information about the business model 1 point is then awarded for: <ul style="list-style-type: none"> <li>• Organisational structure (capital links, relationships);</li> <li>• Environment (market, conditions, regulations, external factors);</li> <li>• Products (portfolio offered);</li> <li>• Customer relationships (brand, customer value, etc.);</li> </ul> A maximum of 5 points if all the items are present.

Source: Compiled by the authors.

The criterion of business model assessment assumes 1 point is assigned where no information on this area is available. Thus, 1 is a negative evaluation, yet it's also the starting point to which scores are then added for the four remaining elements assessed as part of the first area. One point is assigned for information relative to each of the four business model components listed in Table 1.

Organisational structure is the first. A point should be granted where an insurance company presents its structure in a comprehensible, clear, and transparent manner. This means the information required should include not only the names of affiliated entities but also how they are affiliated and what the type of their relationship is (e.g., information on shareholdings in the particular entities). A user should be able to determine the degree of this affiliation, which is of great importance to the possible effects of e.g., group decisions or financial issues. The absence of full information means no points, 0.

The environment is the second element to be evaluated as part of the business model. Like in the case of organisational structure, 1 point should be given if an insurance company discloses information about the market, its conditions, regulations, and competition in full, clearly and intelligibly to users (e.g., addressing market threats and opportunities, the biggest competitor, the changes of insurance regulations).

Products are the third part of the business model. Information about the portfolio of insurance products is evaluated here. An insurer should present their products in a clear and comprehensible way, so that users are capable of placing a given insurance company in the insurance market, indicating products typical for a given insurer or which are their speciality. Thus, an insurer should base this information on their sales range.

Customers are the final element of the business model. A point is awarded where an insurance company presents and describes its customer relationships, customer service, information policy, as well as the perception of the insurer's brand among customers. This information substantially contributes to the creation of an insurance company's image, which plays a major role in the process of customer acquisition. Insurance products are sold under contracts, occasionally long-term, and the capacity for acquiring custom is largely conditional on what trust they have in a given organisation.

Table 2 describes how non-financial information published by insurance companies about risk and the way it is managed is assessed.



**Table 2.**  
*Scoring awarded for the evaluation of non-financial information about risk and the methods of its management*

Area	Assessment criterion/scoring
Risk and the methods of its management	1 point - the absence of any information about risk 1 point is then awarded for: <ul style="list-style-type: none"> <li>• Potential impact and its likelihood;</li> <li>• Time framework and the scale of impact;</li> <li>• Management costs;</li> <li>• Methods of risk analysis;</li> </ul> A maximum of 5 points if all the items are present.

Source: Compiled by the authors.

The method of assessment in the second is the same as in the first area. Other elements are evaluated, however.

One point is assigned only if no information on risk is provided. One point for the assessment of each of the four elements making up risk and the methods of its management is then added to the base 1 point.

The first element relates to the assessment of the potential impact and likelihood of risk on the operations of a given insurance company. The way and scope of disclosure of this information should be clear and transparent to users. It shouldn't only refer to financial or liquidity statements, prepared above all due to the requirements of supervisory authorities, therefore, but should allow all stakeholders to assess the types of risk applicable to a given insurer and the ways they are managed.

The determination of time framework and the scale of risk's impact on an insurance company's operations is assessed as the second element. This assessment is part of the model in order to verify whether this information is presented clearly and intelligibly to every user. This is often additional information, absent from financial reporting. It ought to be 'translated' from the financial to non-financial language.

Another element evaluated in connection with risk is the information about the costs of risk management. The way clear and comprehensible information about this subject is published is subject to assessment. It needs to be remembered this is not only about the value and level of the costs, as this is financial information, but about a description which is designed to explain decisions and actions that are part of an insurer's risk management process. Like in the case of the other scores, this information is to be intelligible to all stakeholders.

The method of risk analysis is the final part in the risk-related part. The criterion of its assessment is similar to the foregoing elements. One point is awarded where an insurance company describes, in a clear and comprehensible manner, how it analyses and selects risk, captures heightened risks, analyses both the internal and external sources of risk, how it monitors risk levels or undertakes due diligence activities.

The next four areas are evaluated in the same way. The criteria of this assessment are shown in Table 3.

**Table 3.**

*Scoring awarded when evaluating non-financial information concerning: environmental, labour, and social issues, respect for human rights, counteracting bribery and corruption*

Area	Assessment criterion/scoring
Environmental, labour, and social issues, respect for human rights, counteracting bribery and corruption	1 point- the absence of any information 1 point is then awarded for: <ul style="list-style-type: none"> <li>• Policy description;</li> <li>• A description of the policy's effects;</li> <li>• A description of key indicators;</li> <li>• Information about impact on financial results.</li> </ul> A maximum of 5 points if all the items are present.

Source: Compiled by the authors.

The method of assessment for the remaining four areas is identical, namely, 1 point is given if there is no information and this single point is the base to which the successive scores are added. The maximum score is 5, where one point is given to all the components. The scope of information is the same for all the four areas, though.

A policy description is the initial element to be evaluated, of course, this refers to the policies concerning environmental, social, labour, and other respective issues. In this connection, an assessment depends primarily on the fact whether such a description is available. In addition, the evaluation should also be applied to the question if a description is comprehensible to the users of non-financial information.

The effects of policies in a given area are then assessed. An insurance company should clearly state what are the effects of a policy adopted in a given area. These effects may vary, yet first of all, actions undertaken must be shown and references made to changes during several years.

A description of key indicators in an area is the following element. This is quite strongly quantitative and its evaluation is relatively simple.

The last element to be evaluated is the information about the impact of policies giving rise to actions in a given area on financial results. This element comes last, but is of paramount importance as it points to relationships between non-financial and financial information, crucial to the understanding of the need to have non-financial information published by insurance companies and of its utility. These are not two separate areas of action, since any action, even if not always measurable and quantitative, has financial consequences, both direct (costs) and indirect (improved sales). To understand the current and future financial position of an insurer in full, stakeholders need both financial and non-financial information.

This model is a proposal that may require improvement and modifications, since the subject of non-financial reporting is relatively new and a number of questions must still be specified and regulated in more detail. Nonetheless, non-financial reporting has already become part of business practice that gives rise to a range of debates, ambiguities, and problems. A standardised presentation of this information is another step which should facilitate its comparability but will beyond any doubt also affect the proposed model for assessing the comparability of non-financial information.

## 4. Results

The study using the proposed model of comparability assessment of non-financial information relates to three years in the Polish insurance market, i.e., from 2019 to 2021. A review of the scopes of non-financial information published and available on the websites of insurance companies active in both the categories suggested its availability is very limited. This restricted the objective scope of this research. In addition, no full report on non-financial information for 2021 was found for Ergo Hestia in a file format, only a report of a somewhat different nature was available on socio-economic effects. A sustainable development report of that group for 2021 was published on the website as tabs, not a solid description. It's not addressed in this paper as a result.

Therefore, these results should be seen as a pilot study and a point of reference for future research. The reports of the following insurance companies have been evaluated: PZU, Ergo Hestia, and UNIQA. Six areas designated as factors (S) are assessed, numbered 1 through 6.

### 4.1. Business model (S1)

Table 4 contains the review results for the 2019-2021 reporting in respect of factor S1.

**Table 4.**

*Business model (S1) – results*

Entity/year	2019	2020	2021
PZU	3	3	4
ERGO HESTIA	5	4	na*
UNIQA	3	4	3

na\* - not applicable

Source: Compiled by the authors.

As part of S1 assessment, 2-5 points are assigned for the descriptions of:

1. organisational structure, including such detailed criteria as: the designation of affiliated organisations, the type and nature of their affiliations, relationships, both direct and indirect;
2. the environment, including such detailed criteria as: a description of market conditions, regulatory requirements, current situation in the market, and competitors;
3. products, including such detailed criteria as: a description of product portfolio, the identification of products key to a given insurance company that distinguish it, are innovative or have a large share in sales;
4. customer relationships, including such detailed criteria as: a description of customer service process, the characteristics of customer groups typical for a given insurance company.

The study concluded the results are relatively good and similar for all the three entities. Ergo Hestia stands out, scoring the maximum in 2019. That information was not 100% full, however, but extensive enough to establish the undertaking meets the requirements and criteria of assessment.

It should also be noted the assessment results fail to display a growing trend and even occasionally deteriorate. This may be evidence that, any standards absent, insurance companies don't know how to report non-financial information and look for solutions to meet user requirements.

Information about the environment and products was the most frequently missing. On the other hand, information on the organisation structure was available but incomplete, the relationships were not described and only the names of affiliated entities were given. The presentation of customer relationships proved best.

#### 4.2. Risk and the methods of its management (S2)

Table 5 contains the review results for the 2019-2021 reporting in respect of factor S2.

**Table 5.**

*Risk and the methods of its management (S2) – results*

Entity/year	2019	2020	2021
PZU	1	3	2
ERGO HESTIA	2	2	na*
UNIQA	2	2	2

na\* - not applicable

Source: Compiled by the authors.

As part of S2 assessment, 2-5 points are assigned for the descriptions of:

- 1) Potential impact and its likelihood,
- 2) Time framework and the scale of risk impact,
- 3) The costs of risk management,
- 4) The methods of risk analysis.

The results for S2 were markedly worse than for the remaining factors. The maximum of 3 points was scored by PZU for 2020. Interestingly, PZU was granted the lowest result, 1, meaning the lack of any information for the area, for the preceding year, 2019. Its remaining scores were 2. Since 1 point means the absence of information, 2 denotes the publication of non-financial information on risk to a minimum extent. A point was added for information about the methods of risk analysis in each case. Only PZU's report for 2020 indicated the time frame and the scale of risk impact.

In non-financial reporting, the organisations referred their users to solvency reporting as far as risk information was concerned. This is an error, since the nature and users of these reports are different. Non-financial risk information should supplement, not replace, financial information about the same risks.

### 4.3. Environmental issues (S3)

Table 6 contains the review results for the insurers' 2019-2021 reporting in respect of factor S3.

**Table 6.**  
*Environmental issues (S3) – results*

Entity/year	2019	2020	2021
PZU	4	4	4
ERGO HESTIA	4	4	na*
UNIQA	4	4	3

na\* - not applicable

Source: Compiled by the authors.

As part of S3 assessment, 2-5 points are assigned for the descriptions of:

1. the policy, including such detailed criteria as an insurance company's declaration on environmental management, the extent and objectives of the impact, management support, and links between the policy and the main business strategy of the organisation,
2. the policy effects, including information about: the environmental management system and its parts, an assessment of an insurance company's environment impact, the division of environment protection responsibilities, staff awareness raising and training, improvements to products' energy efficiency, waste reduction, external environmental audits,
3. key performance indicators divided into those related to energy, water, and material consumption, the share of renewable energy sources, greenhouse gas emissions, water and air pollution, waste production,
4. impact on the financial result.

It turns out PZU scores highest among all the evaluations under all the criteria tested, namely, 4. Environment issues were discussed clearly and most detailed criteria were addressed. Ergo Hestia's reports for 2 of the years reviewed scored 4 as well.

What is noteworthy, the assessments of Uniq'a's descriptions of environmental issues diminished over time. All the insurance companies reviewed were graded 4, the highest assessment scored, in 2019 and 2020. However, Uniq'a's 2021 report contained less information about environmental issues than its reporting in the earlier years did.

No information on the impact of environmental actions on the financial performance was provided in any of the reports. The process of assessment raised doubts as to the detailed criterion of management support for the realisation of the environment policy. Since the very fact an undertaking is involved in such actions suggests management support, the criterion was found to be met.

#### 4.4. Social and labour issues (S4)

Table 7 contains the review results for the insurers' 2019-2021 reporting in respect of factor S4.

**Table 7.**  
*Social and labour issues (S4) – results*

Entity/year	2019	2020	2021
PZU	4	4	4
ERGO HESTIA	4	4	na*
UNIQA	4	3	3

na\* - not applicable

Source: Compiled by the authors.

As part of S4 assessment, 2-5 points are assigned for the descriptions of:

1. the policy, including planned social commitment actions, particularly in the fields of education, health and safety, and culture; in respect of labour rights, the transparency of actions in the area of working conditions and the rules of remuneration,
2. policy effects, including welfare policy actions (such as COVID-19 protection, the promotion of healthy lifestyle, safety, cultural sponsorship or charity actions) and policy on labour issues (including working conditions, the rules of remuneration, corporate culture, worker protection against COVID-19, employment health and safety, cooperation with trades unions, professional staff development, extra non-financial actions for employees and their families),
3. key performance indicators, e.g., the structure and levels of spending on social issues, the quantity of actions promoting healthy lifestyle, the structure and numbers of volunteer actions, the quantity of actions supporting culture, the average base wages of women and men (the Gender Pay Gap indicator), the gender and age structures of staff, the structures of educational qualifications and jobs, the number and frequency of work-related accidents, the numbers of trades union members, the number of hours for training, the numbers and types of non-wage benefits, indicators related to staff medical testing, the number of workplace accidents, the number of those leaving their jobs,
4. impact on financial performance.

The data analysed suggest social and labour issues are most clearly regulated by PZU. It describes its social and labour policy actions at a great length. It is clear employment issues are of the essence to most insurers. The insurance companies examined are aware staff development affects company development. Care for worker health is of paramount importance, which became especially evident during the COVID19 pandemic. The impact of social and labour issues on financial performance was not addressed in any of the reports. It's quite understandable in the former case, however, the effect of questions like wages or training on the insurers' performance deserves more attention.

#### 4.5. Respect for human rights (S5)

Table 8 contains the review results for the insurers' 2019-2021 reporting in respect of factor S5.

**Table 8.**

*Respect for human rights (S5) – results*

Entity/year	2019	2020	2021
PZU	4	4	4
ERGO HESTIA	4	4	na*
UNIQA	4	4	3

na\* - not applicable

Source: Compiled by the authors.

As part of S5 assessment, 2-5 points are assigned for the descriptions of:

1. the policy, including adherence to major legal regulations, the determination of principles of respect for human dignity, non-discrimination against particular social groups, and of clear recruitment rules,
2. the policy effects, including any actions for diversity and respect for human rights (such as the prevention of mobbing, discrimination based on gender, nationality, race or religious convictions), respect for human rights in customer relationships (e.g., oriented products, including services for children, the elderly and disabled), the application of gender equality policies, the promotion of a corporate culture based on the respect for human rights following the principles of the UN Universal Declaration of Human Rights,
3. key performance indicators, e.g., the composition of supervisory authorities, management and supervisory board in terms of gender, age, and diversity – employees by age and origin,
4. impact on financial performance.

Ergo Hestia deserves particular attention as far as the human rights information is concerned. For instance, in 2019 it compiled a version of Sustainable Development Report dedicated to the visually impaired, entitling its 2020 report 'Man is Born Again'. It should be noted, too, PZU paid special attention to the presentation of human rights results with regard to gender and age.

What is important, insurance companies devote increasing space to respect for human rights, however, they should continue improving their actions in this respect. The impact of human rights issues on the financial performance wasn't mentioned in any of their reporting, possibly because these issues are hard to measure.

#### 4.6. Counteracting bribery and corruption (S6)

Table 9 contains the review results for the insurers' 2019-2021 reporting in respect of factor S6.

**Table 9.**  
*Counteracting bribery and corruption (S6) – results*

Entity/year	2019	2020	2021
PZU	4	4	4
ERGO HESTIA	2	2	na*
UNIQA	4	1	3

na\* - not applicable

Source: Compiled by the authors.

As part of S6 assessment, 2-5 points are assigned for the descriptions of:

1. the policy, including a public undertaking to follow legal regulations and information about management support,
2. the policy effects, including a description of anti-corruption programmes and supervision, the ways of internal programme communication, the means of counteracting bribery and corruption, the frequency of anti-corruption system verifications, the process of monitoring and continuous improvement, requirements set to business partners,
3. key performance indicators, e.g., the number of workers trained on anti-corruption policies, corruption risk assessment, the examination of staff awareness, the numbers of court cases, and penalties,
4. impact on financial performance.

PZU was found to score the highest, that is, 4, on all the test criteria. The questions of counteracting bribery and corruption are discussed in depth, even designating the types and values of gifts that employees can accept, and describing the procedure in case these values are exceeded.

Information on the impact of actions to counteract bribery and corruption on the financial performance is not provided in any of the reporting. The realisation of the detailed criterion of management support for counteracting bribery and corruption raised doubts in the assessment process, too. Since the very fact such actions are conducted suggest management support, this criterion is treated as fulfilled.

## 5. Discussion

The authors have found some aspects other than the factors studied affect the comparability of non-financial reporting.

First, reports on non-financial information are hard to obtain. Institutions like insurance companies, public trust entities, can be expected to share information about their environmental, social, and economic actions with stakeholders interested in these areas. As part of this research, financial statements were only procured from 3 out of 15 insurance companies listed by the



Polish Chamber of Insurance PIU (2021) as operating in category I and 15 listed in category II<sup>1</sup>. We believe it would be advisable to publish this information in downloadable files on websites to improve the information policies of insurance companies in this respect. Insurance activities in various countries pose a challenge. Where a parent entity is based in another country and non-financial statements are compiled in a language other than of group members, attaching translations into the languages of all daughter companies to websites seems recommendable. In practice, only a single insurer, UNIQA, has taken such a step.

The comparability and even the very procurement of non-financial information is also hindered by a great variety of nomenclature of this reporting. This diversity can be observed not only between the particular insurance companies but also across the reporting periods examined. This is an impediment to research by means of internet browsers. A great divergence of volumes of the reports studied is another distinct and major interference with the comparability both in time and space. The relevant details are included in Table 10.

**Table 10.**

*The names and numbers of pages of non-financial reports by the insurance companies reviewed*

Year	Document name	Pages in non-financial report
<b>PZU</b>		
2019	Statement of non-financial information of PZU and PZU SA Capital Group for 2019	88
2020	Statement of non-financial information of PZU and PZU SA Capital Group for 2020	112
2021	Statement of non-financial information of PZU and PZU SA Capital Group for 2021	124
<b>Ergo Hestia</b>		
2019	ERGO HESTIA. Care. Community power. SUSTAINABLE DEVELOPMENT REPORT 2018-2019	131
2020	ERGO HESTIA. Care. SUSTAINABLE DEVELOPMENT REPORT 2020	111
2021	A diversity of perceptions, interpretations, and actions. Sustainable Development Report of ERGO Hestia Group 2021	na*
<b>UNIQA</b>		
2019	LIVE SAFER, BETTER, LONGER. The statement of non-financial information 019. UNIQA Insurance Group AG	45
2020	SEEDING THE FUTURE. Non-financial report 2020 UNIQA Insurance Group AG	58
2021	Non-financial statement 2021. UNIQA Group. Living better together	21

na\* - not applicable. A report on non-financial information presented as website tabs

Source: Compiled by the authors on the basis of the insurance companies' non-financial reporting.

The analysis of non-financial reporting also suggests no clear trend in their volumes (more or fewer pages). Increasing the volume of a statement/ report can be seen as a good development, on the one hand, as a growing quantity and accuracy of information can be expected. On the other hand, it can be feared very extensive reports will also include immaterial data that will obscure essential information (the so-called information noise). At this stage of

<sup>1</sup> Since some insurance companies have separate entities operating in categories I and II, yet their non-financial reports are prepared jointly, the study covers a total of 20 insurance undertakings. They are detailed in the Methods section. As part of the research, PKO Bank Polski SA Capital Group Board Report was secured, including a non-financial section. As no mention of insurance activities was made there, this reporting has been excluded from the study.

their research, the authors only point to the lack of such a tendency and make no judgment whether increasing the volumes of non-financial reporting is a good, neutral or negative development. The authors believe the substantial fluctuations in the numbers of pages of Uniqua's non-financial reports (45 (2019) – 58 (2020) – 21 (2021) pages) can be seen to adversely affect the comparability of these statements. The changed presentation of non-financial information by Ergo Hestia for 2021, i.e., as tabs on its website, hinders the comparability as well.

In four out of six areas evaluated (namely, environmental, social and labour issues, respect for human rights, and counteracting bribery and corruption), the authors looked for any descriptions of the impact of environmental, labour, and corporate governance actions on financial performance. The impact has been shown in none of the reporting assessed. Although the authors are convinced such information would be important, addressing this criterion in any further evaluations of larger research samples should be considered.

Although a precise scoring for the particular main categories was adopted, their assessment was subjective. As it was hard to assign scores to the particular, detailed criteria as part of the key criteria (i.e., policy description, a description of policy effects, a description of key indicators)<sup>2</sup> in each of the six areas, the authors are thinking of expanding the grading scale.

## 6. Summary

A literature review and empirical research were carried out to analyse the comparability of non-financial reporting from insurance companies. Non-financial reports of 3 companies (PZU, Ergo Hestia, and UNIQA) for 3 years (2019, 2020, 2021) were surveyed as part of the empirical study. The choice is due to the limited availability of non-financial information on insurers' websites, which has restricted the subjective scope of the study. Six areas were assessed, i.e., business model, risk and its management, environmental, social, and labour issues, respect for human rights, and counteracting bribery and corruption.

The research and literature review suggest the following conclusions:

- the methods of presenting non-financial information by insurance companies are highly varied, which greatly obscures their comparability,
- the scopes of most non-financial information can be considered relatively good and similar for all the three undertakings in some areas,
- 4 on a five-point scale was the most common rating of non-financial information comparability,

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<sup>2</sup>The main and detailed criteria of evaluation in the particular areas are described in the Methods section.

- what's noteworthy, the scopes of non-financial information made available vary in time and occasionally contract instead of expanding,
- the appearance of reports and other non-financial information changes as the insurers learn how to present them,
- since the ways of presenting the information are not standardised (in the period reviewed), it's very difficult to assess and compare the information and, in particular, to draw any far-reaching conclusions,
- as non-financial information is not measurable, its presentation is narrative,
- non-financial reporting affects the creation of an insurer's image, therefore, this subject matter will be of paramount importance in the coming years,
- non-financial reporting combined with financial reporting make up a full view of an insurer and allow stakeholders to assess a company properly.

As the research sample is limited, the study doesn't allow for the creation of a model for the assessment of non-financial information comparability and should be treated as a pilot project. The results can serve as a starting point for further, more in-depth empirical research. The development of systemic standard non-financial statements and a standardisation of indicators to assess the situation of insurance companies is another recommendation.

Non-financial information is an important part of sustainable development. It's therefore necessary to maintain its adequate features, in particular, comparability. It influences the quality and transparency of decision-making processes. This study is part of research into sustainable development, in particular, reporting information about sustainable development.

This study fills a research gap in the assessment of the comparability of insurance companies' non-financial information by reviewing the current state of affairs with reference to new regulatory challenges and determining an original methodology of assessment. It's important to both insurance companies and their stakeholders, in particular, policyholders, that is, those deciding to purchase insurance protection.

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## UNDERSTANDING THE POWER BEHIND INFLUENCER MARKETING IN TODAY'S WORLD

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**Purpose:** Today's marketing observes many changes. Especially the after-pandemic world empowered skilled individuals, called influencers, to affect quantifiable actions or buying habits of their audience, by uploading some form of content on their social media platforms. Often such following is gathered on YouTube, Instagram, TikTok or LinkedIn. Influencers increasingly provide sources of information and innovation to many consumers. Those techniques sell regardless of the influencer's knowledge on the matter. Proposed article highlights how a congruence psychological mechanism, leveraged in influencer marketing proposes success to many businesses of today's world, mentions the costs of it, the need for its presence in companies' yearly budgets, as well as marketing power behind the newly created phenomenon.

**Design/methodology/approach:** The paper uses the desk research method of analysis.

**Findings:** Today's marketing is highly affected and shaped, to a tremendous degree, by the social media world as well as its influencers who nowadays create the newest trends in the advertising sphere.

**Social implications:** Social needs should be highlighted as a priority and implemented solutions should be adopted accordingly.

**Originality/value:** The article is an original approach to understand the newest ways marketing is created, as well as how much value (monetary and not only) is present in this way of advertising.

**Keywords:** influencer, marketing, influencer marketing, new advertising, digital marketing, social media.

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

## 1. Introduction

By some the current stage of civilization development is referred to as the Information Age; to others is it rather understood as the Entertainment Era. Meaning, many of our life decisions, shopping, finding the right education, job, place to live or even a life partner is based on the well-crafted marketing hiding in various forms of entertainment. As follows, the basic attribute of such development is information management which mostly uses the Information Technology and Cybersecurity, so called ICT. As a matter of fact ICT, refers to the components and infrastructure that allow modern computing (App, 2023), which undoubtedly gave rise to the New Economy and changed the way of operating for many businesses around the world. As a result to unlimited access to information and free transfer of knowledge among all market entities, the Web 2.0 that make possible creation and exchange of user-generated content” (Kaplan, Haenlein, 2010). Web 2.0 phenomenon was the effect of creating a new quality of websites where the Internet had ceased to be a network of interconnected files of information, and had forms of their functioning are constantly changing. The dissemination of information and communication technologies has changed the concepts of modern marketing. Influenced by global Internet network, technology information and communication technologies, evolve into the form of technological marketing, becoming the basic area of activity for many businesses, organizations, determining their development, openness to innovation and comprehensive change for ways of functioning (Mazurek, 2018).

Solutions for using newer and newer technologies, constantly displace traditional tools (Łaszkiwicz, 2022). Social media is referred to as “a group of web applications based on the ideological and technological foundations of to evolve into a network of relationships interpersonal interactions” (Opalska-Kasprzak, 2016). As a matter of fact, it is a space for active individuals, social groups, institutions, business entities (Peszko, 2016).

Originally created Social Media had an intention of “supporting” human interactions; however now, the same medium of communication is used to do so much more. As nowadays, humans do not just receive the “support,” but at times they rely almost every aspect of their lives on the use of technology. That increase of the need for technology significantly changed the functioning of societies in most of the countries in the world, but more so the well-developed ones. Therefore, as described by Dr Magdalena Brzozowska-Wos in an information society, a network society, was created (Brzozowska-Woś, 2013). Its functioning does not only concern technological aspects, but also, above all, cultural aspects (Dąbrowska, Wódkowski, Janoś-Kresło, 2009).

In addition to private use, social media is used for promotional purposes such as advertising. As follows, it seems to be not only an important element of the activity of many entities wishing to reach a large group of potential customers, but it also seems to be almost the “only way” to find today’s client, regardless of the product in question.



## **2. The importance of online marketing in Poland**

As published in the Global Digital Insights Report, the state of digital adoption in Poland in 2023 is quite intriguing. In a country of a total population of 41.48 million, in January 2023, there were 36.68 million Internet users, which makes up for 88.4% of the country's population. Out of that impressive number, the social media was used by 27.50 million, equating to 66.3% of the total population. What is even more interesting is the number of cellular connections in the whole country, it made up for 52.95 and that figure is equivalent to 127.7% of the whole population. "Kepios analysis indicated that Internet users in Poland increased by 2.9 million (+8.5 percent) between 2022 and 2023"(Kemp, 2023).

The information published in the ad planning tools of top social media platforms indicated that there were 24.10 million users aged 18 and above using social media in Poland at the beginning of 2023, which was equivalent to 71.0%. More broadly, 75.0% of Poland's total Internet user base (regardless of age) used at least one social media platform in January 2023. At that time, 50.6% of Poland's social media users were female, while 49.4% were male (Kemp, 2023). Especially the last information was extremely prominent throughout the whole study.

### **2.1. Usage of Facebook**

When it comes to the most famous platforms, Facebook (the parent company, which in 2021 has changed its name to Meta, in reference to the metaverse, which combines social media with virtual and augmented reality) (Houge, 2023), had 17.85 million users in Poland in the early 2023. Which means, that anything advertised on that particular platform would have a reach of 43% of households. Again, advertising catered more towards women would be advisable on this particular media outlet, since females use this platform more often than men, ranking 53.4% compared to the male representation of 46.6%.

### **2.2. Usage of YouTube**

"Updates to Google's advertising resources indicate that YouTube had 27.50 million users in Poland in early 2023. (...) However, the company's own data suggests that YouTube's ad reach in early 2023 was equivalent to 66.3 percent of Poland's total population at the start of the year. To put those figures in perspective, YouTube ads reached 75.0 percent of Poland's total Internet user base (regardless of age) in January 2023"(Kemp, 2023). Again, almost 51% of the audience were women, even in the products which were potentially considered more "men interest dominated", which made up for a clear indication of the marketing demographic.

### **2.3. Instagram users in Poland**

"Numbers published in Meta's advertising tools indicate that Instagram had 10.40 million users in Poland in early 2023. The company's recently revised figures suggest that Instagram's

ad reach in Poland was equivalent to 25.1 percent of the total population at the start of the year. However, Instagram restricts the use of its platform to people aged 13 and above, so it's helpful to know that 28.8% of the "eligible" audience in Poland uses Instagram in 2023. In early 2023, 57.8% of Instagram's ad audience in Poland was female, while 42.2% was male" (Kemp, 2023). Again, the composition of that statistic clearly indicates who the adds should be geared towards.

#### **2.4. TikTok users in Poland in 2023**

Figures published in ByteDance's advertising resources state that this social media platform had 10.14 million users aged 18 and above in Poland in January 2023. The same report mentions that TikTok ads reached 29.9% of all adults aged 18 and above in Poland at the start of 2023. As follows also this platform has more female (almost 55%) than male users (Kemp, 2023).

#### **2.5. Polish representation of LinkedIn**

Figures published in LinkedIn's advertising resources indicate that LinkedIn had 5.50 million "members" in Poland in early 2023. The company's advertising reach figures suggest that LinkedIn's audience in Poland was equivalent to 13.3% of the total population at the start of 2023, and the writer of portrayed article decided to mention this particular platform mostly because, it is one of not many popular social media platforms where a major part of the statistic 51% is assigned to the male audience.

#### **2.6. Following of Pinterest in Poland**

Not as common or widely understood as a platform – Pinterest has a very short lifespan. As it is mostly used by individuals who are looking for creative solutions only for a short period of time. Majority of the users download the application for up to 33 days and use it mostly in their free time, from 8-11 pm. With its peeking hour 9 pm (Marie, 2023). Data published in Pinterest's advertising resources indicate that Pinterest had 5.42 million users in Poland in January of 2023. However, the interest for the platform is growing as it increased by 1.2 million (which makes up for 28% of an additional audience) within just one year from 2022 to 2023. As the report progresses, it implies that almost 80% of users are made up by females (Kemp, 2023). Therefore, the question of - who the target demographic is - does not seem to present a high level of difficulty while answering and creating adequate marketing campaigns.

The portrayed data indicates that Facebook (Meta) is among the most popular platforms. YouTube, LinkedIn and Instagram (Jung, 2010) or any of these mediums have similar ideas, but slightly different functions (Marzec, 2022). Overall, social media is the foundation of personal entertainment, as well as today's way of creating a successful business. The idea of such means (for communities getting together, having something advertised to them and purchasing it), is known in the history of civilization for a long time, but the Internet has introduced an element of a mass communication to the process and that is quite innovative.

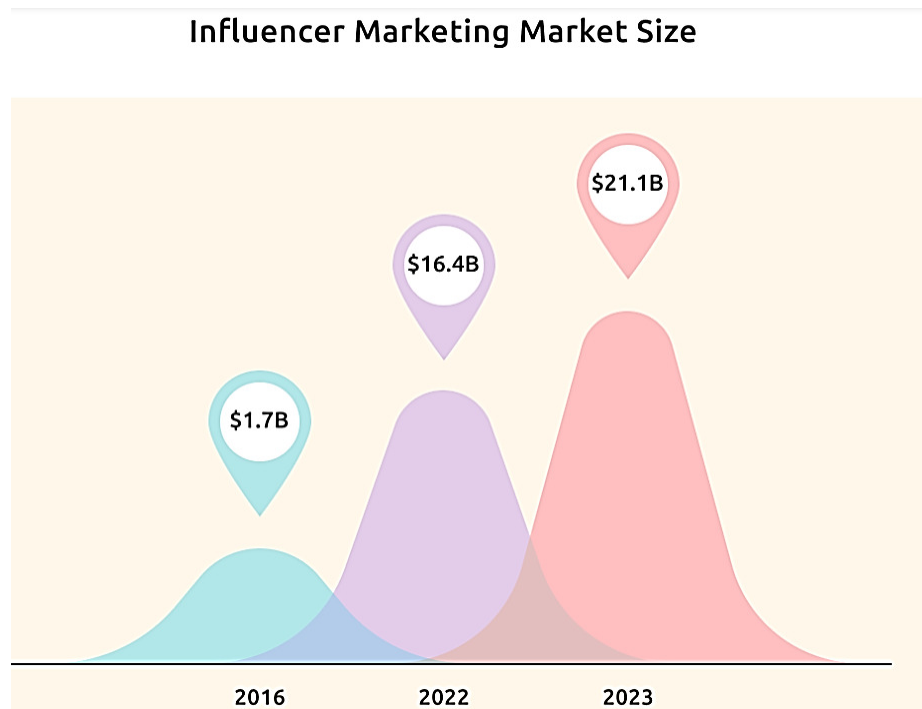
The author of portrayed article created a study in one of the taught be her classes, where 100 participants (73% women, 27% men, aged 19-24) were asked to answer a couple of Internet/influencer marketing related questions, to which answers presented themselves accordingly:

- How many of you does not read the online reviews before buying anything?  
There was no positive answer.
- On average how many times do you buy products advertised to you by your favourite influencer (given that you can afford it)?  
87% of the class answered every time.
- How much do you trust your favourite influencer's recommendations?  
93% answered positively.

Among the answers to the question “why” regarding the last question in the provided survey, the most common answer was, “because we trust them”.

### 3. Marketing Influencers

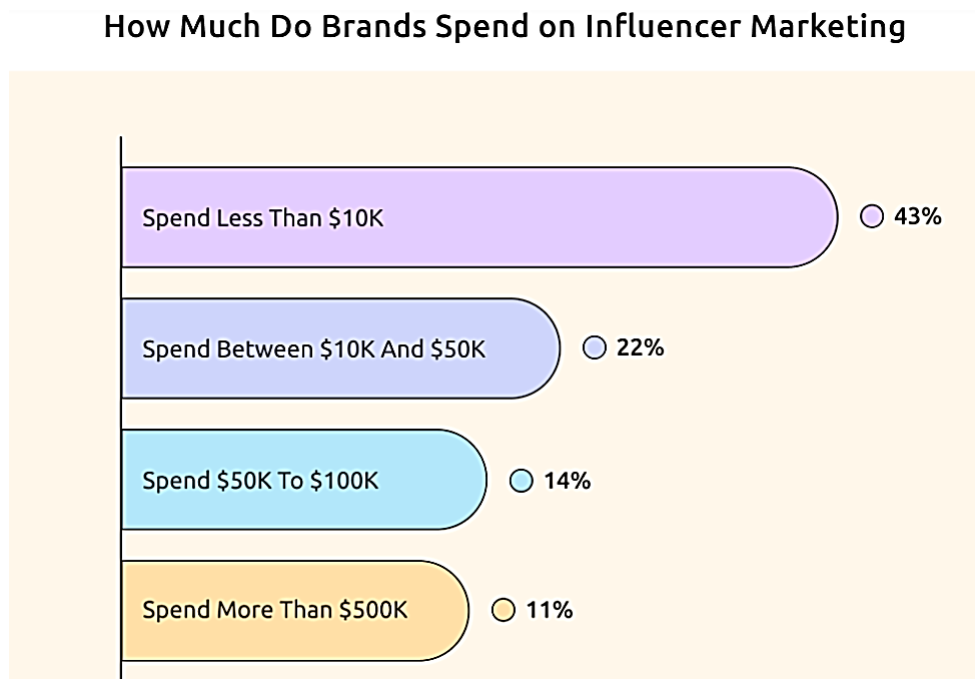
In today's world, it is not just the opinions of consumers which are taken into consideration while creating a marketing campaign, but also a new type of advertising called “marketing influencers” who seem to impact many purchasing decisions. As per definition, “an influencer is a person who can influence the decisions of their followers because of their relationship with their audience and their knowledge and expertise in a particular area, e.g. fashion, travel or technology. Influencers often have a large following of people who pay close attention to their views. They have the power to persuade people to buy things, and influencers are now seen by many companies as a direct way to customers' hearts. Brands are now asking powerful influencers to market their products. With some influencers charging up to \$25,000 for one social media post, it is no surprise that more and more people are keen to become influencers too” (Social..., 2023). That is probably why the number of influencers and the need for them grew tremendously (by an 80% since the year 2017) within the past couple of years (Figure 1).



**Figure 1.** Influencer Marketing Market Size.

Source: Geysler.

The vast majority of respondents believe the influencer marketing to be very effective. Unsurprisingly, considering the overall positive sentiment expressed about influencer marketing - over 83% respondents believe influencer marketing to be one of the most successful for of marketing in today's world. In order to work with constantly changing world of marketing, many brands create budget assigned only to influencer marketing. About 82% of major American brands indicated that they would be dedicating a budget to influencer marketing in 2023. This number seems to be a great increase since 2017 (back then only 37% of companies declared that budget to that medium of marketing) and is a slight increase from last year's 77% (Social..., 2023) (Figure 2).

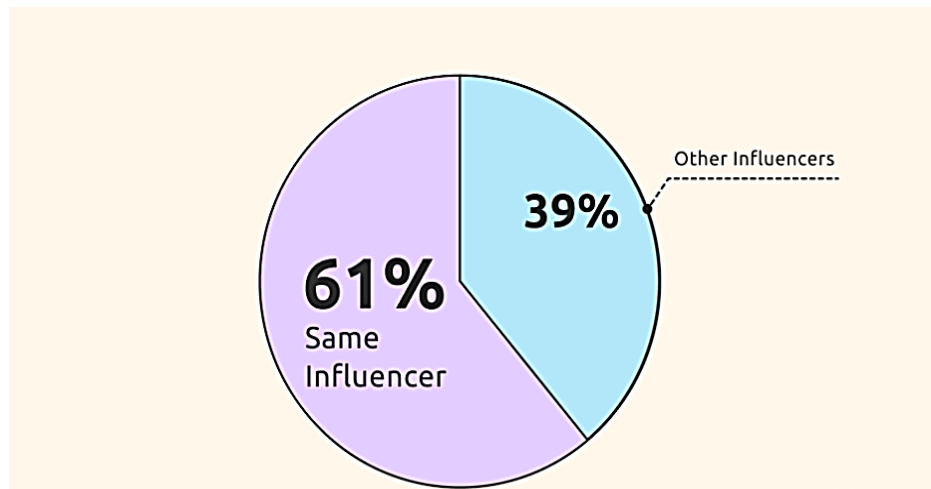


**Figure 2.** How much do brands spend of Influencer Marketing.

Source: Geysler.

As follows, “although most brands spend less than \$50K on Influencer Marketing, more than 11% spend over \$500K. Brands of all sizes participate in influencer marketing. Therefore, it should be no surprise to see quite some variation in what firms spend on the activity. 43% of the brands surveyed said they spend less than \$10K annually on influencer marketing (higher than last year's 37% - these are probably newcomers dabbling with influencer marketing). 22% spend between \$10K and \$50K (down from last year's 30%). A further 14% spent \$50K to \$100K (higher than in 2022), 10% \$100K to \$500K (unchanged), with a noticeable 11% spending more than \$500K (nearly 3x more than last year)” (Social...,2023). So it seems that many brands noticed a positive experience with influencers and a great revenue assured by brand deals. Therefore, “brands with happy influencer marketing experiences have increased the percentage of their marketing budget they spend on the activity. However, brands that have experienced less happy outcomes have decreased or eliminated spending on the activity, turning their attention to other forms of marketing” (Social..., 2023) (Figure 3).

### One-Off vs "Repetitive" Influencer Partnerships



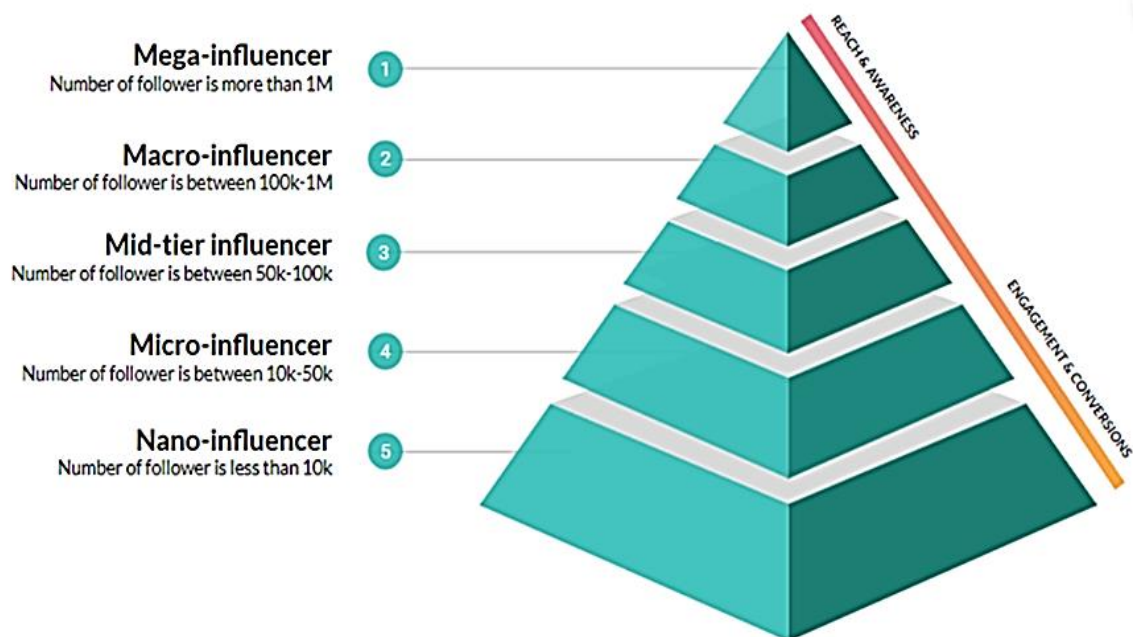
**Figure 3.** One- off vs “Repetitive” Influencer Partnerships.

Source: Geysler.

As it is clearly pointed out on the above graph, brands favour working with the same influencers and base their relationship on already established grounds. Additionally, so called “repetitive” influencers, who can predict their following and assure the brand with an estimation of a potential gain. Additionally, not many brands base their marketing reach only on one influencer. Sometimes, the nature of the campaign calls to reach out to a different niche, demographic or a target audience. “The 4% increase in firms working with existing influencers probably indicates the natural increase in influencer-business relationships over time” (Social..., 2023). Which translated into a simple, logically driven truth: “the more successful an influencer campaign is, the greater the likelihood that the parties will want to work together on other campaigns” (Social..., 2023).

Of course, different influencers have a different following, hence a diverse marketing power. Therefore, there are a couple of levels of Influencers (Figure 4).

## What are the types of influencers?



**Figure 4.** Different types of Influencers How much do brands spend of Influencer Marketing.

Source: Team.

Upon a quick “Google” search, with a question: “how many influencers are there”, a couple of nanoseconds provide the answer of 64 million. This impressive number is divided into five categories according to the following a particular influencer can accumulate.

### 3.1. Nano Influencer

Nano Influencer is an influencer with the lowest number of followers up to 10,000. Of course, the scale is filled with this category and the world seems to have the most of them. The advantage of working with such influencers is not a very high price, but maybe a bigger engagement in a small, local, territorial or trusting community. Therefore, they are simply ideal for brands with a clear (relatively small, locally centered) target audience. Those influencers specialize in niche markets and maintain has a close relationship with their followers.

### 3.2. Micro Influencer

This level is represented by influences with up to 50,000 followers. However, it is not only the amount of following that is different from Nano influencers, but also the content of managed channel or platform is presented in much more professional way than the one with lesser following.

### **3.3. Mid-Tier Influencer**

Mid-Tier Influencer is an influencer with following which falls under a number from 50,000 up to 100,000 followers. As follows, channels created by mid-tier influencers have a high quality content created and they build on a reasonably well understood idea of a brand recognition.

### **3.4. Macro Influencer**

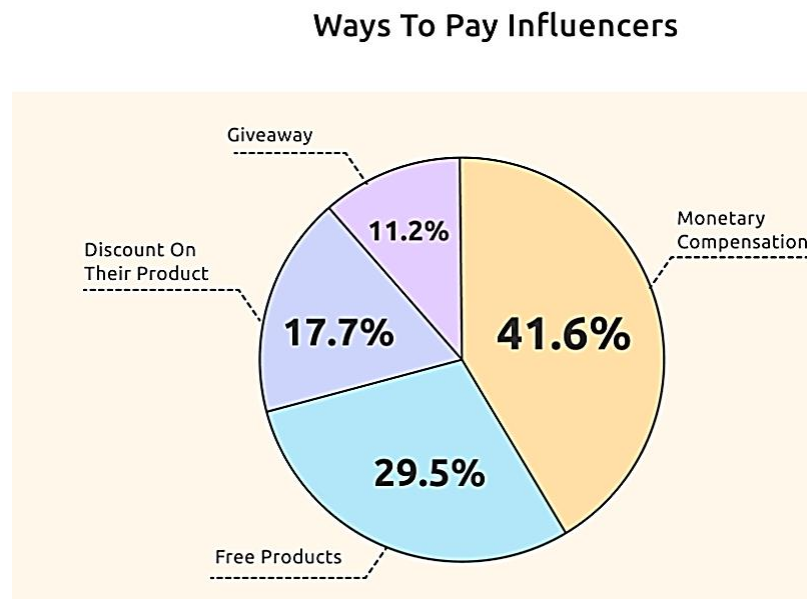
Macro Influencer is a person with followers ranging from 100,000-1,000,000 people. Very often they are already pretty famous and well recognized individuals in the represented society, such as actors, signers (who already made their name in the industry) and then become influencers, to either sustain their presence in the media, gain even more recognition, or branch out to different markets. Since it usually is an already well-established person, their recognition is quite high, what follows, the price for a potential cooperation would be quite high as well. Companies might prefer to work with such individuals, not only because of an immediate success of their marketing, but also because of the level of professionalism attached to the possible engagement.

### **3.5. Mega Influencer**

Mega Influencer is someone whose numbers of following are higher than 1,000,000 followers. Of course they are also known Celebrity or Mass Publishers. An incredible advantage of working with such influencers is the media reach – a powerful person and a potential immediate success of the marketing campaign, as the brand recognition would be potentially noted by millions. However, those kinds of influencers usually work with many brands at once, so the scheduling and price might be of a quite high.

Even though, usually platforms for the working influencers are free, and posted material does not cost much to watch, listen to or download – since all a potential audience needs is a charged device with an Internet connection and Wi-Fi signal. In order for the material to be well received, it needs to be well prepared and presented which is not free. So how do influencers get paid (Figure 5)?





**Figure 5.** Ways influencers get paid.

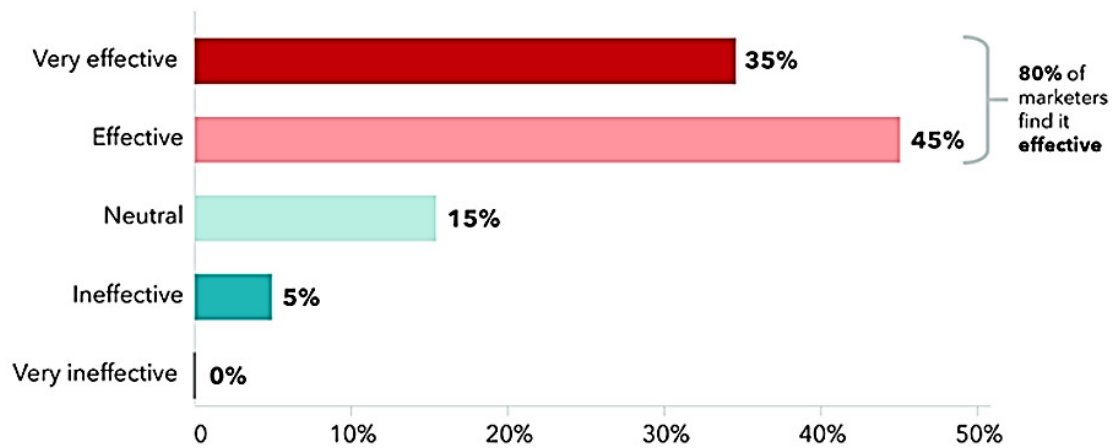
Source: Geysler.

Many brands, especially when working with smaller influencers pay them with free products. This way, helps the influencer create a material for their channel, hence gain more viewers, become more recognizable and get to the largest portion of the graph presented above (41.6%) and get the monetary compensation for mentioning the company's product on their channel. Many others, get products from brands to create some form of a give-away segment on their channel, but they are required to mention the sponsor, they can also get a discount, or provide their viewers with an affiliate, promotional link (but just like in a case of sponsorship, an influencer has to clearly inform the viewer about the affiliation). Apparently, within the last year many more brands opted for the monetary compensation while working with mentioned form of marketing. That usually gives influencers a lot of creative freedom when prompting the product and very often gives the audience the "feeling of authenticity," while hearing about the item or a service.

#### **4. Does influence marketing work?**

As mentioned above, an influencer is a rather famous person and an influencer of any online media. However, "the term influencer does not mean that one must be a celebrity, an artist, a public figure, but can also be a natural person or a page with followers on social media and the ability to influence their followers. Every influencer is different. It must be the character (identity) of that influencer, as well as the style of content creation of each influencer that will distinguish which influencer is suitable for which brand or product" (Team, 2023) (Figure 6).

## HOW EFFECTIVE IS INFLUENCER MARKETING?



**Figure 6.** How effective is influence marketing.

Source: Team.

In testimonials of many marketers, the influencer marketing is a very effective medium of marketing. As very often influencers have a “halo effect” (“which is a type of cognitive bias in which the overall impression of a person influences how people feel and think about their character. Perceptions of a single trait can carry over to how people perceive other aspects of that person”) (Msed, 2023) for their audience. Influencers give an impression of someone who is a friend and builds trust on the premise of friendliness and being “there” for the audience. Some of the influencer based communities are very active and they share many thoughts under every uploaded material and that creates a sense of unity, that differs from others. According to the studies, “influencer marketing is more trustworthy” than traditional advertising, because it gives an impression of real users who recommend or share the value of the product for themselves (Team, 2023). Of course, in many of those cases, money buys vulnerability, consistency in posting the material and simple likeness for the influencer usually buys trust – so the truth of the matter is – it all works quite well and many companies choose this pathway for many of their advertising campaigns.

### 5. Problems with Influencer Marketing:

Some marketers state that “brand engagement is considered to be fully related to influencer marketing” (Team, 2023). In traditional advertising customers had to get to know the product in order to decide if they liked it. The “word of mouth advertising” also worked in the past,

the only difference now is that the “word of mouth” is not carried from one friend to another ten colleagues; nowadays it is passed from one influencer to a “small community of a million closest friends” (Jung, 2010) and that is the power of a potential financial gain that today’s marketers seem to recognize better than anyone else.

The problem with influence marketing is the fact that people create and publish, almost anything (as long as, it does not violate the law) and anyone can watch blogs, vlogs, podcasts and more forms of “influenced” creativity. By the dictionary provided definition, an influencer is a person who has gained popularity on the Internet and uses their fame, influencing their viewers, readers, their worldview, taste. According to Dr William Wolg, “that taste does not always have to be tasteful; however, the influencer always influences, even the tastes they did not intend to influence” (Wolg, 2023).

Regardless, of what is understood as tasteful in today’s world, the growing popularity of influencers and the increase in their importance contributed to the rise of influencer marketing is tremendous. The cooperation of the brand with online creators - concerns promotion selected products, which, apart from advertising, focuses on public relations (Kuczamer-Klopotowska, Piekarska, 2016). Influencer marketing can owe its effectiveness to Internet users who see influencers as role models and authorities. The observers “trust” the brand and their products just because it is recommended by their favourite entertainment creators. A popular person can maintain constant contact with his fans, which is not possible in the case of classic advertising (Wolska-Zygata, 2018). Influencer marketing requires very thorough analysis and planning, when preparing a campaign, it is necessary to:

- get to know the target group,
- know the size of the target audience, as not everyone in the group of subscribers has to be a potential target audience for the advertised product,
- determine whether a given product should be promoted by a chosen influencer,

The popularity of influencer marketing is primarily due to sale efficiency. As a matter of fact, “it is a method that generates a multiple return on investment. Much more than other forms of advertisements” (Woods, 2016). There are a couple of problems with influencer marketing; meaning, influencers have a lot of freedom while advertising particular products, often on the basis of specific guidelines, however, sometimes it is not subjected for verification by the principal prior to publication. Another problem is the lack of clear indications about the sponsored promotion. In Poland, on the 26<sup>th</sup> of September 2022, the President of the Office of Competition and Consumer Protection (UOKiK), published special guidelines for brand cooperation with influencers. The purpose of introducing the regulation is to protect the interests of the consumer and compliance with the principles of a fair competition. Influencer marketing is an element of modern marketing transformations, and it becomes more and more individualized, directed to a specific recipient, potential customer. As mentioned above, it enables directing the marketing’s message to specific group of recipients, it is very precise and still relatively competitive when it comes to its price.

## 6. Summary

Lockdowns during COVID-19 pandemic did not only make many societies spend time at home and get more accustomed to the online sphere of life. Many of us by spending more time online either got more familiar with many social media platforms, others moved major aspects of their lives online, such as jobs, schools or shopping trends. Apparently, we moved to the era of entertainment where much of what we know comes for the platforms that were created with a completely different purpose in mind. Many of us get their daily news from Twitter, creative ideas how to arrange their homes from Pinterest, some probably buy into lifestyles influenced by the rich and famous, others are influenced by the people who seem “likeable” online. Regardless of what it is, one needs to remember that so much of what is being sold in today’s world, comes from people being influenced by not one (trustworthy) friend who lives next door, but by about a million of the “closest” following strangers.

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

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

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

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

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

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

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

## 1. Introduction

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

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

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

## 2. The concept of sustainable development

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

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

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



Declaration, and the declaration *The Future We Want* by the UN. It was then that the relationship between economic development and environmental protection began to be discussed. The Rio Declaration is a set of principles that address future development and environmental commitments. In 2001, meanwhile, the EU adopted a strategy for sustainable development. It was revised in 2006 and "enabled the realization of a long-term vision of sustainable development that combines mutually supportive economic growth, social cohesion, and environmental protection." Subsequently, since 2009, sustainable development has officially become one of the long-term goals of the European Union in accordance with Article 3(3) of the Treaty on the European Union (Zrównoważony rozwój, <https://eur-lex.europa.eu/>..., Aug. 24, 2023). In subsequent documents, namely the United Nations Millennium Declaration. (Resolution adopted by the General Assembly [without reference to a Main Committee (A/55/L.2) 55/2. United Nations Millennium Declaration, New York, 6-8 September 2000), in the United Nations declaration *The Future We Want* (*The Future We Want: final document of the Rio+20 Conference Rio de Janeiro, Brazil June 20-22, 2012*) and the 2030 Development Agenda (*Transforming Our World: the 2030 Agenda for Sustainable Development*, United Nations, 2015), has remained essentially unchanged in its context. Sustainable development thus emphasizes the parallel development of the economy, society, and the environment.

Sustainable development can therefore be defined in two ways:

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

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

are fundamental pillars of sustainable development that focus on: workers, society, and the economy (Figure 1). In fact, it is only when we address their essence that we can confidently talk about the growth of an organization. As can easily be seen, organizational creativity is the missing link here. That is why the authors of this publication propose to extend these pillars by combining them through the fluid creativity of organizations.

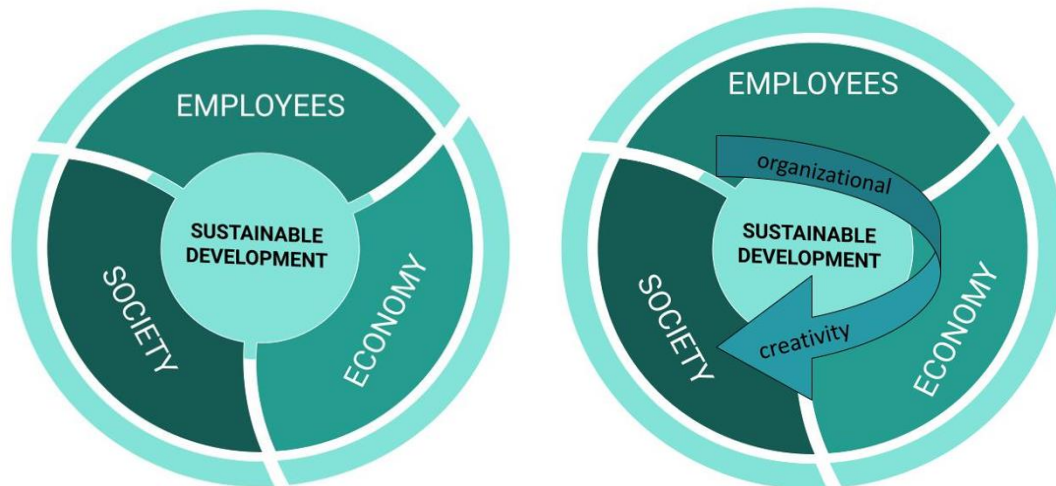


Figure 1. Pillars of sustainable development & organizational creativity as the key competence.

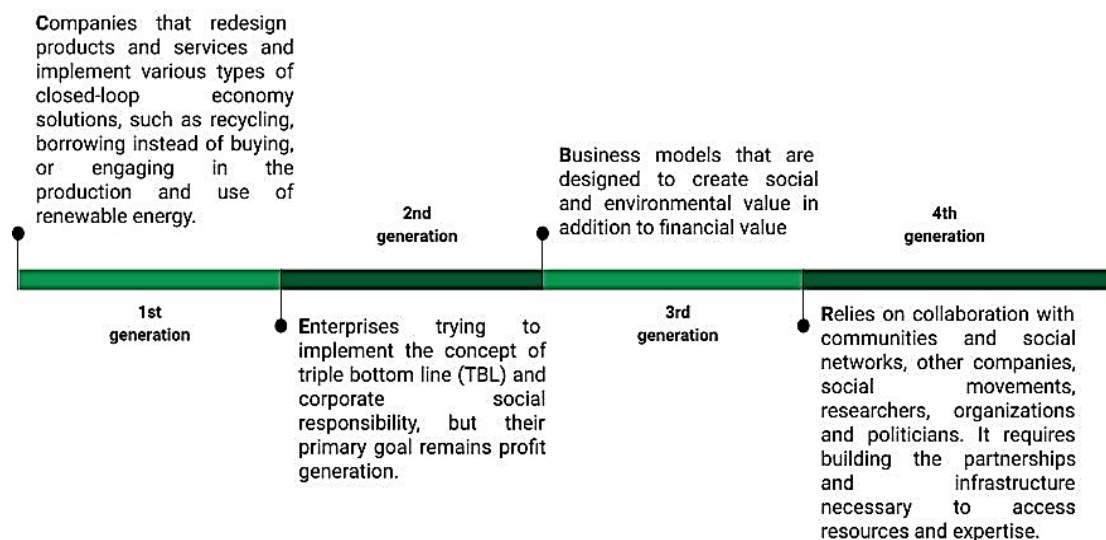
Source: own research.

The idea of organizational sustainability is increasingly well-known and widespread. "For the business enterprise, sustainable development means adopting business strategies and activities that meet the needs of the enterprise and its stakeholders today while protecting, sustaining, and enhancing the human and natural resources that will be needed in the future". (Business Strategies for sustainable development Based on the book *Business Strategy for Sustainable Development: Leadership and Accountability for the 90s*, published in 1992 by the International Institute for Sustainable Development in conjunction with Deloitte & Touche and the World Business Council for Sustainable Development, <https://www.iisd.org/system/...>, Aug. 26, 2023).

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

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

In an effort to explain what sustainable business models will look like, we should refer to the genesis of the emergence of business models that integrate sustainability goals with business strategy. An interesting look at this evolution as well as the possible direction of development of this concept was presented by F. Melissen and L. Moratis (2016, pp. 8-16). According to them, four generations of sustainable business models can be distinguished (Figure 1). Three generations of sustainable business models, by definition, do not change the rules of the game, as they operate according to existing market rules. Organizations that want to go beyond the patterns of the current system must apply business models that go beyond the solutions proposed by the first three generations. To do this, consumer acceptance and support are needed (only then can sustainable products and services have a positive impact on society).



**Figure 1.** Four generations of sustainable business models.

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

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

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

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

**Table 1.**

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

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

Source: own research.

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

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

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

For the paradigm of sustainable development, creativity is increasingly important (d'Orville, 2019, pp. 65-73; Mitchell, Walinga, 2017 pp. 1872-1884). Creativity and sustainable development are two key factors influencing the development of civilization. As S. Kaufman writes, in the world of the infinitely rich creativity of nature, man is an active co-creator of it (Kauffman, 2011, pp. 60-63). Adopting such a perspective enables us to relate creativity to the study of organizational phenomena. From this perspective, creativity can be treated as an attribute of contemporary organizations (Dereń, Skonieczny, 2016). Organizational creativity is commonly believed to refer to the production by individuals or groups of new and potentially useful ideas about products, services, working methods, processes, and procedures (Amabile, 1988, pp. 123-167). In this sense, creativity is different from innovative activity (Klijn, Tomic, 2010, pp. 322-343), which focuses not so much on generating creative ideas as on putting them into practice. If the generation of useful novelties takes place among the participants of the organization, we are talking about organizational creativity. More precisely, "organizational creativity is the creation of a valuable, useful, new product, service, idea, procedure or process by individuals working in the social system" (Woodman, 1993, p. 293). Organizational creativity is also defined as the ability to think beyond accepted ideas and conventional thinking patterns, to combine previously acquired knowledge in an unprecedented way (Kraft, 2005, pp. 16-23); new mental models (Lozano, 2014, pp. 205-216); the ability to abandon habitual ways of thinking and accumulate pieces of previously unrelated knowledge and experience (Geschka, 1983, pp. 169-183); the ability and power to develop new ideas (Wehrich, Koontz, 2005); generating innovative and adequate ideas - solutions - for open problems in any domain of human activity (Amabile, 1997, pp. 39-58); combining cognitive, affective and social domains (Runco et al., 1998, pp. 1-17), and solving problems in an unconventional way (Reiter-Palmon, Illies, 2004, pp. 55-57; Mitchell, Walinga, 2017, pp. 1872-1884). Organizational creativity arises thanks to units cooperating with each other in a complex social system, which is influenced by individual and group creativity as well as the organizational environment (Borghini, 2005, pp. 19-33; Skonieczny, 2019, pp. 113-171).

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

**Table 2.***Organizational creativity in the conditions of sustainable development of the organization*

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

Source: own study.

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

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

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

business; building networks inside and outside the organization, influencing people and attracting others to ideas (McCrae, 2013).

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

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

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

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

- the principle of eco-development,
- the principle of environmental integrity (ecosystem integrity); its essence is the recommendation to "think globally (holistically), but act; locally",
- the principle of economization, also known as the principle of economic efficiency and ecological eco-development (including environmental protection); calls for the implementation of such a policy so that the environmental goals are achieved at the minimum social cost,
- the principle of prevention, also known as the principle of active policy or, in a narrower interpretation, the principle of elimination of pollution at source,
- the principle of reacting to the existing ecological threats, also called - not always in a justified way - the principle of passive politics; a manifestation of passive politics is e.g. the formulation of declarations and subsequent programs with a clear underestimation of the implementation side,
- the principle of partnership (cooperation) and public (social) participation, also known as the principle of community participation in solving environmental problems or the principle of socialization,
- the principle of regionalization of eco-development programming (including ecological policy), is understood as a postulate to adapt protection requirements to regional and local conditions and to enable regional and local authorities to choose tools for implementing the idea of eco-development,
- the principle of the rule of law, which means that the ecological law system and the manner of its implementation must be restructured in such a way that each provision is strictly observed and it is impossible to replace the provisions with arguments so well known to the public about "higher necessity", "social interest", "we are yet to be protected the environment cannot afford "or" we are too poor to protect the environment "etc.,
- the principle of observing intergenerational (intergenerational) ecological justice, is sometimes also called the principle of intergenerational ecological egalitarianism (Berner, 2006).

C. Cucuzzella also writes about the need to respect the principles of sustainable development by organizations implementing creative design projects, emphasizes the special importance of two principles: prevention and precaution, considering them to be key and decisive in reducing the risk of a project undertaking (Cucuzzella, 2016, pp. 1548-1558). Organizational creativity conceptualized in the article in the conditions of sustainable development of the organization fits in with the concept of green creativity proposed by Chen and Chang, which concerns the development of original, innovative, and useful ideas for ecological products, services, processes, and practices (Chen, Chang, 2013; Eide et al., 2020). Green Creativity involves the ability to present novel ways to improve performance in



an environmentally sustainable manner (Mittal, Dhar, 2016, pp. 118-127); it can therefore be expected to lead to innovation in services, eco-friendly practices, actions to preserve cultural heritage, and actions that add value to both customers and businesses (Bhutto et al., 2020). Shaping green creativity depends on various organizational and individual antecedents (Chen, Chang, 2013; Eide et al., 2020; Song, Yu, 2017, pp. 135-150). However, the current thinking, attitudes, and behavior of leaders and managers towards environmental problems are of key importance for its implementation in practice (Arici, Uysal, 2022). It allows you to generate and develop new values that serve the well-thought-out use of resources in such a way that they will be enough to build the prosperity of the current generation, but also be able to meet the needs of the future.

## 5. Summary

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

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

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

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

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## ASSESSMENT OF THE MANAGEMENT AWARENESS OF THE USE OF LM METHODS AND TOOLS IN THE AUTOMOTIVE INDUSTRY

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**Purpose:** The article presents the results of a survey on the use of methods and tools of the Lean Manufacturing (LM) concept by middle management in an automotive industry company in Poland. The conducted study will allow to assess the management's awareness in terms of knowledge of LM solutions, their use in everyday work, the impact of LM tools on improving the organization of production and occupational health and safety, and involvement in improvement projects. Knowledge, commitment, and support for employees are important factors in shaping the Lean culture in the company. The middle management, who manages the work in individual departments of this company, through appropriate attitudes and behavior builds the awareness of the entire team. The article ends with conclusions that can be treated as a form of guidance for top management to take improvement actions.

**Design/methodology/approach:** The study of employees' awareness of the use of methods and tools of the LM concept was carried out using the survey method. The research group consisted of middle management in the automotive industry company in Poland (respondents indicated by top management). To achieve the assumed goal, a four-stage research methodology was developed. In the first stage, a questionnaire was developed, which concerned three areas: OSH, LM methods and tools, and implemented management systems. For the purposes of the study and the assumed goal, one research area was taken into account, related to the use of LM methods and tools and the awareness of the middle management staff in this area. In the second stage of the research, the research sample was characterized. In the third stage, the minimum number of respondents was determined (using the PQStat tool). In the fourth stage, the results obtained were analyzed and conclusions were formulated, which may serve as guidelines for managers responsible for continuous improvement of processes in this company.

**Findings:** The conducted research made it possible to assess the awareness of the middle management regarding the use of LM solutions in the enterprise. The assessment of awareness was a subjective assessment resulting from the analysis of each survey question. Based on the conducted research, it was found that the vast majority of middle management has knowledge and high awareness in the field of continuous improvement, in the form of using the methods and tools of the LM concept in everyday work. Employees are aware of the impact of these solutions on various areas of activity (quality, safety, organization of production), engage in improvement projects, and identify and solve problems, but also see the difficulties associated with the implementation of LM methods and tools. The knowledge and awareness of middle management translate into the attitudes and behavior of production employees, which affects the culture of continuous improvement of the company. Based on the research results, areas requiring improvement were also identified.

**Research limitations/implications:** The conducted survey research was limited to assessing the awareness of a specific group of respondents, i.e. middle management. The direction of further research should focus on assessing the awareness of production employees to obtain more complete information related to shaping the Lean culture in this company.

**Practical implications:** The conducted research may provide important information for the management staff on the awareness of middle management in the application of solutions of the LM concept in this company. The research results also allow to identify areas requiring improvement actions.

**Social implications:** The article discusses issues related to the awareness and involvement of employees that shape the culture of continuous improvement in organizations.

**Originality/value:** The analysis of the literature for the years 2018-2023 showed that there is a research gap regarding the assessment of awareness of the LM concept among employees of automotive companies. Therefore, the article refers to the study of the awareness of middle management in the use of LM methods and tools in the automotive industry - in a large company in Poland.

**Keywords:** management awareness, Lean Manufacturing, continuous improvement, Toyota culture, Lean culture.

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

## 1. Introduction

Dynamic changes in the environment, growing competition, and customer requirements make industrial enterprises look for ways to maintain a strong market position. One of the most important, and at the same time, necessary conditions for achieving this goal is the continuous improvement of all company processes (Furman et al., 2018). Many organizations use different management concepts to streamline processes and achieve intended results. One of the most popular concepts implemented in enterprises around the world is Lean Manufacturing (LM) (Gupta, Jain, 2013). The LM concept was developed in the 1990s based on the Toyota Production System (TPS), which was created by Taiichi Ohno and Shigeo Shingo. The system includes a set of methods, tools, and practices implemented at Toyota Motor Company since 1948 (Holweg, 2007; Pavanskar et al., 2003). The LM concept has been considered the main

approach to operations management for many years, and its importance among practitioners is constantly increasing (Kunyorla, Aila, 2022). It is widely recognized that organizations that have mastered lean manufacturing methods gain a cost and quality advantage over those still practicing traditional mass production (Fleischer, Liker, 1997).

Production in the LM system is referred to as lean because, compared to mass production, it uses significantly fewer resources in half the time (Womack et al., 2008). The goal of Lean Manufacturing is to produce high-quality products at the lowest possible cost and in the shortest possible time by eliminating waste (*muda*) (Dennis, 2007). *Muda* is defined as all activities occurring in processes that do not add value to the product from the customer's point of view (Bicheno, Holweg, 2016; Imai, 2006). These are the following categories: overproduction, inventory, unnecessary motion, unnecessary transport, over-processing, defects, and waiting, as well as the unused potential of production workers (Melton, 2005; Parczewski et al., 2022). As part of the Lean Manufacturing concept, various methods and tools are used, which eliminate or reduce identified wastes and streamline processes, striving for excellence by the principles of LM (Womack, Jones, 2003). The most common practices used by enterprises include: the 5S technique, visual management, standardized work, value stream mapping, Poka-Yoke, Just in Time, kanban, one-piece-flow, SMED, TPM, kaizen (Palange, Dhattrak, 2021; Jasti, Kodali, 2015; Pearce, Pons, 2013). As part of the Lean Manufacturing concept, quality management tools are also used to solve problems and eliminate losses. The most commonly used are Ishikawa diagram, 5 Why analysis, Pareto diagram, 8D report, A3 report (Zasadzień, 2020). The use of LM solutions can bring many benefits to enterprises, including: the elimination of errors and quality defects, reduction of inventory, reduction of the production cycle and changeover time, increase in productivity, or improvement of work safety (Małyśa, Furman, 2021; Pavanskar et al., 2003). It is worth emphasizing that LM methods and tools are effective wherever they are properly selected and where there is the ingenuity and involvement of employees to bring out and accept a change in their working method or culture that will lead to a better working environment (Palange, Dhattrak, 2021).

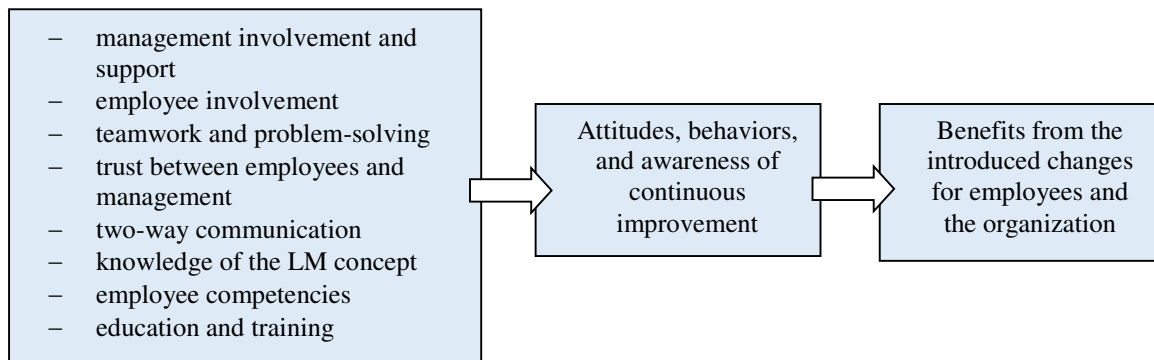
The literature on the subject (Moradi, Sormunen, 2023; Grycuk, 2016; Podobiński 2015) also points to barriers in the use of lean solutions, which cause the undertaken actions to fail (the introduced changes are not maintained, and there are no expected results). One of the most important barriers is the lack of knowledge, support, and commitment of the management.

Commitment is perceived as a kind of attitude, or behavior of an organization employee in relation to the set goals and assigned tasks (Trenkner, Truszkiewicz, 2015). Thanks to the involvement of employees, it is possible to continuously improve processes. However, it requires appropriate thinking, teamwork, support from managers, and an organizational culture that values the search for opportunities to introduce changes (Brajer-Marczak, 2014). Each company has its own organizational culture, defined (Schein, 2004) as a set of basic assumptions developed by members of the organization, which teaches how to deal with the problems of external adaptation and internal integration. Organizational culture plays

an important role in shaping the right attitudes and behavior of employees. It promotes the pro-effective behavior of employees - thanks to this, employees replicate patterns of behavior and assumptions shaped in the organization (Serafin, 2015).

In companies whose production systems are based on TPS, a culture of continuous improvement (the Toyota culture, known as the Toyota Way) plays an important role. It is focused on people and their knowledge. The Toyota culture emphasizes the role of managers who are leaders (responsible for continuous improvement) and teachers. They teach employees to identify, analyze, communicate, and solve problems. The commitment of management and employees is one of the most important principles of a Lean culture and contributes to its sustainability. Thanks to the continuous support of the management and its positive attitude, the awareness of continuous improvement is shaped throughout the company (Imai, 2007; Liker, Hoseus, 2016; Liker, Meier, 2008).

Therefore, companies that use LM methods and tools as part of their production system and want to gain a sustainable competitive advantage on the market should constantly undertake activities involving employees (especially management) in the process of continuous improvement. In this way, it is possible to shape the right attitudes and behaviors and influence awareness in the field of continuous improvement (Figure 1).



**Figure 1.** Factors affecting the shaping of attitudes, behaviors, and awareness in the field of continuous improvement in the organization.

Source: Own elaboration.

Researchers show significant interest in the subject related to the study of employees' awareness of the use of Lean Manufacturing methods and tools in manufacturing enterprises. To analyze the literature in this area, the Scopus and WoS databases and keywords were used: "awareness" and "lean". Table 1 presents selected results of the literature analysis in the years 2018-2023.



**Table 1.***Selected results of empirical research on employees' awareness of the LM concept*

<b>Authors</b>	<b>Research area</b>
Musa et al., 2023	Assessment of the level of awareness and barriers to the use of Lean techniques in the construction industry in Nigeria. Research method: survey. Research group: construction professionals.
Bamisaye et al., 2023	Assessment of the level of awareness and adaptation of the Lean concept in the garment industry in Nigeria (small and medium enterprises). Research method: survey. Research group: managers, owners, directors, supervisors.
Keles, Yilmaz, 2022	Research on the level of awareness and knowledge in the field of lean manufacturing among employees of construction inspection institutions. Research method: survey. Research group: engineering employees
Wassan et al., 2022	Study of awareness, implementation, barriers, and benefits of the LM concept in small, medium, and large manufacturing companies in Pakistan (textile, metallurgical, automotive, and pharmaceutical industries). Research method: survey. Research group: managers, executives, and engineers from various departments.
Morshidi et al., 2022	Assessment of awareness and application of the LM concept in the aspect of improving safety in the construction industry in Malaysia. Research method: survey. Research group: construction professionals (safety managers, construction managers and project managers).
Podloch, Nowacki, 2022	The article presents an introduction to the research on the level of awareness of issues related to the LM concept among the management staff in many enterprises belonging to one international corporation (no industry specified); there are no results of this research yet.
Fateh, Sulaiman, 2021	Research on the level of awareness of the Lean concept among entities operating in the construction industry in Malaysia. Research method: survey. Research group: architects, quantity surveyors, engineers, contractors.
Klimecka-Tatar, 2021	Research of awareness and knowledge of LM principles in the context of the tools used in production companies in Poland (no industry specified). Research method: survey. Research group: production workers
Adzrie, Armi, 2021	Assessment of awareness of implemented Lean Manufacturing practices that have already been applied and TQM and TPM implementation in small and medium-sized enterprises in Malaysia (beverage industry). Research methods: survey. Research group: senior management.
Ahmed et al., 2021	Study on LM tools awareness, barriers, and challenges related to the implementation of LM tools in the construction industry in Bangladesh. Research method: survey. Research group: construction practitioners in different types of construction organizations.
Amade et al., 2021	Determining the scope and level of awareness about Lean techniques in the construction industry in Nigeria. Research method: survey. Research group: construction professionals.
Gelmez et al., 2020	Studying the awareness of enterprises in the field of lean manufacturing and the barriers encountered during the implementation of LM in Turkey. Research method: survey. Research group: textile companies.
Sahoo, 2020	Studying the status of Lean Manufacturing in Indian enterprises in terms of adopting the LM concept, its understanding, benefits, motivation, and challenges related to the implementation of LM practices (automotive component manufacturing SMEs). Research method: interview, observation, survey. Research group: entrepreneurs and managers at different organizational levels.

Cont. table 1.

Yahya et al., 2019	Studying the awareness, implementation, level of effectiveness, and potential future use of LM tools and techniques in enterprises in Malaysia (various industries) Research method: survey. Research group: directors, managers, engineers, executives, and academicians.
Bajjou, Chafi, 2018	Studying the level of awareness of Lean Manufacturing practices in the construction industry in Morocco, to identify the benefits and identify barriers to the implementation of LM practices. Research method: survey. Research group: construction practitioners.

Source: Own elaboration.

It can be noticed that many publications on employee awareness of the use of LM tools relate to the construction industry. One of the publications (Table 1) refers to the automotive industry in India (Sahoo, 2020). Therefore, there is a research gap related to the assessment of awareness of the use of LM tools in the automotive industry. Automotive companies were the first to implement Toyota Production System solutions and they are widely used there. However, there are no results of research on the assessment of employees' awareness in this area.

Therefore, the study focused on assessing the awareness of middle management staff and the use of their knowledge in the field of applying the methods and tools of the LM concept in the automotive industry company in Poland. The obtained results will allow to identify areas requiring improvement actions in this enterprise.

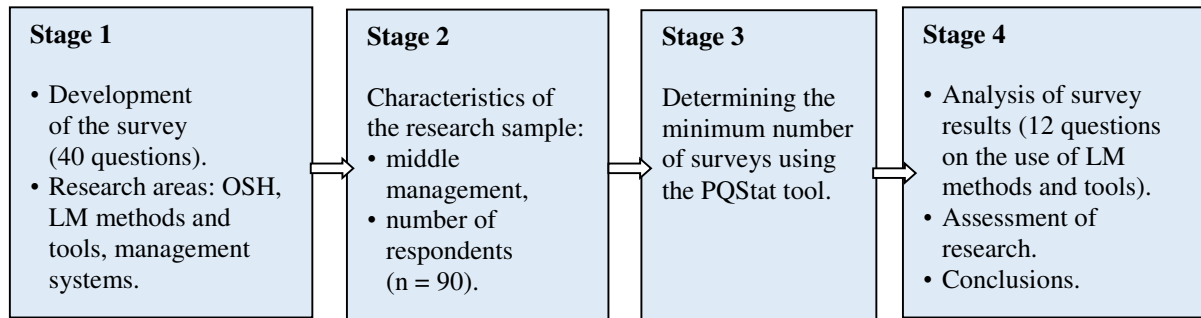
## 2. Methodology

The study of employee awareness in the use of methods and tools of the Lean Manufacturing concept was carried out using the survey method, addressed to a specific research group. The assessment of employee awareness is a subjective assessment resulting from the analysis of each question in the survey. To achieve the assumed goal, a four-stage research methodology was developed (Figure 2).

In the first stage, a questionnaire consisting of forty questions was developed. The questionnaire referred to issues related to three areas:

- occupational safety and health (OSH),
- applied methods and tools of the LM concept,
- implemented management systems.

For the purposes of the study and the assumed goal, one research area was taken into account, related to the use of LM methods and tools and the management's awareness in this regard.



**Figure 2.** Research methodology.

Source: Own elaboration.

In the second stage of the research, the research sample was characterized - the developed questionnaire was addressed to middle management (90 respondents). The number of respondents was determined by the company's top management.

In the third stage, the minimum number of respondents was determined. For this purpose, a statistical analysis tool (PQStat) was used. With the assumptions of a significance level of 0.05 and an estimation error of 0.02, it was estimated that the necessary number of surveys should be 87.

In the fourth stage of the research, the results obtained were analyzed and conclusions were formulated, which may serve as guidelines for managers responsible for continuous improvement of processes.

### 3. Awareness of the management in the use of methods and tools of the LM concept

#### 3.1. Characteristics of the research sample and the questionnaire

The survey was conducted in the first quarter of 2023. The research was addressed to middle management to assess awareness and knowledge of LM concept solutions used in the company. The survey was conducted among 90 respondents working in two production plants, in a 2-shift system. Respondents are persons managing work in the following departments: quality, maintenance, technology, production, logistics/warehouse, and administration - the largest group was production department managers (23 persons). Most respondents are persons aged 41-50 with 16-20 years of work experience (at their current employer). The survey, in addition to the respondent's identification data (demographics), contained 12 single and multiple-choice questions regarding (Table 2):

- applying methods and tools derived from Toyota Production System (5S, Kaizen, suggestion system, SMED, TPM, Autonomous Maintenance, standardization, Visual Management),
- using Problem-Solving tools in everyday working (5 Why analysis, 5W+1H analysis, Ishikawa diagram, Pareto diagram),
- the impact of the applied solutions on improving the organization of production and OSH,
- difficulties (or lack of difficulties) with the implementation of these solutions in the managed departments,
- involvement in improvement projects (Kaizen and the suggestion system).

**Table 2.**

*Survey question, number of respondents, and number of answers returned*

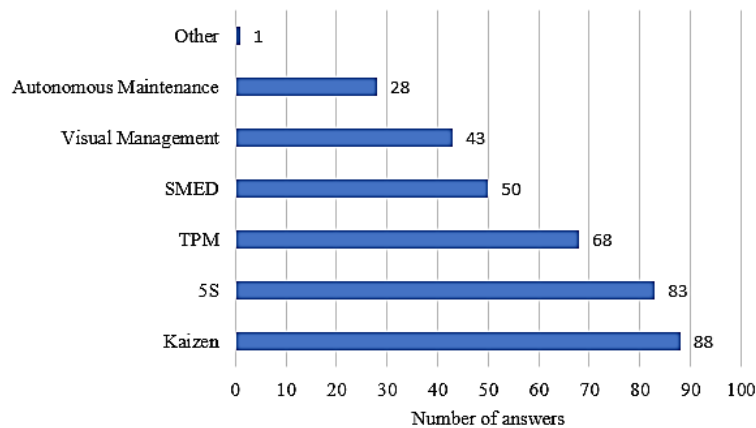
Question	Number of respondents	Number of answers returned
What tools are used in the company's daily functioning as part of the implemented systems? (multiple-choice question)	90	90
How long have you known and used these tools? (single-choice question)	90	90
What tools in the field of Problem-Solving are used in your company? (multiple-choice question)	90	90
In which areas do you use Problem-Solving tools? (multiple-choice question)	90	90
What is the type of impact of the implemented management methods and tools on improving the organization of production? (single-choice question)	90	90
Which tool, in your opinion, has the greatest impact on improving the organization of production? (single-choice question)	90	89
What is the type of impact of the implemented management methods and tools on OSH's improvement? (single-choice question)	90	90
Which tool, in your opinion, has the greatest impact on OSH's improvement? (single-choice question)	90	89
Which tools were the most difficult to implement in your company? (multiple-choice question)	90	87
Which tools were the easiest to implement in your company? (multiple-choice question)	90	87
Do you submit ideas in the Suggestion Program (Kaizen)? (single-choice question)	90	89
What scope do you submit your Kaizen ideas from? (multiple-choice question)	90	88

Source: Own elaboration.

The answers obtained will allow the assessment of knowledge in the field of solutions used in everyday work for process improvement and the assessment of the level of involvement of middle management in these activities. This translates into employee awareness and a culture of continuous improvement in the company.

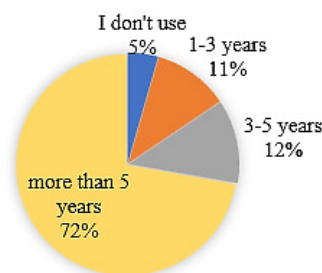
### 3.2. Analysis of the conducted research - discussion

The company in which the research was conducted has systems supporting the optimization of production and production-related processes, e.g. a system based on TPS - under which methods and tools from the LM concept are used. The most frequently used tools in everyday work are (Figure 3): Kaizen and the 5S method (171 responses in total), followed by TPM, SMED, and Visual Management (VM) (161 responses in total). The fewest answers (28) concerned Autonomous Maintenance (AM), although it is an important pillar of the TPM system (indicated in the survey). Different answers may result from the fact that not all departments in which the respondents work use the tools mentioned (e.g. administration, warehouse). Among all respondents, 72% have known and used these tools for more than 5 years, 12% - for 3-5 years, 11% - for 1-3 years (Figure 4). The results indicate that the middle management has the knowledge and high awareness in applying solutions to the LM concept. It should be noted, however, that 5% of the respondents do not use any of the tools listed. This is important information for the management to take improvement actions.



**Figure 3.** What tools are used in the company's daily functioning as part of the implemented systems? – results.

Source: Own elaboration.

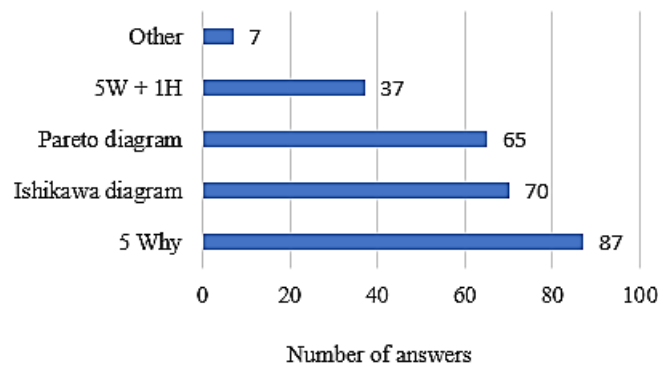


**Figure 4.** How long have you known and used these tools? – results.

Source: Own elaboration.

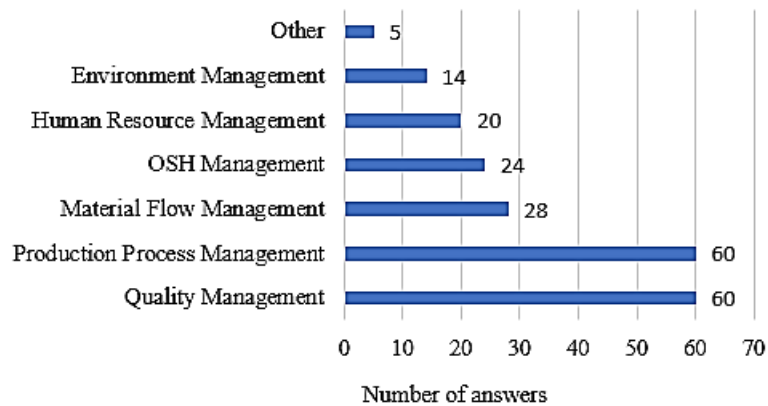
Problem-solving is an integral part of the continuous improvement process and is at the heart of TPS. It emphasizes the role of management (as leaders) in engaging employees to identify and solve problems, which translates into increased awareness of continuous improvement. In the company where the research was conducted, the middle management

knows and uses the following most often (Figure 5): 5 Whys analysis (87 responses), Ishikawa diagram (70 responses), and Pareto diagram (65 responses). These tools are easy to use and can be used in any area of the enterprise. In the survey, respondents most often use Problem-Solving tools in two main areas: quality management (60 responses) and production process management (60 responses). This is justified due to the profile of the plant's activity (automotive industry) and high requirements in terms of technology and quality. Problem-solving tools are also used in the areas of production logistics, health and safety, human resources management, and the environment (Figure 6). The answers obtained indicate that the respondents have the knowledge and high awareness of the use of Problem-Solving tools in their daily work.



**Figure 5.** What tools in the field of Problem-Solving are used in your company? – results.

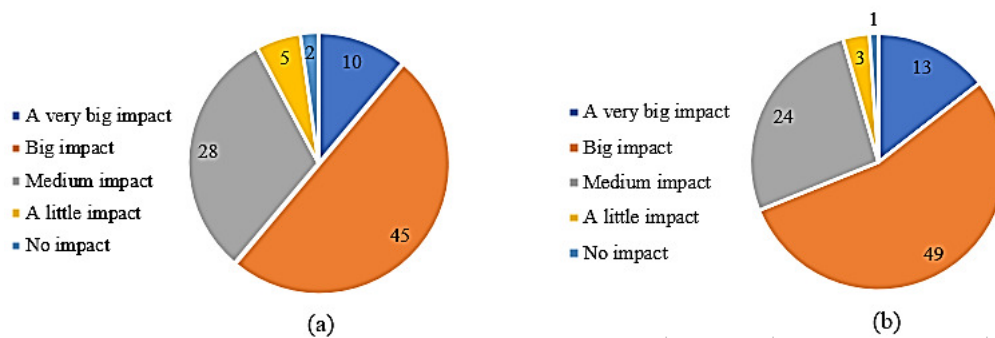
Source: Own elaboration.



**Figure 6.** In which areas do you use Problem-Solving tools? – results.

Source: Own elaboration.

The methods and tools of the LM concept, as indicated in the literature review, affect the processes in enterprises and bring many benefits. Therefore, the survey asked respondents about their subjective assessment of the impact of the tools they use on two aspects: organization of production and work safety. According to the majority of respondents, the tools used have a large and very large impact on improving the organization of production (55 respondents) and OSH (62 respondents). Only 3 respondents believe that these tools have no impact on these two areas (Figure 7a-b).

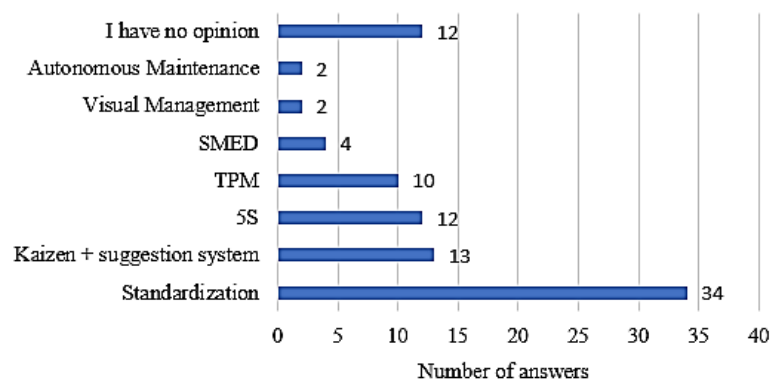


**Figure 7.** What is the type of impact of the implemented management methods and tools on improving the organization of production (a) and OSH (b)? – results.

Source: Own elaboration.

According to the respondents, standardization has the greatest impact on the organization of production (34 responses). This is indicative of a high degree of awareness in the field of applied LM solutions - standardization is considered the most important LM tool without which processes cannot be improved. Subsequently, the respondents indicated (Figure 8):

- Kaizen and the suggestion system (13 responses) – through the implementation of improvement projects,
- 5S method (12 responses) – which organizes and standardizes work at workstations,
- TPM (10 responses) – which ensures reliable operation of machines.



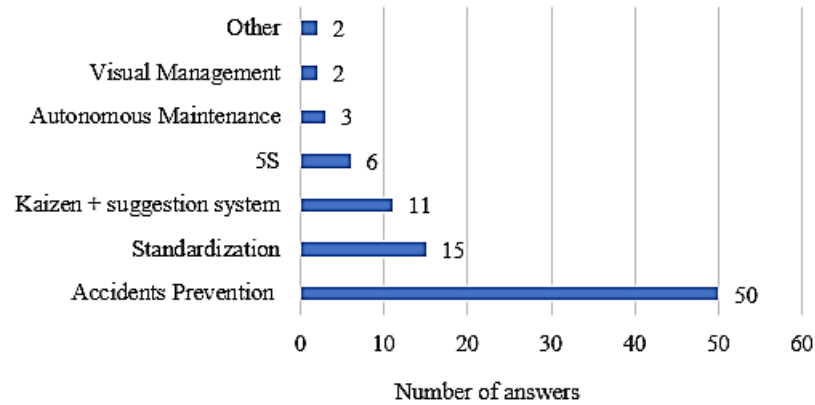
**Figure 8.** Which tool, in your opinion, has the greatest impact on improving the organization of production? – results.

Source: Own elaboration.

Only four respondents indicated the SMED method, which affects the flexibility of the process and reduces the changeover time. Twelve respondents expressed no opinion, which may indicate a lack of knowledge about the effects of using these tools (important information for the management) – Figure 8.

More than half of the respondents (50) indicated the measures taken as part of Accident Prevention as a tool that has the greatest impact on improving work safety (Figure 9). This is not a tool classified as LM solutions, but such an answer is indicative of a high level of awareness of middle management in the field of work safety. Subsequently, the respondents indicated three LM tools that have an impact on improving OSH: standardization

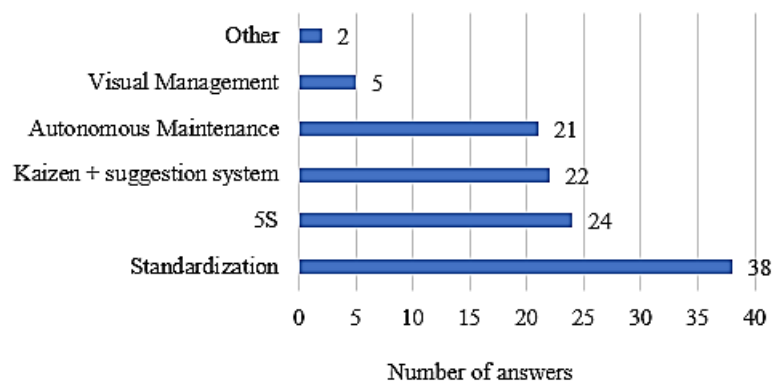
(15 respondents), Kaizen and the suggestion system (11 respondents), and the 5S method (6 respondents). These are the solutions most often used by enterprises of various industries, which have an impact on improving work safety. The answers obtained confirm the knowledge and high awareness of the respondents in this area.



**Figure 9.** Which tool, in your opinion, has the greatest impact on OSH's improvement? – results.

Source: Own elaboration.

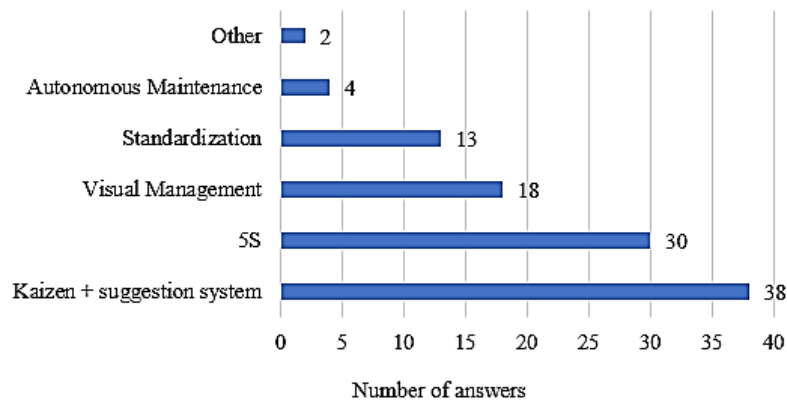
An important aspect of using LM solutions in everyday work is also the ease of their implementation. This affects the involvement of employees in the actions taken. Therefore, respondents were asked to assess which tools were the easiest and which were the most difficult to implement. (Figure 10-11). Standardization, the 5S method, Kaizen and the suggestion system, and AM are the tools that, according to the respondents, caused the greatest difficulty in implementation. The easiest tools to implement, according to the respondents, were: Kaizen and the suggestion system and the 5S method. This diversity in answers may result from the department in which the respondents work and the involvement of employees in the change process. This is important information for the management to analyze this aspect and take appropriate improvement actions. Nevertheless, the answers obtained testify to the respondents' awareness in this area (the ability to identify problems).



**Figure 10.** Which tools were the most difficult to implement in your company? – results.

Source: Own elaboration.

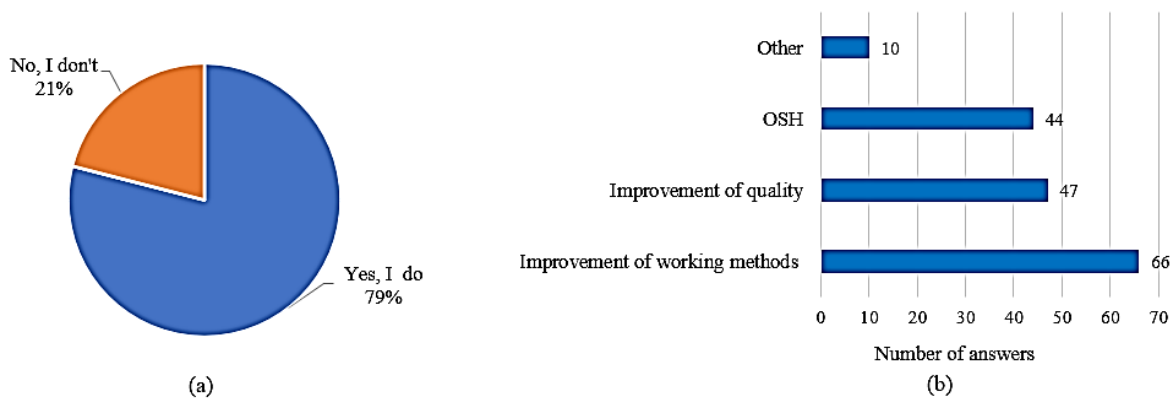




**Figure 11.** Which tools were the easiest to implement in your company? – results.

Source: Own elaboration.

The involvement of the middle management in improvement projects was also assessed, which is an important element of the culture of continuous improvement (Lean culture) and translates into shaping the awareness of all employees in this aspect. The vast majority of respondents (70) submit ideas through the Suggestion Program (Kaizen). Most ideas concerned areas related to improving working methods, quality, and work safety (Figure 12a-b). Therefore, the obtained answers indicate high awareness of employees in this area. It is worth mentioning that the impact of the applied solutions of the LM concept on improving the organization of production, OSH, and quality was confirmed by the respondents in several questions of the survey. However, 19 respondents did not submit ideas, which is important information for the management staff.



**Figure 12.** (a) Do you submit ideas in the Suggestion Program (Kaizen)? (b) What scope do you submit your Kaizen ideas from? - results.

Source: Own elaboration.

## 4. Summary

The conducted surveys made it possible to assess the awareness of middle management in the use of methods and tools of the Lean Manufacturing concept. The assessment of awareness was a subjective assessment resulting from the analysis of each survey question. Based on the conducted research, it was found that the vast majority of middle management has knowledge and high awareness in the field of continuous improvement, in the form of using LM methods and tools in the daily functioning of the company.

High awareness results from the knowledge of methods and tools derived from the Toyota Production System, which most of the respondents have been using for many years (5 years and more). In addition, employees know methods of solving problems and apply them in various areas (mainly in the field of quality management and production process management). More than half of the respondents are aware of the impact of the methods and tools used on the organization of production and work safety, indicating the tools that have the greatest impact on these areas. Respondents are also aware of the difficulties associated with the implementation of LM methods and tools in the departments in which they work. The results of the research also indicate the high commitment of the management in the form of submitting improvement ideas, which mainly affect the improvement of working methods, quality, and OSH.

The research results also indicate areas requiring improvement (awareness of the use of LM methods and tools is low):

- 5% of respondents do not use LM tools,
- 3 respondents believe that used tools do not affect the improvement of the organization of production and OSH,
- 12 respondents have no opinion on which tools improve the organization of production,
- 19 respondents do not submit ideas in the Suggestion Program,
- a discrepancy was found regarding the ease/difficulty of implementing different LM tools.

The obtained results (regarding low awareness) are important information for the management staff, allowing them to find out the reasons and take improvement actions. These can be, for example, additional training in the field of LM methods and tools, meetings at action boards to discuss current problems, or obtained results.

The important role of management in the process of continuous improvement should be emphasized. The knowledge and awareness of the management translate into the attitudes and behavior of employees (their commitment). This increases the level of the culture of continuous improvement in the company and can bring many benefits.

The conducted research was limited to assessing the awareness of a specific group of respondents (middle management), and the assessment was based on the results of 12 questions of the survey. Therefore, the direction of further research should also focus on assessing the awareness of production employees to obtain more complete information related to the development of the Lean culture in this company.

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## TRANSFORMING UNDERGROUND COAL MINE WORKINGS INTO CRITICAL CYBER SECURITY FACILITIES IN THE PERSPECTIVE OF THE EUROPEAN GREEN DEAL PLAN

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I believe that if you show people problems and provide solutions,  
you will stimulate them to take action.

*Bill Gates*

**Purpose:** in the cognitive space, the article focuses on cybersecurity as one of the top priorities of the European Commission and a cornerstone of a digital and connected Europe. The increase in cyberattacks during the coronavirus crisis has shown how important it is to protect hospitals, research centers and other infrastructure. Decisive action is needed in this area to future-proof the EU's economy and society. Therefore, cybersecurity is a key element to ensure the safe and effective implementation of the European Green Deal plan.

**Methodology:** the theses presented in the article were verified using the following methods: literature review, critical analysis of literature, analysis and comparison of documents and an example of good practices.

**Result:** the results of analyzes and research clearly revealed that cyberattacks do not stop at state borders, therefore it is necessary to strengthen cooperation between EU Member States, exchange information on threats and develop common standards and best practices in the field of cybersecurity. This allows for effective protection against attacks and minimization of risk to critical infrastructure related to the European Green Deal.

**Originality:** in the perspective described in the article, important and significant challenges arise in the field of protecting critical infrastructure against cyber threats. One of them is the transformation of underground workings of hard coal mines into facilities critical for national cybersecurity. The theses presented in the article were verified using the following methods: literature review, critical analysis of literature, analysis and comparison of documents and examples of good practices.

**Keywords:** transforming, coal, cyber security.

## 1. Introduction

In recent years, the world has been experiencing an increasing reliance on digital technologies and interconnected systems affecting a wide variety of fields and economic sectors, making cyber security a critical concern across global, regional and national policy dimensions (Gałaszka, Ptaszek, Żuchowska-Skiba, 2016). When writing about cyber security, it is important to note that the term cyber security refers to a set of technologies, processes and practices for protecting and defending networks, devices, software and data from attack, damage or unauthorized access (Bhardwaj et al., 2022). As Jana Pieriegud (Pieriegud, 2016) notes, the digitization of the economy and society is one of the most dynamic changes of our time, which opens up new opportunities in the creation of business models, but at the same time brings with it uncertainty and various risks related to, among other things, the social impact of the automation of manufacturing processes or security in the broadest sense. Digitalization as a continuous process of convergence of the real and virtual worlds is becoming a major driver of innovation and change in most sectors of the economy. The key drivers of the digital economy today are:

- Internet of Things (IoT) and Internet of Everything (IoE).
- Internet of Everything (IoE),
- ubiquitous connectivity (hyperconnectivity),
- cloud-based applications and services (cloud computing),
- big-data analytics (BDA) and big-data-as-a-Service (BDaaS),
- automation (automation) and robotization (robotisation),
- multi-channel (multi-channel) and omni-channel (omni-channel) distribution models for products and services.

A new reality of cyber threats is taking shape in this space. Their dynamic evolution poses a serious challenge to national security. Sophisticated hacking techniques, attacks sponsored by various organisations and cyberterrorism are becoming more common. In this new reality, states, organisations or institutions, faced with the challenge of protecting critical infrastructure from cyber threats, are creating innovative counter-threat approaches and solutions. Cybersecurity centres seem to be an important element of these projects, allowing not only to secure key information systems in the area of proper functioning of the state, but also to collect sensitive data and, through their redundancy, to secure the possibility of restoring data in case of loss (Górka, 2018). In this situation, the aspect of locating such centres takes on particular significance, primarily from the point of view of the possibility of destroying them using conventional methods, e.g. in the event of an armed conflict or terrorist attack. One possibility worth considering is the transformation of underground mine workings of decommissioned hard coal mines into facilities - cybersecurity centres of key importance for the state. It is worth noting here that, in line with the ongoing transformation of the coal mining industry,



such initiatives, particularly those concerning new applications for the underground infrastructure of closed mines, are of great interest to decision-makers in this process, as they fit in with the social, environmental and security agendas of the EU.

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## **2. Cyber security in the perspective of the European Green Deal Plan**

The European Green Deal Plan is a strategic initiative of the European Union aimed at sustainable economic and environmental transformation (Regional cohesion..., 2022). The plan covers a wide range of areas, such as energy, transportation, agriculture, and waste management. Each of these areas uses increasingly advanced technologies that increase efficiency, improve productivity and contribute to environmental protection. Cyber-security plays an important role, as threats from cyber-attacks can significantly hamper the achievement of sustainability goals. Cyber security is one of the European Commission's top priorities and a cornerstone of a digital and connected Europe. The increase in cyber attacks during the coronavirus crisis demonstrated the importance of protecting hospitals, research centers and other infrastructure. Decisive action is needed in this area to future-proof the EU's economy and society. Therefore, cyber security is a key element in ensuring the safe and effective implementation of the European Green Deal Plan (Joint Communication..., 2020).

Implementing such ambitious goals requires advanced technologies that are linked to the digital economy and extensive use of data. The increase in data and digital technologies comes with a greater risk of cyberattacks. Therefore, protecting critical infrastructure, energy systems, transportation systems, communication networks and personal data becomes extremely important. In the above perspective, a significant challenge is the need to ensure adequate security measures, counter threats and risk management in the context of the activities undertaken within the framework of the European Green Deal Plan (Mielke et al., 2021). The indicated measures should take into account both technical and organizational aspects to minimize the potential risk of cyber incidents. To this end, the European Commission and European Union member states should cooperate and invest in the development of advanced cyber security solutions, training of personnel and strengthening of incident response capabilities. In addition, it is necessary to establish appropriate security regulations and standards to ensure consistency and harmonization of activities at the European level.

In the space described above and in the face of certain challenges, it should be noted that cyber security is an ongoing and dynamic process. With the development of technologies and threats, also the procedures related to the elimination of incidents must be systematically

updated (Hoffman, 2018). In this context, it is important to take into account the following aspects related to cyber security - resulting from the European Green Deal Plan. The first is education and awareness. In this regard, those involved in the implementation of the European Green Deal Plan – project managers, employees and communities – should be properly trained on digital risks. The indicated action makes it possible to develop awareness and perception of current digital threats, including minimizing the propensity to succumb to potential cyber-attacks. An extremely important space is the protection of critical infrastructure. Critical infrastructure, i.e. systems and their constituent functionally related objects, including buildings, equipment, installations, services that are key to the security of the state and its citizens and that serve to ensure the smooth functioning of public administration, as well as institutions and businesses, must be adequately protected against cyberattacks (Ustawa z dnia 26 kwietnia 2007 r.). Putting in place strong defense mechanisms, such as intrusion detection systems (IDS – Intrusion Detection System) or attack protection systems (DDoS – Distributed Denial of Service) is a necessary measure. It is worth noting that at the end of 2016, there were three continuous DDoS attacks on domain name system (DNS) provider Dyn. This was a wake-up call about the dangers of targeted DDoS attacks. DDoS attacks have become one of the most serious threats to network security, and the first reported attack was published by Computer Incident Advisory Capability in 1999. Although a number of threat mitigation systems have been developed in academic and industrial environments, DDoS attacks remain serious and are increasing every year (Abu Bakar et al., 2023).

Another area identified by the Green Deal European Plan is data security. Due to the significant increase in the amount of data collected, it is necessary to properly secure the information collected, such as environmental, climate change, energy or mobility data - and to properly store and process it in accordance with data protection regulations (RODO – Data Protection Regulation (Dziennik Urzędowy Unii Europejskiej L 119, 2016)/GDPR – General Data Protection Regulation (Rozporządzenie o Ochronie Danych Osobowych...)). In this space, it is important to recognize that data security is the practice of protecting digital information from unauthorized access, damage or theft throughout its lifecycle. It is a concept that encompasses every aspect of information security, from the physical security of hardware and storage devices to administrative and access controls, as well as logical application security. It also includes organizational policies and procedures. Properly implemented, robust data security strategies not only protect an organization's information assets from the actions of cyber criminals, but also protect against insider threats and human error, which remains one of the leading causes of data security breaches today. Data security involves implementing tools and technologies that improve an organization's insight into where its critical data is and how it is being used. Ideally, these tools should enable security features such as encryption, data masking and redaction of confidential files, and should automate reporting to improve audits and compliance with regulatory requirements. In this light, digital transformation is

fundamentally changing every aspect of how today's companies operate and compete. The sheer volume of data that companies create, process and store continues to grow, creating a greater need for data management. In addition, computing environments are more complex than ever and routinely include the public cloud, the corporate data center and numerous edge devices, from Internet of Things sensors to robots and remote servers. This complexity creates an expanded attack surface that is increasingly difficult to monitor and secure ([www.ibm.com/topics/data-security](http://www.ibm.com/topics/data-security), 2023).

The European Green Deal plan also centers around issues of international cooperation. Cyber security is a global phenomenon, so it is important for European Union member states to cooperate on an international level. As the European Commission emphasizes, cyber security is crucial to both our prosperity and security. As our daily lives and economies become dependent on digital technologies, we are becoming increasingly vulnerable. Cyber-security incidents vary both in terms of who is responsible and the objective they seek to achieve. Malicious cyber activities threaten not only our economies and the pursuit of a digital single market, but also the very functioning of our democracies, our freedoms and our values. Our future security depends on transforming our ability to protect the European Union from cyber threats: both civilian infrastructure and military capabilities rely on secure digital systems. This was recognized by the European Council in June 2017 ([www.consilium.europa.eu/...](http://www.consilium.europa.eu/...), 2023), as well as in the European Union's Global Strategy on Foreign and Security Policy (<http://europa.eu/globalstrategy>, 2023). Cyber threats come from both non-state and state actors: they are often criminal in nature, motivated by profit, but can also be political and strategic in nature. The threat of crime is compounded by the blurring of the line between cybercrime and "traditional" crime, as criminals use the Internet both as a way to scale up their activities and as a source for finding new methods and tools to commit crimes. In this perspective of an increasingly digital and interconnected world, protecting EU citizens from cyber threats is a top priority for the EU. The new proposed measures aim to strengthen cooperation on cyber security in the EU and globally, stimulate innovation and invest in awareness and capacity building. In parallel, the EU and NATO are conducting coordinated exercises to test their ability to respond to cyber and hybrid threats (Wspólny komunikat..., 2017). By sharing information and taking action together, cross-border digital threats can be addressed more effectively.

Research and innovation is another area of intervention of the European Green Deal Plan, which reads that supporting research and innovation in the field of cyber security is key to developing advanced defense technologies. This is evidenced by the following facts. By 2021, cybersecurity will already cost the global economy \$6 trillion a year, up from an estimated \$3 trillion in 2015. (estimated global GDP in 2020 is \$138 trillion) (Cybersecurity Ventures, „2019 Official Annual Cybercrime Report”, 2020). The costs of cybercrime include data corruption and destruction, theft of money, loss of productivity, theft of intellectual property, theft of personal and financial data, disruption of the normal course of business after an attack,

and loss of reputation. The European Systemic Risk Board (- hereafter ESRB) estimates that the average cost of a cyber incidents increased by 72% between 2015 and 2020 (ERRS, Europejska Rada ds. Ryzyka Systemowego, 2020). Secondly, according to a 2020 study, cybercrime adversely affects different sectors of the economy in different ways (PWC, Fighting fraud..., 2020). It was the most destructive form of fraud in the government and public administration sector, the technology, media and telecommunications sector, and the health sector. It was also the second most destructive form of fraud in the financial sector and in the industrial and manufacturing sectors.

The objectives and actions indicated above are referenced in the EU Cyber Security Strategy, which aims to ensure a global and open Internet with strong safeguards where there is a threat to the security and fundamental rights of people in Europe. As a consequence of the progress made under previous strategies, it contains concrete proposals for the use of three main instruments, which are regulatory, investment and policy initiatives. These address the following three areas of EU action:

- resilience, technological sovereignty and leadership,
- operational capacity for prevention, deterrence and response,
- cooperation for the development of a global and open cyberspace.

The EU is determined to support this strategy with unprecedented levels of investment in digital transformation over the coming years. This represents a quadrupling of previous investment levels. This demonstrates the EU's commitment to its new technology and industrial policy and reconstruction agenda. The EU's new cybersecurity strategy is a key element of the Shaping Europe's Digital Future strategy (Shaping Europe's Digital Future..., 2020), the Recovery Plan for Europe (Rozporządzenie Rady (UE) 2020/2094 z dnia 14 grudnia 2020 r.) and the Security Union Strategy 2020-2025 (Komunikat Komisji..., 2020).

Thus, investments in areas such as artificial intelligence, machine learning and big data analytics can help identify new threats and respond quickly to potential attacks. By properly securing digital infrastructure and data, it will be possible to minimize the risk of potential attacks, which will contribute to the successful implementation of the European Green Deal Plan and accelerate the achievement of the set goals related to environmental protection and the fight against climate change. Ultimately, the success of the European Green Deal Plan depends on the effective and secure use of digital technologies. Ensuring an adequate level of cybersecurity will avoid potential losses, environmental risks and damage to the long-term implementation of this important plan for the future of Europe and the world.

### 3. Cyber security in the mining transformation process

The process of transformation of the mining industry is not only the end of mining operations, but also the beginning of a new stage of economic development for regions that have been strongly linked to this economic sector. The decommissioning of mines creates a number of new challenges, among which it seems that the key one is the effort to adapt to changing social, economic and environmental conditions. Mining areas that have based their economies on mining for many years also face the need for adaptation and diversification, which enable them to achieve the following goals (Leininger et al., 2018):

- dissipation of economic risks associated with vulnerability to commodity price fluctuations,
- sustainable development of mining areas,
- development of diverse economic sectors,
- creation of new jobs,
- increase in investment and infrastructure development,
- development of innovation and new technologies,
- environmental protection,
- increasing cultural and social diversity,
- development of new educational programs.

The transformation of mining areas from monoculture to modern, diversified economies is key to ensuring the sustainable development of these regions. Adaptation and diversification respond to the challenges of natural resource depletion, changes in the market for raw materials and the need to protect the environment. Diversity, in turn, contributes to the development of innovation, the creation of new jobs and increased investment in infrastructure and research and development. Transformation, while not without challenges, is opening up opportunities for development and progress in the regions, resulting in sustainable and diversified socioeconomic development. As mining areas undergo transformation and adapt to new functions such as tourism, recreation and new technologies, it is innovative to build new spaces and infrastructure related to cyber security (Nowakowska, Rzeńca, Sobol, 2021).

The process of decommissioning mining poses many challenges, but at the same time opens up new opportunities for growth and adaptation for local communities and industries operating in the transformed areas. As mines close, existing mining spaces and infrastructures can be transformed into new cyber security facilities. As the authors of the Technology Trends Outlook 2022 report note, technology continues to be a major catalyst for change in the world. Technological advances are giving companies, governments and public sector institutions greater opportunities to raise productivity, create and change reality anew, and contribute to humanity's prosperity. And while it is still difficult to predict how technology trends will evolve, world leaders can better plan for the future by tracking the development of new

technologies, anticipating how companies can use them and identifying factors that influence innovation and adaptation (Chui, Roberts, Yee, 2022). Second, as the authors of the report, *Digital technologies for a new future*, note, digital technologies foster eco-innovation that contributes to sustainable development by reducing environmental impact and optimizing resource use. As these technologies develop and converge with biotechnology and nanotechnology, they can generate exponential innovations that will contribute to a sustainable future (The difficult balance..., 2021).

Achieving the above goals requires a number of conditions, among which the key ones may be having adequate resources and infrastructure. This may involve investment in the development of roads, schools, or new technologies, which can be time-consuming and expensive. In the social sphere, the involvement of residents of transformed areas in decision-making processes and increased public awareness of the benefits of diversifying economies may prove to be important factors. Finally, the transition from mining to a different structure of transformed economies may require labor resources to acquire new skills and competencies (Wirth et al., 2018).

In the above-described perspective, the transformation of existing mining spaces and infrastructure into new cyber security facilities has many benefits for both local communities and the economic development of transformed mining regions, including (Marszowski, 2020):

- can determine the influx of investors and regional development. Post-mining areas, thanks to modern infrastructure related to cyber-security, can become an attractive place for IT and cyber-security companies and professionals. This will contribute to the regions' international competitiveness;
- allows diversification of the economy, creation of new jobs, development of innovation and strengthening of digital security. This is an opportunity to minimize the negative effects of mining decommissioning into a positive boost for the development of local communities and the region as a whole;
- areas that previously served as training centers for miners can be transformed into state-of-the-art training centers related to cyber security. They can offer courses, workshops and training for IT professionals and those wishing to pursue a career in cyber security;
- existing facilities and buildings can be adapted into cyber security research and development centers. Such centers can support the development of innovative technologies and strategies to protect against cyberattacks;
- areas after the decommissioning of mines can be transformed into technology parks that will attract companies related to cyber security, IT and IT technologies. Indicated parks can foster the development of the local business ecosystem and create new jobs;
- post-mining facilities can also be used to locate cyber-security monitoring and management centers. These can be places where specialists can focus on detecting threats and responding to attacks;
- large areas after mine decommissioning can be used to build industrial data centers that provide secure data storage and hosting services for various industries.

However, this process also brings challenges related to a lack of resources and infrastructure, as well as resistance to transformation by local communities. Therefore, strategic planning and the involvement of all stakeholders is necessary for the effective and harmonious transformation of mining areas into diversified centers for socio-economic development. Centers can be the basis for transforming underground coal mining pits into cyber-critical facilities. This is a comprehensive approach that combines innovation, critical infrastructure protection and regional development to leverage existing coal mining resources.

Thanks to the rationale described above, accompanying the transformation, mining regions can face the challenges of mining decommissioning and at the same time contribute to strengthening the country's digital security. In conclusion, diversification of mining areas is an integral part of economic transformation. Reduction of economic risk, sustainability, job creation and the development of innovation are key benefits of diversification.

#### **4. Cyber security in the underground workings space**

In the European Green Deal Plan, one of the key areas of transformation is mining, and special attention should be paid to transforming underground mine workings into critical cyber security facilities. Their potential stems from infrastructure that can be adapted for new purposes, such as energy storage, data storage or renewable energy installations. Underground mine workings in the cyber security space have a unique advantage over existing infrastructure. These spaces are often characterized by robust construction, flexible power supply and natural environmental isolation. By repurposing these pits, societies can optimize their resources and reduce the need to build new facilities, saving the time and costs associated with building them from scratch. An extremely important element of the space described is that underground mine workings are designed to withstand extreme conditions and ensure physical safety. These features make them ideal for storing critical cyber-security infrastructure, as they provide a level of protection against physical threats such as sabotage, theft or natural disasters. The inherent resilience of these underground structures adds an additional layer of security to the national cybersecurity infrastructure (Pałka, Rizaoglu, 2019).

Transforming underground workings into a cyber security space can contribute to a number of important and significant goals, including (Aligning Policies..., 2015):

- sustainable development, improving the economy in regions that have depended on mining,
- reducing CO<sub>2</sub> emissions,
- increasing energy efficiency,
- creating new jobs in the new technology and renewable energy sectors,
- compensate for job losses in mining.

It also has great significance for the transformation process. These unique infrastructures have the potential to attract investment, create jobs and stimulate economic growth. However, in order to achieve these benefits, it is essential to ensure adequate levels of cyber security. Good security of these facilities attracts the trust of investors and users, which is crucial to their success. In addition, cyber-critical facilities can serve as important technology facilities for other sectors, such as banking, healthcare and government. Their reliability and security are integral to the proper functioning of these sectors (Spychała, 2017). In addition, the development of such facilities can contribute to the revitalization of mining areas and improve the living conditions of local communities. The creation of new jobs, investment in digital infrastructure and the development of local technological competence contribute to economic growth and improve the quality of life of local residents (Wariantowe Ramy Transformacji..., 2023). While transforming underground mine workings into cyber-critical facilities brings a number of benefits, it also requires focused efforts aimed at protecting infrastructure and data. The physical and cyber security of these facilities is essential to the success of the transformation process and to ensure investor and user confidence (Cybersecurity strategy...).

Transforming underground coal mine workings into facilities critical to the country's cyber security can also play a number of important roles in the mining transformation process. As mining changes, underground coal mine workings are becoming cyber-critical facilities. Transforming these areas into new, innovative data centers or other technological infrastructures brings many benefits, but also new challenges in protecting against cyberattacks. Transforming underground pits into cyber-critical facilities involves protecting both the infrastructure itself and the data stored there. These facilities can be used as data processing centers that store huge amounts of information of high business or personal value. Their security is crucial, as an attack on these facilities can lead to data loss, service disruptions and even threats to user security and privacy.

Equally important is the regularity that indicates that transforming underground pits into cyber-security facilities can help diminish distributed and redundant infrastructure, increasing the overall resilience of a nation's cybersecurity state. By strategically deploying these facilities in different regions, countries can minimize the risk of a single point of failure and ensure business continuity even in the face of local disruptions or targeted attacks (Michałkiewicz, 2016).

As a result of developing efforts to convert underground mine workings into critical cyber security facilities, their use as energy storage or photovoltaic installations also allows the production of clean energy, thereby reducing greenhouse gas emissions. Secondly, the existing infrastructure in underground mine workings, such as ventilation systems or transportation routes, can be used as the basis for building new facilities, related to related to cyber security – which can significantly speed up the transformation process – saving time and resources. However, it should be remembered that transforming underground mine workings into critical



cyber-security facilities requires significant investment. In view of this regularity, governments and European institutions should secure adequate funding and provide support to businesses and local communities to assist them in transforming these areas. As countries face the challenges of protecting critical infrastructure and information from cyber threats, repurposing these pits shapes a unique and innovative approach to ensuring cyber resilience and protecting national interests. With careful planning, cooperation and investment, countries can leverage the advantages of underground mining infrastructure to enhance their cyber security capabilities (The Sustainable Development Goals Report, 2021).

As researchers at the University of Nevada note, another reason why cybersecurity is important is the dramatic increase in the sheer number of cyberattacks, along with the increasing sophistication of cybercriminals' tactics - both of which cause significant financial losses. New malware capabilities, coupled with an increase in data security breaches, have increased the total cost of cybercrime. Potential losses from these reported cybercrimes have exceeded \$6.9 billion. Cybercrime magazine estimates that cybercrime will cost the world \$10.5 trillion annually by 2025. Hackers are using sophisticated strategies to steal login credentials to gain access to smart phones and computers, hack phones via Bluetooth headsets and spy on people using public Wi-Fi networks. Cybercriminals are becoming increasingly cunning and harder to stop, and cybersecurity professionals must be able to keep up (Why Is Cybersecurity Important? 2023).

In this perspective, underground mine workings that are not used for coal mining can be transformed into special facilities to serve as centers for operations and management of cyber security. Due to their structure and characteristics, such facilities can provide optimal conditions for storing and managing cyber-security resources, such as servers, monitoring systems and threat detection tools. It is also worth noting that underground mine workings have the necessary infrastructure for adapting cyber security operations and management centers in their space, such as power systems, ventilation, resistance to external factors, which can facilitate adaptation and reduce the cost of building new cyber security facilities. The spaces described can help ensure the independence of national systems. Thus, in the event of cyberattacks or other threats, there is a potential opportunity to continue operations and protect the country's key assets. However, this requires very consistent building of a specialized environment associated with highly skilled personnel who can manage these facilities to ensure cybersecurity. Such targeted actions can determine the development of local labor resources in transformed areas and the growth of an education system focused on cyber security competencies and skills. As a result, the dynamic development of digital technologies and the influx of cadres and talents related to cyber security may follow in these areas.

Physical protection of cyber security facilities is also an important aspect. Since they are located in former mine workings, it is necessary to provide adequate security measures, such as monitoring, access control and protection against unauthorized entry. Special attention should be paid to protection against physical intrusion to prevent physical access to these facilities by

unauthorized persons. Protecting the infrastructure from cyber-attacks is another important aspect. Ensuring adequate network security, such as firewalls, intrusion detection systems (IDS/IPS) and event monitoring, is key to preventing attacks and identifying anomalies in real time. Regular security audits should be conducted to detect potential security vulnerabilities and take appropriate corrective action. In addition, an important element is the protection of stored data. Data centers in these facilities may store sensitive information, such as financial data, personal data or industrial secrets. Adequate safeguards such as strong data encryption, physical security and authentication systems are needed to prevent unauthorized access to this information. Regularly backing up data and storing it in secure locations are also key to minimizing the risk of data loss.

In this perspective, many coal-related countries are shifting to cleaner and renewable energy sources. With the disappearance of mining-related activities, the repurposing of existing mine workings is in line with sustainable development goals (Sulich, 2021). By transforming them into critical cyber-security facilities, societies can not only address cyber-security challenges, but also promote environmentally friendly activities by repurposing existing mining infrastructure with its consolidation and preservation (Borky, Bradley, 2018).

However, the success of transforming underground mine workings into cybersecurity-critical facilities does not depend only on the technical aspects of protection. Education and awareness of the importance of the transformation among mining employees and local communities is also an important factor. Employees responsible for managing and operating these facilities should be trained in cyber security. They should be aware of the latest security threats and practices, and know the procedures to follow in the event of a cyber security attack or incident. Regular training and awareness of cyber risks are key to building defense capabilities and minimizing risks. In addition, the local community should be involved in the transformation process and aware of the importance of cyber security. Local authorities, community organizations and community representatives should be informed about cyber threats and security measures to protect these facilities. Increased awareness among residents can contribute to reporting suspicious activity and supporting prevention efforts. Finally, collaboration with government agencies, cyber security experts and the private sector is essential to effectively ensure cyber security at these facilities. Coordinated efforts, sharing of threat information and best practices, as well as joint research and development initiatives can help create a strong cyber security ecosystem that is resilient to evolving threats. In this light, he concluded, "transforming underground mine workings into cyber-security critical facilities is a key part of the transformation process. Infrastructure and data protection, employee and community education, and cross-sector collaboration are essential to the success of this transformation. With the right approach, these transformed facilities can be secure technology centers, contributing to socioeconomic development and improving quality of life" (Strategic Agenda ECCC. ..., 2023).

As a result, activities aimed at transforming underground coal mining pits into cyber-security critical facilities contribute to the diversification of economies in transformed areas - particularly in areas where coal mining plays or has played a key role. Transforming these areas into cyber security centers can create new opportunities for economic growth and social development. This could include the creation of new jobs related to the management and maintenance of cyber-security facilities, digital security training, and the development of cyber-security-related businesses and services. The indicated positive effects of transformation can thus minimize problems of unemployment, social exclusion and poverty - while contributing to the revitalization of these areas through the creation of new jobs and innovation-related industries becoming a source of economic growth and recovery (Large, 2014).

Transformation in the cybersecurity space can serve as a catalyst for the diversification of transformed mining areas and, as already noted, support their innovation. Achieving the above goals requires cooperation and knowledge sharing. The repurposing of underground mine workings determines the need for cooperation between government bodies, private entities, research institutions and local communities in transformed areas. The outlined challenge fosters knowledge exchange and encourages interdisciplinary and international cooperation. Transformation projects can create a platform for the exchange of expertise, best practices and technological advances, contributing to the overall improvement of capabilities in cybersecurity at the national level (Brunetti et al., 2020).

In conclusion, the need to transform underground coal mine workings into critical facilities for national cyber security is driven by various factors. Evolving cyber threat space, use of existing infrastructure, increased physical security, geographic distribution, synergy with energy transition, economic transformation and opportunities for cooperation are important reasons determining the transformation of underground coal mine workings into critical cyber security facilities (Konieczna-Fuławka et al., 2023).

## **5. Central Mining Institute National Research Institute Experimental Mine "Barbara" Poland - an example of good practice**

The above-described perspective of cybersecurity as a subject of critical concern in terms of global, regional and national policies corresponds perfectly with the concept of adapting the infrastructure of underground excavations and facilities on the surface of the Central Mining Institute (hereinafter GIG) of the Experimental Mine "Barbara" (hereinafter EM Barbara) for the purposes of establishing the Silesian Cybersecurity Center (Analysis of the possibilities..., 2022). The development of the concept of the center - the Silesian Cybersecurity Center based on the underground infrastructure of GIG EM Barbara is part of the plans to transform the mining sector in Upper Silesia. The concept of a potential investment assumes maximum use

of the existing infrastructure of EM Barbara and its expansion, modern and alternative to the original function.

As part of the preparation of the work concept, it is planned to create a monitoring system for the mining transformation processes and to build a modern cybersecurity infrastructure on the premises of the GIG EM Barbara. Implementation of the project involves the modernization and equipping of the facilities of EM Barbara with the necessary equipment for: collecting, processing, storing, delivering and securing digital data.

The transformation process monitoring system will consist of thematic quantitative and qualitative databases covering various scopes. The concept of the system assumes that data and quantitative indicators resulting from economic, financial, scientific and other statistics (currently collected and available in various databases) as well as qualitative data will feed the system on an ongoing basis. A special role in the System will be played by data on mining activity and its consequences, important for monitoring the transformation and planning the development of the region, which are a separate competence of the Central Mining Institute. For years, the Institute has been collecting, verifying and sharing:

- data on seismicity in the Upper Silesian Coal Basin (hereinafter referred to as the GZW);
- data for the European Plate Observation System;
- measurement data and measurement network of PM2.5 and PM10 fractions;
- data on current weather conditions and the GIG meteorological station data archive;
- information on the state of basic natural and technical hazards in hard coal mining;
- data on mining and post-mining areas;
- data on shallow exploitation in the areas of liquidated mines in the GZW.

The statutory works, consulting services, expert opinions and projects carried out at GIG provide a stream of data and information that, after integration and development, can supply the database system, among others, in the following areas of mining and post-mining activity:

- information on the risk of loss of surface stability in the areas of closed mines,
- data on mining waste streams and directions of their management,
- methane emissions from active and closed mines,
- qualitative and quantitative data of the GZW mine drainage system and the use of mine water,
- size of the carbon footprint of e.g. Mining Companies,
- heap fire hazard,
- size and structure of employment in mining and mining-related entities.

Structuring and organizing data sets and supplementing them with data collected by other institutions concerning e.g. social, economic, climate and other aspects, which will enable the preparation of in-depth expert opinions and reports on transformation. The wide spectrum of acquired and processed data is associated with the need to secure the appropriate technical

infrastructure, provide data sources and develop algorithms for their sharing and processing in the form of reports and/or raw data.

The construction of the Transformation Processes Monitoring System will be carried out on the grounds and buildings managed and used by the Central Mining Institute on the premises of EM Barbara in Mikołów, where the necessary infrastructure (Data Center) will be built.



**Figure 1.** Visualization of the supercomputer in underground mining workings of EM Barbara.

Compared to traditional solutions, the newly created facility is characterized by the location of the server room. Server rooms being a building consisting of two basic parts: the server chamber and rooms supporting the functionality of the server chamber equipped with IT equipment installed with UPS, energy distribution, technical, telecommunications, operational, cold distribution facilities and areas for the foundation of power generators, cooling aggregates and fuel tanks. In the present project, the existing underground workings of EM Barbara will be used for the construction of the data processing center, which requires their appropriate adaptation - securing, strengthening and enclosing.

The new, pilot approach to the ways of developing post-mining areas means that the project is part of the transformation process and gives the opportunity to give new functions to the existing post-mining facilities.

## 6. Summary

Cyberattacks do not stop at national borders, so it is essential to strengthen cooperation between member states, share information about threats, and developing common standards and best practices in the field of cyber security. This allows for effective protection against attacks and minimization of risks to critical infrastructure related to the European Green Deal Plan. Finally, cyber security should also be addressed in regulatory and legislative policy.

The European Union should develop an appropriate legal and regulatory framework that will stimulate investment in cyber security and urge companies to implement effective protection measures. Strict sanctions should also be set for individuals or organizations that commit cyber-attacks, in order to ensure accountability and deter potential criminals. In the context of the above-mentioned regularities - it seems - success related to the transformation of underground mine workings into facilities of key importance to the state's cyber security is determined by a number of considerations, among which a particularly important one is the partnership between mining representation, the private sector and local communities. The indicated cooperation of these entities can determine better use of mining resources and ensure sustainable development for transformed mining areas. However, this requires, once again to be emphasized, investment, support and cooperation between different entities. In summary, the transformation of underground mine workings may represent a unique opportunity to use existing resources and infrastructure to build a sustainable future for Europe and prove to be a key element in the transformation of the Polish mining industry and in achieving the goals of the European Green Deal Plan.

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## IMPROVEMENT OF SECURITY MANAGEMENT IN THE WAREHOUSE SPACE THROUGH THE USE OF A VISION SYSTEM IN A SELECTED ENTERPRISE

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**Purpose:** The purpose of the presented research and analysis was to create design assumptions for a vision system supporting security supervision in the warehouse space to reduce threats.

**Design/methodology/approach:** In the first phase of creating the project concept, two methods of hazard analysis (FTA and ETA) were used in the warehouse facility. Then, at the stage of selecting the devices included in the video surveillance system, a simple FOKUS program was used to scale the cameras.

**Findings:** In order to create a vision system project for a selected warehouse facility, an analysis of its spatial structure, weak points and identification of possible threats was carried out, taking into account the specificity of work performed within the working space of the warehouse. Then, video surveillance zones were determined based on the classification of threats in the space of the facility. The devices included in the vision system were also selected according to the assumed functions of this system and their distribution in the tested object. In addition, the optimal parameters of the cameras (using a scaling program) and the characteristics of other necessary devices of the vision system were determined.

**Practical implications:** The solution can be an aid in making an investment decision by the management in order to improve security management in the examined warehouse facility of company X.

**Originality/value:** As a result of the analyses, an optimal and original design solution for the vision system was obtained for the tested warehouse in company X.

**Keywords:** security management, storage facility security, threat monitoring, video surveillance system.

**Category of the paper:** technical document, case study.

## 1. Introduction

Effective security management in industrial plants of any purpose is possible thanks to the use of all available tools, devices and procedures that are part of security systems (Lewandowski, 2000; Kołodziński, 2011). With the help of these systems, it is possible to ensure effective safety management in production processes, also in the transport phase (Rut, Wołczański, 2015). The task of safety systems is to reduce the risk to a minimum, improve occupational hygiene, but also to increase the quality and efficiency of the production processes carried out. An important role among technical protection systems is played by alarm systems equipped with detection devices that detect and generate information (warning) about the threat (Ignac-Nowicka, 2018). Due to the number of devices used and their functions, three levels of technical protection of the facility can be distinguished in the facility security management:

- low level of technical protection - it is characterized by the simplicity of planning the protection zones of the facility, no perimeter protection zone and the protection of architectural openings, e.g. windows; the most commonly used devices are motion detectors, magnetic door detectors, acoustic siren,
- medium level of technical protection - characterized by multi-zone protection (perimeter protection zone - magnetic detectors and glass breakage in window openings, internal protection zone - various types of motion detectors),
- high level of technical protection - it is characterized by the integration of systems, e.g. access control, burglary and assault alarm and fire alarm, as well as a closed-circuit television system (Wójcik, 2004).

Security systems, such as video surveillance, enable e.g. real-time insight into the production and transportation process. With its help, it is possible to recognize and verify emerging threats in a technical facility before a dangerous situation occurs. The vision system together with other security systems (e.g. fire protection system) creates a high level of technical security of the facility in the security management system.

In the warehouse space, there are problems with documenting threats such as: theft, destruction of goods, improper storage generating threats to employees and goods. The article attempts to solve the problem of effective identification of threats in the warehouse space. For this purpose, an appropriate configuration of the vision system was designed for the tested warehouse. It was assumed that this system would contribute to reducing the number of threats and accidents in the warehouse space.

## 2. Research methods used

In the first phase of creating the concept of the vision system project, two methods of hazard analysis were used: fault tree (FTA) and event tree (ETA) in the warehouse facility. Due to its specificity, the fault tree method (FTA) has a limited scope of application, but it leads in a simple way to determining the causes of threats and shows their logical interrelationships. In this method, events are determined whose combinations lead to a peak event. In this way, the so-called error tree, i.e. events connected by "or" and "and" logic gates. The FTA method can be used to describe events involving technical means (machines) and humans (working crew). In this method, emergency events of technical elements and failures resulting from human error (human factor) can be taken into account at the same time. This gives the possibility of a broader analysis of causes and effects that lead to the final event in the form of an accident or technical failure. The Event Tree Analysis (ETA) method allows for the analysis of alternative outcomes of a particular hazard event. The method of describing an object, process or workplace consists in determining a sequence of events leading from the initiating event to the threat and, consequently, to a specific loss. The event tree diagram consists of a header that contains a sequence of events determined by the procedure of the work process. The event tree method can be used to analyze a working technical object as well as the work of a man with a machine.

Then, at the stage of selecting the devices included in the video surveillance system, a simple FOKUS program was used to scale the cameras. Cameras used in video monitoring systems are characterized by different operating parameters, so each time the parameters should be selected for a specific supervised area. When choosing the parameters of the camera, focus on the two most important parameters: the working range of the camera and the size of the image converter (sensor), which determines the size of the image produced, and the focal length of the lens, as the distance between the image sensor and the central point of the optical system of the lens. Other parameters of the camera will be of secondary importance. The FOKUS program allows you to observe the size of the object seen on the monitor depending on the parameters described above.

## 3. Designing security systems in technical facilities

Designing an alarm system should begin with determining the formal requirements that must be met by the entire installation (due to the investor's expectations, legal conditions or those imposed by the insurer). Creating the initial concept and design as well as system implementation is a process on which the correctness and effectiveness of the security system

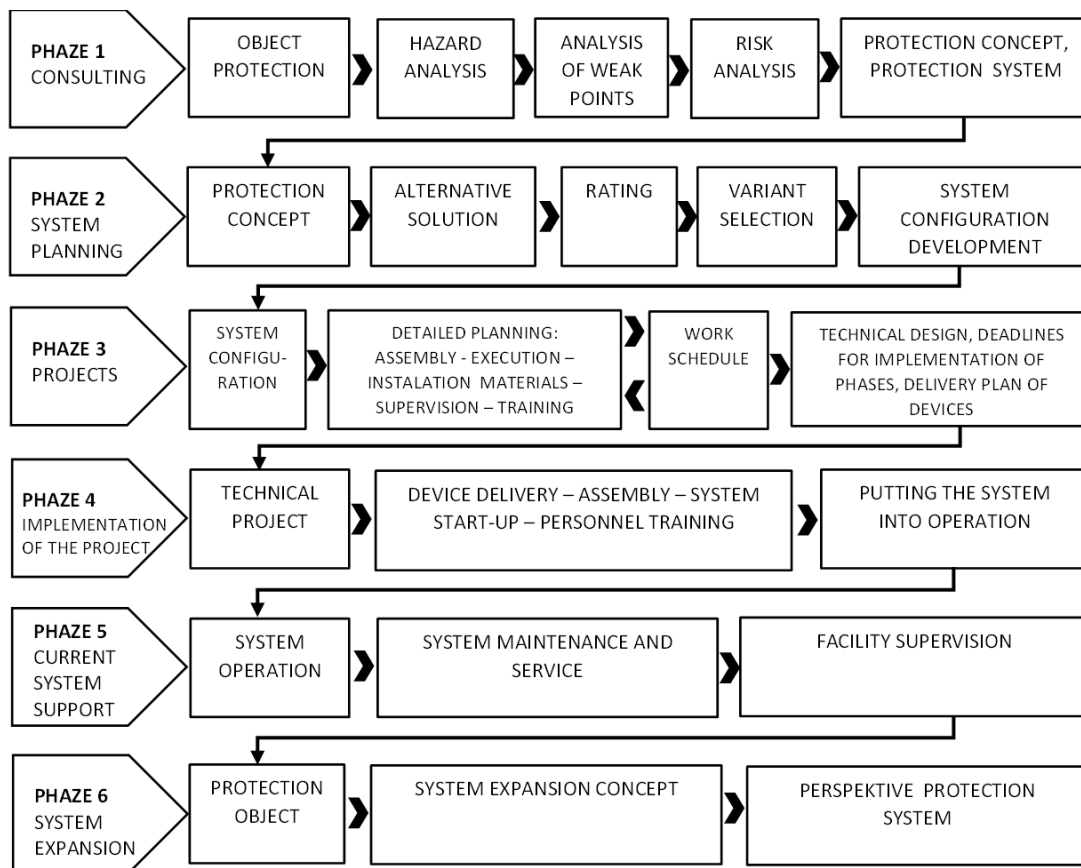
in the facility depend. The designer's duty in the process of creating the concept of the alarm system is to present the real threat to the facility and to plan the security system in such a way that it effectively resists negative actions. For this purpose, the principles of designing alarm systems should be followed, with particular emphasis on the sequence and completeness of the design phases (Prussak, 2011; Sienkiewicz, 2015).

### 3.1. Creating a security system for a warehouse facility

Designing facility security systems requires:

- knowledge of the technical object and its surroundings,
- identification of threats, weak points and dangerous places,
- selection of the security system and its functions,
- determining the proper parameters of all components of the security system.

The process of designing protection systems for a technical facility consists of many phases, which are presented in Figure 1.



**Figure 1.** Scheme of the process of creating a security system in a technical facility.

Source: Ignac-Nowicka, 2018.

In the “consulting” phase, an important stage is the analysis of threats and identifying weak points. For this purpose, an appropriate method of identifying hazards should be selected according to the nature of the technical facility and the specificity of the hazards, taking into account the human factor. In the “system planning” phase, a protection system concept is created (usually in two or more variants), which are then assessed, after which the optimal variant is selected by the investor. In the “projects” phase, detailed planning of the work schedule is carried out in the form of: assembly, execution, use of installation materials, supervision and training of the staff. In this phase, the technical design of the security system is created. In the “project implementation” phase, based on the technical design, the following takes place: delivery of equipment, assembly, and then commissioning of the system, then training of the staff and commissioning of the system. In the "current service" phase of the system, uninterrupted operation of the security system should be ensured through its appropriate maintenance and service, as well as the organization of supervision of the security system. In the last phase, "system expansion", a concept for expanding the security system is created, i.e. a prospective system, indicating the possibilities of expanding the current system in the future (Wójcik, 2004; Jodełka, Rosiński, 2018).

### **3.2. Video surveillance system as a tool to ensure security in the facility**

One of the definitions of video surveillance proposed by the Inspector General for Personal Data Protection in the provisions on video surveillance reads as follows: "monitoring (video surveillance) - remote reception of an image or image and sound from a space within the field of view of cameras installed at specific points near the monitored area ". On the other hand, "a monitoring system is a set of cameras, transmission devices, electronic data carriers, data recording devices, devices reproducing recorded data and software used to achieve a specific functionality in the field of monitoring" (Kardas, Cicekli, 2017). In industrial plants, video monitoring is becoming a standard and a common practice in terms of securing property, especially against acts of vandalism, theft or intrusion of third parties into the enterprise (Ignac-Nowicka, 2016, 2021; Eiharrouss, Almaadeed, 2021). Video monitoring in a company can play an important role of previewing a selected part of the technological process or controlling the behavior of employees by registering, for example, evasion of health and safety regulations. Video monitoring by recording emerging threats allows you to obtain important information related to the level of security in any area of the industrial plant (Badowski, 2021; Matuszek, 2020; Zieliński, 2019).

Due to the nature of the work of video systems in buildings and open spaces, three main functions of the CCTV system can be distinguished: preventive, operator and evidence. The preventive function consists in informing about the installed video monitoring in order to discipline the behavior of people who must take into account the possibility of recording their image and identification. The operator function consists in the reaction of the monitoring operator who tracks the image from the cameras in real time and reacts to threats visible on the

screen. This function is often used in the monitoring of industrial processes and workplace safety. In turn, the evidentiary function consists in recording the image from the cameras on a suitable medium in order to obtain the possibility of reconstructing the events also after some time. This function is particularly useful when determining the course of events after an accident at work. Video surveillance systems are therefore an important means of prevention and protection, which allows you to view places and objects at a distance (Ćwikła, 2013; Ignac-Nowicka, 2018; Lim et al., 2014; Majkucińska, 2012).

The closed-circuit television (CCTV) system should be equipped with appropriate devices so that the video monitoring can fulfill its three basic functions. The vision system usually includes the following devices: cameras, monitors, devices transmitting the video signal, devices controlling utility functions (image changers and image dividers - quads, multiplexers, video switchers, control keyboards), archiving devices (time-lapse video recorders, digital recording). Multiplexers are devices that simultaneously perform the functions of an image changer and a divider. The multiplexer allows you to operate multiple cameras simultaneously and simultaneously display high-quality full-screen images on a split screen. The resolution of the multiplexer determines the quality of the image displayed on the monitor. Video matrix switchers are devices that transmit the video signal from cameras to monitors or multiplexers. They make it possible to organize cable connections for a large number of signals. Thanks to the use of patch panels, you can easily manage the network architecture of the video system. The matrix functions are programmable and allow for free directing of the image to the monitor or recording devices, enabling the creation of any network architecture of the video system (Ignac-Nowicka, Procel, 2019; Deligiannidis, Arabnia, 2015; Donald et al., 2015; Tsakanikas, Dagiuklas, 2018).

#### **4. Identification of hazards specific to work in the warehouse space**

The process of identifying threats and their causes in the tested storage facility was carried out using the Fault Tree Analysis (FTA) and Event Tree Analysis (ETA) methods. In these methods, emergency events of technical devices and events resulting from human error (human factor) can be taken into account at the same time (Ignac-Nowicka, 2017, 2018a, 2018b; Ignac-Nowicka, Krenicky, 2018). This gives the possibility of a broader analysis of cause and effect factors that lead to dangerous events in the warehouse in the form of an accident, destruction of stored products or failure of technical equipment (e.g. forklifts). Identification of threats is an important starting point for the implementation of the facility protection project, which affects the shape of the system (number of cameras and their location).



#### 4.1. Characteristics of the analyzed warehouse facility

The analyzed warehouse facility has the following dimensions: length 90 m, width 70 m and height 15 m. Products are stored up to a maximum height of 10.4 m. The warehouse is divided into 13 corridors marked with capital letters. The corridors differ in length and number of racks. In the M and L corridors there are 36 racks and all kinds of food products are stored there, while in the T and U corridors there are 60 racks where alcohol is stored. The T and U corridors are separated from the rest of the storage space and have two separate entrances at the ends of the corridors. In the other corridors, all kinds of industrial products are stored. Corridors A, B, C and D contain 172 racks, while corridors E, F, G, H, I, J and K have 350 racks.

The analyzed warehouse facility has an appropriate fire safety system, consisting of an early warning system for fire and active extinguishing and smoke extraction. Safety in the warehouse also consists in respecting the permissible load value of the racks, securing the installation and designating passageways of the appropriate width. There are clearly marked corridor zones in the warehouse facility, which greatly facilitates the movement of employees and machines in the warehouse. The adaptation of employees to the rules regarding occupational health and safety in the analyzed warehouse requires, among others:

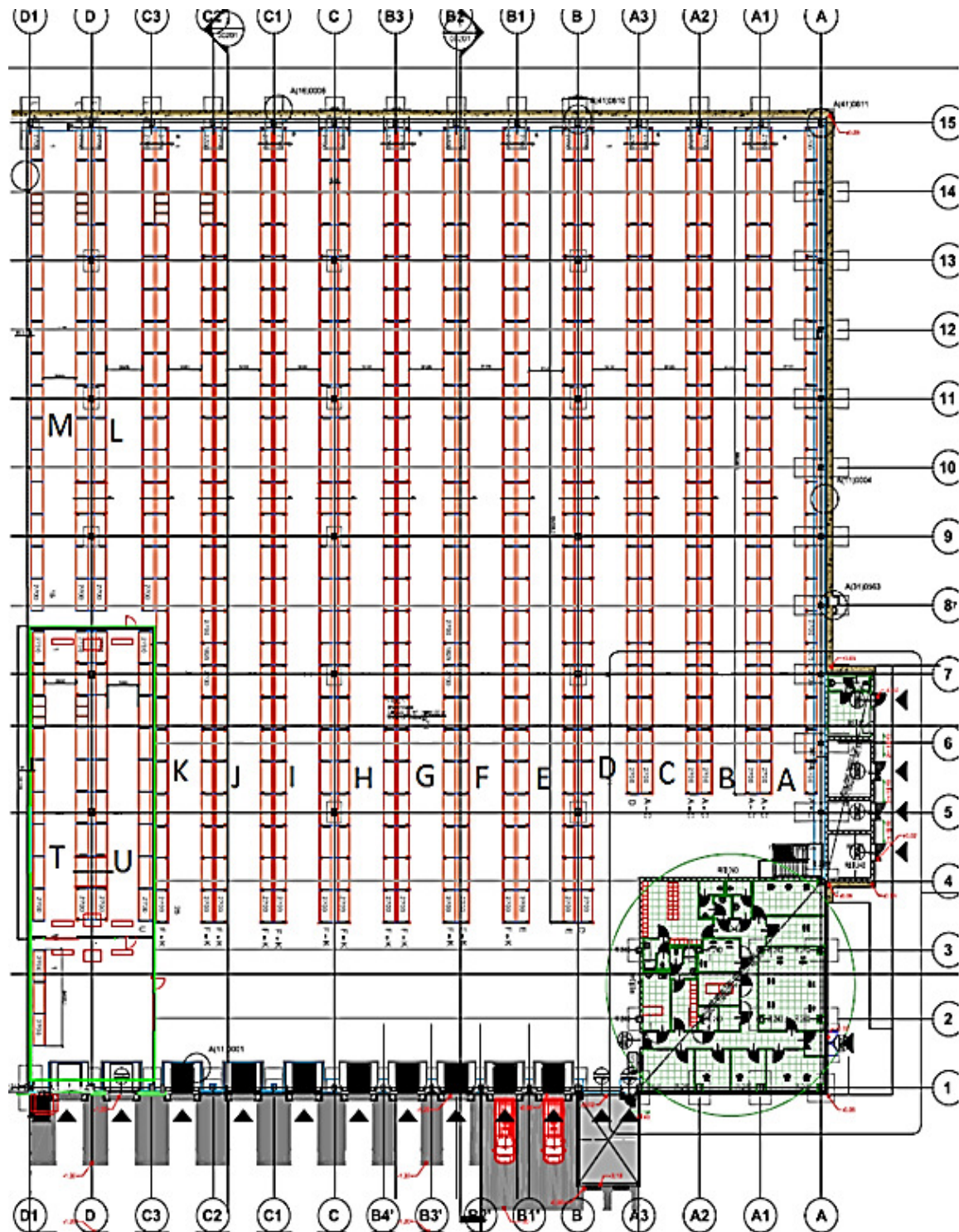
- compliance with specific load capacity or loading weight standards when using means of transport,
- securing transport loads in an appropriate manner,
- comply with the traffic rules on internal roads,
- designing and complying with appropriate signage,
- systematic safety inspections and maintenance of machines and technical devices.

In the space of the entire warehouse, there is a rule of arranging products that constitute stocks on the upper shelves of the rack, while products ready to be issued to order are stored on the lower shelves. Each product is stored on euro pallets, chep pallets or disposable pallets. Products are delivered by trucks to unloading docks (Figure 2) marked with letters from D1 to B, while between docks B and A3 there is an entrance for smaller vehicles (e.g. forklifts). After accepting the delivery, the products are delivered to the racks using forklifts. The general plan of the warehouse facility is shown in Figure 2.

#### 4.2. Identification of threats in the examined warehouse

The use of the event tree analysis (ETA) and fault tree (FTA) method allowed to identify the causes of losses in the warehouse and other undesirable events. In the analyzed warehouse, there may be many threats resulting from both the incorrect behavior of staff and external persons, as well as the specificity of goods received into the storage area. The most common threats identified by the Event Tree Analysis (ETA) and Fault Tree Analysis (FTA) have been grouped and summarized in Table 1.

Some of the hazards listed in Table 1 have a direct impact on work safety in the warehouse, while others have a significant impact on labor costs and difficulties in the work process. In order to increase the level of safety and efficiency of the work process, it was proposed to use video monitoring.



**Figure 2.** Plan of warehouse space divided into sectors (marked with a capital letter).

Source: Own study based on the technical documentation of the warehouse facility of company X.

**Table 1.***Threats that occur most often in the analyzed warehouse facility*

Place or source of danger	Threat description
Warehouse worker risks	<ul style="list-style-type: none"> <li>• falls from a height,</li> <li>• falls due to slipping on a slippery surface,</li> <li>• employees being hit by forklifts or other vehicles moving in the warehouse,</li> <li>• collisions of machines moving in the warehouse,</li> <li>• physical overload of employees related to manual unloading work,</li> <li>• stress caused by employees' financial responsibility for the goods in the process of accepting them into the warehouse</li> </ul>
Mistakes made during the work of warehouse workers	<ul style="list-style-type: none"> <li>• acceptance of goods delivered in damaged loading units,</li> <li>• acceptance of goods that were delivered in incorrect packaging,</li> <li>• acceptance of goods classified as dangerous goods,</li> <li>• improper arrangement of goods on the racks resulting in the fall of goods from the rack</li> </ul>
Threats from bystanders	<ul style="list-style-type: none"> <li>• hazards posed by truck drivers (e.g. improper parking at docks),</li> <li>• unauthorized persons entering the goods unloading area</li> </ul>
Risk of losing goods	<ul style="list-style-type: none"> <li>• damage caused when accepting the delivery of goods,</li> <li>• goods theft</li> </ul>
Environmental hazards in the warehouse	<ul style="list-style-type: none"> <li>• risks associated with improper storage of goods that may be toxic or flammable,</li> <li>• fire in the warehouse,</li> <li>• excessive noise,</li> <li>• presence of an intense smell of goods containing chemical substances</li> </ul>

## 5. Design assumptions for the vision control system of a selected warehouse facility

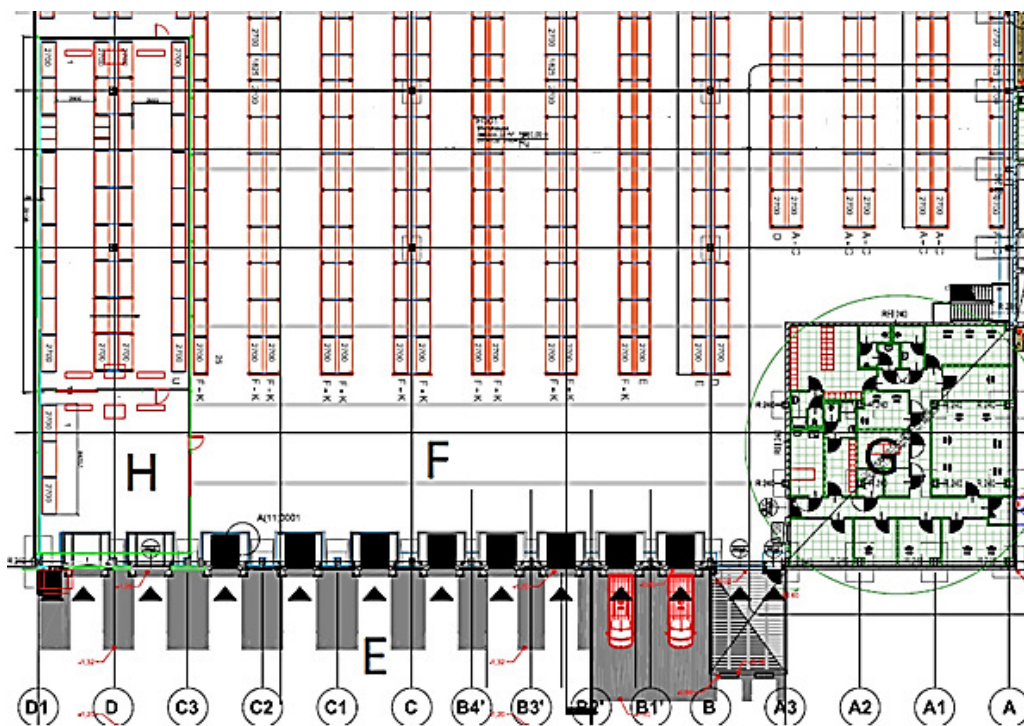
Threats appearing in facilities with large areas, such as: large-format commercial facilities, extensive production halls and large warehouses, are characterized by the difficulty of their monitoring due to the too large area to be controlled. In facilities with a large area, where specialized systems are used, e.g. fire control, explosion control or control of threats intended by people (theft, destruction, sabotage), in the event of activation of the threat signaling, it is difficult to quickly verify the event due to the huge number of sensor devices. Much faster verification of the event, in these cases, is guaranteed by an additional vision system with an operational function, allowing for immediate viewing of selected danger zones in real time.

### 5.1. Definition of video surveillance zones

The analysis of events within the warehouse showed the greatest number and variety of threats in the goods receiving and issuing zones. Providing full-scale protection to a warehouse facility requires securing products throughout the entire unloading process in the warehouse. The entire delivery path must be controlled from the moment the vehicle approaches the unloading docks or enters the warehouse. Due to security procedures, the entire access road must be controlled because in the case of goods that require special unloading restrictions,

full documentation is necessary in the event of violation of procedures. Unloading can always result in physical damage to the packaging or the goods themselves.

On the basis of analyzes of loading and unloading activities, zones of special supervision have been designated, which will be equipped with video surveillance. There are four supervision zones marked in Fig. 3 with the letters: E, F, G, H. The first zone (marked with the letter E) is the zone of unloading docks, the second area where euro-pallets with goods are temporarily stored (marked with the letter F), the third zone is the office (marked with the letter G) and the fourth zone is the place where goods are stored and issued according to the order (marked with the letter H). These zones were selected as video surveillance areas due to the large number of events generating the greatest danger.



**Figure 3.** A fragment of the plan of the warehouse facility with designated supervision zones.

Source: Own study based on the technical documentation of the warehouse facility of company X.

In the area of unloading docks, quite frequent abuses of truck drivers were found, consisting in blaming staff for damage to goods that were damaged as a result of inadequate protection during transport. In the absence of evidence, the storage company incurred financial losses. Warehouse space F is an area where you can efficiently control the condition of packaging of goods on Euro pallets and verify whether the goods have been delivered intact to the warehouse. On the other hand, the office area (zone G) requires control of people entering and leaving in order to limit the movement of unauthorized persons in the administrative area of the warehouse. In zone H, where goods released from the warehouse are collected, additional video surveillance will allow for verification of the correctness of the process of collecting goods by carriers.

## 5.2. Selection of the type and parameters of cameras using the FOKUS tool

In order to determine the appropriate parameters for the cameras operating in a specific warehouse space, a simple FOKUS program was used to support the design of video surveillance systems. Start using the application by entering the appropriate input data into the program. The FOKUS program allows you to enter the following input data:

- range - is the actual planned distance of the camera from the object,
- sensor - describes the type of optics in the camera affecting the quality of the recorded image - the smaller the sensor, the more accurate the image will be,
- focal length – the parameter responsible for the camera's angle of view - the smaller it is, the wider the vision can be obtained (greater angle of view).

By changing the above parameters, the FOKUS program allows you to observe the simulated image that the camera with the given parameters will send to the monitor screen. This allows you to select the parameters according to what will be visible on the monitor and thus recorded, e.g. digitally on a computer disk.

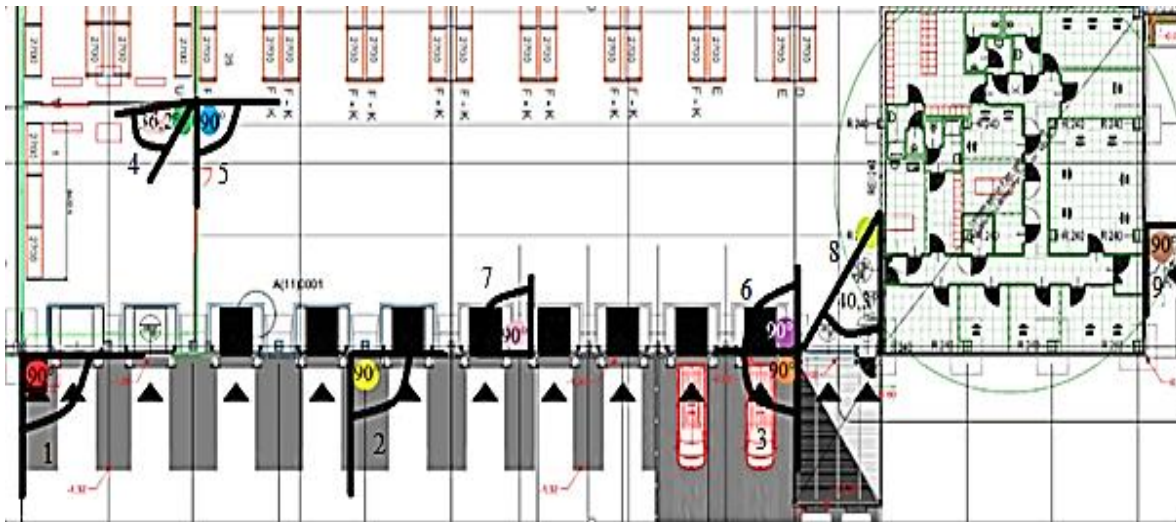
When determining the appropriate camera parameters, it should be remembered that objects in the field of view of each camera may obscure part of the observed area, i.e. create blind zones in video surveillance. This phenomenon can be eliminated by carefully determining the location of the cameras and their appropriate suspension height. For the analyzed surveillance zones (areas E, F, G, H) 9 cameras were provided, for which optimal parameters were set. The results of the initial scaling of 9 cameras are summarized in Table 2, while their distribution is shown in Figure 4. Most cameras differ in their parameters due to the different tasks they are supposed to perform, therefore the video surveillance system can be divided into the following parts:

- monitoring the outer area of the warehouse while the goods are still in the trucks,
- monitoring the internal area of the warehouse when the process of unloading goods on the warehouse area of area F begins (fig. 3),
- office entry and exit monitoring.

**Table 2.**

*Determined camera parameters according to the established monitoring functions in the warehouse facility*

Camera parameters	Camera number					
	1, 2, 3	4	5	6, 7	8	9
Sensor	3/4	1/3	1/2	1	3/4	1/2
Focal length	4,4 mm	5,5 mm	3,2 mm	6,4 mm	12 mm	3,2 mm
The distance of the camera from the object	30 m	20 m	50 m	30 m	15 m	10 m
The height of the monitored area	60 m	17,5 m	100 m	60 m	11 m	20 m
The width of the monitored area	45 m	13,1 m	75 m	45 m	8,3 m	15 m
Horizontal angle	90°	36,2°	90°	90°	40,3°	90°
Vertical angle	73,7°	47,1°	73,7°	73,7°	30,8°	73,7°



Legend:

- |   |   |
|---|---|
| <span style="color: red;">●</span> - Camera number 1    | <span style="color: purple;">●</span> - Camera number 6     |
| <span style="color: yellow;">●</span> - Camera number 2 | <span style="color: pink;">●</span> - Camera number 7       |
| <span style="color: orange;">●</span> - Camera number 3 | <span style="color: lightgreen;">●</span> - Camera number 8 |
| <span style="color: green;">●</span> - Camera number 4  | <span style="color: brown;">●</span> - Camera number 9      |
| <span style="color: blue;">●</span> - Camera number 5   |   |

**Figure 4.** Arrangement of cameras in the designed vision system of the warehouse facility.

Source: Own study based on the technical documentation of the warehouse facility of company X.

Individual cameras arranged as shown in Figure 4 perform the following functions:

- cameras no. 1, 2 and 3 monitor the unloading docks,
- camera no. 4 monitors the goods issue area,
- cameras no. 5, 6 and 7 monitor the areas of temporary storage of deliveries,
- camera no. 8 monitors the exit from the office to the warehouse area,
- camera no. 9 monitors the entrance to the office from the outside.

The viewing angles of the cameras shown in Figure 4 are horizontal angles according to the parameters shown in Table 2.

### 5.3. Organization of the vision system

The designed vision system has 9 cameras arranged as shown in Figure 4. In order to fulfill the three functions of video monitoring (preventive, operational and evidence), the cameras were connected via cables to a room in which a video surveillance center equipped with a monitor, multiplexer and a computer with suitable drive for archiving the recorded video.

The video surveillance system will be operated by one person responsible for monitoring in the security room, which is provided in the office area near the entrance to the warehouse. This enables a quick response to threats detected by the camera preview on the monitor (operator function). Due to such location of the security room, the employee servicing the monitoring has a real impact on security in the warehouse facility.

In order to meet the design assumptions, the video monitoring system was equipped with the following equipment:

- cameras of the DVS-HA5028NT-IRs model were proposed for positions 1, 2 and 3 - these are cameras with a durable IP66 housing, which makes them fully resistant to weather conditions (these cameras are located outside the warehouse facility); their wide-angle lens allows you to eliminate dead zones while maintaining image details,
- the LC-353 AHD model was proposed for the position of the camera number 4 - it is an internal camera and is intended for monitoring the goods issue area,
- the BCS-SDHC5230-II model was proposed for the position of the camera number 5 - it is the camera with the greatest range of view, because it monitors the entire area of the temporary unloading of the delivery,
- for camera positions no. 6 and 7, the proposed equipment is LC-676 AHD PREMIUM - these are cameras supporting camera no. 5 in monitoring the temporary place of unloading goods,
- for camera position no. 8, the proposed equipment is the LC-353 AHD model - the camera should monitor the entrance to the office from the warehouse side and the entrance for forklifts,
- for camera position no. 9, the proposed equipment is the IPC-HFW1431S-0280B-S4 camera, whose task is to monitor the entrance to the office from the outside, equipped with an IP66 housing, it guarantees full resistance to water jets (in case of fire) and dust,
- multiplexer model LV-NVR9918S connecting all cameras, supports up to 9 high-quality cameras, equipped with live image, recording, playback and archiving functions,
- a computer with a graphics card, a disk with a very large capacity - HDD Sata III disk, it is possible to store movies with a capacity of up to 8TB,
- monitor - Samsung 24 Odyssey G3 (LF24G35TFWUXEN) was proposed, with a screen ratio of 16:9 and a diagonal value of 24 inches (IVEL.PL store, Monitoring, Alarm systems ... downloaded on June 2, 2023).

## 6. Summary and Conclusions

The purpose of the conducted analyzes was to create a project of a video surveillance system for the warehouse facility under test. The vision system project was developed in October 2022. The implementation of the vision system in the warehouse space is scheduled for 2023. No feedback has yet been received on its operation at the facility.

The introduction of a technical element in the form of a vision system into the warehouse facilitates the detection of threats and can increase the level of security in the facility. The system consisting of 9 cameras provides surveillance of the area that is most exposed to undesirable events involving people and equipment. Video monitoring enables such control of threats that it facilitates the process of security management in the facility both at the stage of prevention and intervention in real time against threats, as well as at the stage of collecting documentation on threats. The vision system design concept for a selected warehouse facility presented in the article can provide information about such threats as:

- incorrect approach of vehicles to the unloading docks (surveillance of cameras no. 1, 2, 3), unauthorized intrusion into the warehouse or office (surveillance of cameras no. 1, 2, 3, 9),
- collision of means of internal transport (forklifts) with people and devices (surveillance of cameras no. 5, 6, 7),
- other accidents of employees, e.g. falling from a height or tripping (surveillance of cameras no. 1, 2, 3, 8),
- theft or destruction of goods ready for release (surveillance of camera no. 4),
- delivery of damaged goods to the warehouse or their damage during unloading (supervision of cameras no. 5, 6, 7),
- thefts in the area of temporary storage of goods - between the office and the warehouse (surveillance of camera no. 8).

The concept of a video monitoring system proposed in the article can help the company's management decide to implement an additional surveillance system in order to neutralize or reduce the number of events dangerous for employees and material losses resulting from the destruction of goods or equipment.

In recent years, certain trends in the offered equipment working in vision systems have emerged. Publication (Szymanek, 2022) describes six such trends that appeared on the market in 2022. There are also systems supporting the operation of cameras that enable automatic identification of events. Publication (Szwoch et al., 2009) describes an algorithm that can be used in a video surveillance system that automatically detects events in camera images. There is also the possibility of detecting events supported by 3D technology in video surveillance. The 3D technology makes it easier to observe details in the image from the cameras, enabling full identification of the event as described in publication (Balcerek et al., 2017).

The implementation of video surveillance is a costly investment. It seems, however, that it can significantly facilitate security management in specific technical facilities such as warehouses.



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## CONSUMER ATTITUDES AND BEHAVIOURS TOWARDS INNOVATIVE FAST-MOVING PRODUCTS FOR CHILDREN

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**Research background:** The fast-moving consumer goods (FMCG) sector is considered to be an environment where purchasing habits prevail, thus not conducive to the implementation of innovative products. In this context, implementing innovative food products into the market is particularly difficult. Nevertheless, companies are constantly developing new goods and introducing them to market. Increased price sensitivity and high competitive pressure force companies to develop continuously, which in the market segment under consideration is primarily incremental development.

**Purpose of the article:** The main purpose of the manuscript is to identify purchasing behaviour and factors influencing the purchase of fast-moving infant and toddler products.

**Methods:** In order to answer the research problem posed, statistical analyses were carried out using the IBM SPSS Statistics 26 package. It was used to perform an analysis of basic descriptive statistics with the Shapiro-Wilk test, a frequency analysis with the chi-square test of concordance, the Mann-Whitney test, the chi-square test of independence and Pearson's r correlation analysis. The significance level in this chapter was considered to be  $\alpha = 0.05$ . The data analysis was based on the responses of 440 respondents ( $n = 440$ ).

**Findings & Value added:** This article attempts to identify food product innovations and consumer behaviour towards the introduction of these innovations. The wide range of fast-moving goods on offer has influenced the narrowing down of the adopted product group of the FMCG sector. Analysis will focus on fast-moving food products for babies and young children. Thus, it will be the parents who will make the decision to purchase such products.

**Keywords:** management, benefits, innovation, products, economy, buying behaviour, FMCG sector.

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

## 1. Introduction

The Fast-Moving Consumer Goods (FMCG) industry is one of the branches of the economy that supplies stores with products usually considered as necessities. Otherwise, they are referred to as fast-moving goods due to their systematic marketability. FMCG products are small-scale consumer purchases that are made at the grocery shop, supermarket, and point of sale. Examples include non-durable household items such as bread, dairy products, fruit and vegetables, fizzy drinks, detergents and cleaning products, over-the-counter medicines, as well as baby food, ready meals, and processed foods (Muranko et al., 2021, p. 2609; Kuzmina et al., 2019, pp. 74-88).

A significant aspect of addressing the topic consists in the role of the FMCG sector in the global economy. It is one of the fastest growing branches of the industry. This market is on an upward trend and with a large impact on the country's economy. It owes its resilient development mainly to its customers, whose needs and expectations are constantly changing. There is currently a strong trend in Poland, as well as internationally, towards superfoods, organic and eco food, as well as dietary supplements of all kinds. It is possible to notice clear changes in terms of the purchasing behaviours. Both the development of e-commerce as well as shopping services impact the way consumers shop for FMCG products and what products are available on the market. The FMCG sector in Poland is constantly growing. According to NielsenIQ, the value of the fast-moving consumer goods market in Poland in 2021 increased by 4.1% year-on-year, reaching PLN 201 billion. In 2020, the FMCG market was worth as much as PLN 198.2 billion. The largest increase in value in 2021 was reported for the grocery basket - up 4.8% to reach £143.7bn. The chemical basket increased by 3.5% to the value of PLN 15.7bn, while cosmetics recorded a decline of 1.9% reaching PLN 13.2bn. Similar trends are evident in the global economy. Together, the top 40 FMCG companies generated more than \$1 trillion in sales in the last financial year (Marud, 2022).

The above considerations constitute the main reason for choosing the topic for the article. Its main objective is to identify the purchasing behaviours and factors impacting the purchase of innovative food products for infants and young children. In order to obtain the results, the authors conducted a survey among 440 parents in all provincial cities in Poland. The paper compares people who buy innovative products with people who do not, in terms of their opinion about them and their shopping frequency and habits, as well as the intensity of individual predictors of purchase. From a scientific point of view, the results presented in the article constitute a valuable source of information concerning the relatively new research on customer preferences for fast-moving consumer goods.

The article takes advantage of a social research method using a questionnaire and quantitative methods. In terms of the empirical analysis, the following were used: the basic descriptive statistics analysis with Shapiro-Wilk test, frequency analysis with chi-square test of

concordance, Mann-Whitney test, chi-square test of independence and Pearson's  $r$  correlation analysis.

After an introduction describing the research objective of the study, Chapter 2 presents the theoretical background related to consumer behaviour and an overview of research concerning the FMCG sector. Next, the research methods and results of a survey including 440 respondents were presented. The study ends with a discussion and conclusions, including an indication of the limitations of the conducted research.

## **2. Literature review**

In an era of the growing trend of consumerism (Skinner, Bryant, 2006, pp. 22-25), globalisation of consumption (Steenkamp, 2019, pp. 1-19) and an active participation of consumers as market entities in the economic and social life, conducting research on their behaviour is a necessity. Consumers reporting a demand for goods and services constitute a significant driving force of contemporary economies. Consumer behaviours on one hand verify the production decisions made by companies, and on the other hand impact the allocation of resources in the economy. In the case of companies, analysing consumer behaviours is a valuable source of information concerning the factors impacting consumption or forming consumption trends. In reference to the state, information concerning consumer behaviour is used in conducting efficient policies in various fields of the economy or making economic forecasts (Akerlof, Kranton, 2010). Moreover, consumer behaviours have an impact on the behaviour of other market entities whose decisions and choices translate into the functioning of the economy (Bańka et al., 2023).

Consumer behaviour research mainly focuses on how a consumer purchases a product, what influences his or her decision, what factors are taken into consideration in a given choice, where does the consumer perform the purchase (Sharma et al., 2022, pp. 1-15), which payment methods are most convenient for that person (Piersiala, 2022, pp. 912-915). The typology of consumers is also widely undertaken (see: Mundel et al., 2017, pp. 68-75). Issues concerning the role of the brand in the consumer decision-making process are being addressed (Guliyev, 2015; Taanady, 2022, pp. 93-98). Customer preferences and behaviours concerning sustainable supply at the final stage are also indicated (Guo et al., 2022; Kiba-Janiak et al., 2022). In contrast, it is difficult to find literature concerning consumer choices in the fast-moving consumer goods industry regarding the purchase of children and infants' products, especially innovative products. There is a research gap in the comprehensive approach to analysing the fast-moving goods market for innovative food products.

In the same way, the FMCG industry is widely discussed. Bocken et al. (2022, pp. 799-814), Muranko et al., (2021, p. 2609) conducted research relating to the innovation concerning packaging of fast-moving goods to the circular economy programme. They point out that there is an increasing number of research on reusable packaging systems in the FMCG sector, but the industry practice focusing on packaging reuse rather than just recycling is limited (Wojtaszek, Miciuła, 2019). There are several studies relating to sustainable packaging in the FMCG industry (Priyanshi, Manoj, 2022; Rambabu, Porika, 2020, pp. 67-78). Realini and Marcos (2014, pp. 404-419) and Restuccia (et al., 2010, pp. 1425-1435) carried out a study on evaluating consumer adoption of active and intelligent packaging, which represents consumer purchasing behaviour regarding innovative food packaging techniques.

Today, the average consumer is more aware of the environmental impact of made choices than a consumer from just a few years ago (Kabus et al., 2019; Dziadkiewicz, 2014). The change is real and can no longer be ignored. As the awareness of sustainable development and its significance increases and the rise of environmentally friendly regulations, sustainable purchasing behaviour is a concern for customers now more than ever (Cavaliere et al., 2014, pp. 9494-9509; de Maya et al., 2011, pp. 1767-1775; Miciuła, 2018). Current market requirements are more and more often related to environmental effects and sustainability (Szturo et. al., 2021). Creating environmental values by the consumer will result from the extent of consumer knowledge and sustainable practices (Jakubowska, Radzymińska, 2019, pp. 433-452; Pilelienė, Tamulienė, 2021, pp. 269-299). An example of environmental consumer behaviour consists in paying attention to healthy and unprocessed food, GMO-free, without artificial dyes, BIO-certified, and gluten-free. Consumer awareness in this regard is growing (Marcon et al., 2022, pp. 76-91). Seghal and Singh conducted a study concerning the impact of environmentally friendly products on consumer behaviour (Singhal, Malik, 2018, pp. 514-531). The aim was to find a link between the generous nature of consumers and purchasing organic products. The results showed that buying organic products gives more added value to consumers than purchasing conventional products. Meanwhile, Lorek (2015, pp. 115-129), analysed current trends in consumer behaviour towards organic products. In order to better understand consumer choices, Mancini, Marchini, and Simeone conducted a study on "What features of sustainable development influence actual consumption behaviours?" (Mancini et al., 2017, pp. 1839-1853). In their research, they divided their sample into two focus groups and conducted three rounds of discussions to gain more insight beyond the empirical research. One of the key points of their findings was the correlation between education and consumer attitudes and behaviours towards consumption.

After a detailed study of many academic articles on sustainable consumer behaviours in the FMCG industry, we can conclude that there is a clear research gap concerning the analysis of consumer behaviour on purchasing innovative products for children and infants. This study aims to gain insights into consumer behaviour, especially about environmentally friendly and sustainable behaviours in the FMCG sector in Poland.



### 3. Research methodology

It should be emphasized that the authors adopted the definition of infants and young children according to Regulation (EU) No 609/2013 of the European Parliament and of the Council of June 12, 2013 on food intended for infants and young children and on food for special medical purposes and foodstuffs intended to replace the total daily diet, for weight control, which reads: "'young child' means a child between one and three years of age" (Official Journal of the European Union, 2013). Whereas the food products included in the research analysis are intended for infants and young children, which the aforementioned regulation considers to be 'follow-on formula' (Official Journal of the European Union, 2013). These are foods intended for children when appropriate complementary feeding and dietary diversification are introduced.

The considerations concerning the problematic nature of the adopted objective allowed to formulate the following research hypotheses:

- H01. Loyalty to brands makes it easier to make a decision to buy innovative products immediately after introducing them to the market.
- H02. There is a link between buying products as soon as they are launched and the opinion whether innovative products are more desirable than traditional ones.
- H03. There is a correlation between the assessment of whether the current range of innovative products is sufficient and the frequency and quantity of buying particular products in particular places

The course of the research was shaped in the following seven stages:

1. Analysing source literature available on the Polish and international markets.
2. Formulating the research problem.
3. Defining the purpose of the study.
4. Adopting an appropriate research method.
5. Designing the survey questionnaire.
6. Conducting the survey.
7. Processing and analysing data.

The survey was considered the primary research method. The survey was conducted using a research technique in the form of an individual questionnaire. The measurement tool took the form of a structured questionnaire, which was developed by the authors of the article. The survey consisted of 3 pages. The first contained a preamble mentioning the subject matter of the survey, the purpose of the survey and instructions for completing the survey. At the same time, the respondents' attention was drawn to the anonymous nature of the questionnaire and the intention to subject the results of the survey to analysis as part of summary statistics. It was emphasized that the results of the study will be used for the commercialisation of the undertaken problem and used in a scientific article. Based on the results of the literature

review, nine questions concerning innovative food products for infants and young children were identified. The study addressed the following main issues:

- Making decisions to purchase innovative foods for infants and young children,
- Traditional food versus innovative food.

The 6 questions of the questionnaire consisted in closed questions; the survey participants could only select one of several provided answers. In 3 questions a forced scale was used where the respondent indicated a strictly defined category on the scale, these questions did not provide the opportunity to express an opinion. The respondents' task was to address a given response possibilities, according to a specific degree to which they agreed with them. The intensity of the respondent's attitude was measured using a bipolar, five-point ordinal scale, described both verbally and numerically. Responses were assigned numerical values (e.g., from 1 to 5), maintaining the principle that the assigned values increase according to the nature and direction of the defined characteristic. The Likert scale was used, where 5 means very often; 1 means very rarely.

The questions were formulated unambiguously so that everyone could understand them. The questionnaire was laid out in such a way that each question concerned only one specific thing. Specialized terms, industry slang, and words from a foreign language were not used. Due to the nature of the respondent population, the conducted survey was considered a consumer opinion survey.

The final element of the questionnaire was a metric, including respondents' data such as gender, age, education, and place of residence. The research presented in the article was conducted in Q3 and Q4 of 2022.

The survey was aimed at 500 people residing in Poland who are parents of infants and/or young children. Ultimately, 440 (88%) correctly completed questionnaires were returned, i.e., questionnaires including answers to all individual questions. When calculating the minimum (required) number of people in the sample (in a population-based sample survey), a confidence level of 95%, a fraction size of 0.5 and a maximum error of 5% were assumed. With the assumed values, it was estimated that the required population size was 387 people. 440 persons were surveyed, which is considered to be a representative group of the studied population. Respondents were guaranteed confidentiality. Due to the above it is not possible to identify the person filling out the survey. The questionnaire provided complete information on the purpose of the activities and marked the anonymity of the survey. The obtained number of questionnaires allows to conclude that the requirements for representativeness of the sample have been met.

In order to deepen the analysis and verify the research hypotheses, statistical analyses were carried out using the IBM SPSS Statistics 26 suite. It was used to perform an analysis of basic descriptive statistics with the Shapiro-Wilk test, a frequency analysis with the chi-square test of concordance, the Mann-Whitney test, the chi-square test of independence and Pearson's  $r$  correlation analysis. The significance level in this chapter was considered to be  $\alpha = 0.05$ .

## 4. Results

In the first stage of the analysis, the distributions of the quantitative variables were checked. For this purpose, basic descriptive statistics were calculated, together with the Shapiro-Wilk test examining the normality of the distribution. The results of the analysis are presented in Table 1.

**Table 1.**

*Basic descriptive statistics of the studied variables with the Shapiro-Wilk test*

<b>General questions</b>	<b>M</b>	<b>Me</b>	<b>SD</b>	<b>Sk.</b>	<b>Kurt.</b>	<b>Min.</b>	<b>Maks.</b>	<b>W</b>	<b>p</b>
Number of types of innovative products purchased	3,29	3,00	1,40	0,35	-0,04	1,00	7,00	0,94	<0,001
Buying innovative nutrition products immediately after introducing them to the market	3,91	4,00	0,72	-0,65	0,74	2,00	5,00	0,80	<0,001
Opinion on whether brand loyalty makes it easier to make purchase decisions	4,23	4,00	0,73	-0,79	0,60	2,00	5,00	0,79	<0,001
Opinion on whether innovative products are more desirable than traditional ones	3,83	4,00	0,92	-0,23	-0,92	2,00	5,00	0,84	<0,001
Opinion on whether the current offer of innovative products is sufficient	3,71	4,00	0,88	-0,71	0,62	1,00	5,00	0,85	<0,001
<b>Most frequently purchased food products for infants and young children</b>	<b>M</b>	<b>Me</b>	<b>SD</b>	<b>Sk.</b>	<b>Kurt.</b>	<b>Min.</b>	<b>Maks.</b>	<b>W</b>	<b>p</b>
Fruit mousses in tubes	3,67	4,00	1,30	-0,58	-0,73	1,00	5,00	0,83	<0,001
Porridges	3,55	4,00	1,05	-0,31	-0,75	1,00	5,00	0,89	<0,001
Freeze-dried fruit	3,09	3,00	1,21	0,08	-0,80	1,00	5,00	0,90	<0,001
Dinners in jars	3,38	3,00	1,20	-0,42	-0,57	1,00	5,00	0,89	<0,001
Desserts in jars	3,47	4,00	1,27	-0,47	-0,67	1,00	5,00	0,88	<0,001
<b>Predictors of purchasing food products for infants and young children</b>	<b>M</b>	<b>Me</b>	<b>SD</b>	<b>Sk.</b>	<b>Kurt.</b>	<b>Min.</b>	<b>Maks.</b>	<b>W</b>	<b>p</b>
Price	3,49	3,00	1,05	-0,44	0,14	1,00	5,00	0,85	<0,001
Packaging	3,82	4,00	1,01	-0,66	0,11	1,00	5,00	0,85	<0,001
Brand	3,75	4,00	1,06	-0,44	-0,35	1,00	5,00	0,85	<0,001
Opinion of others	3,75	4,00	1,03	-0,90	0,50	1,00	5,00	0,84	<0,001
Child's preferences	4,34	5,00	0,90	-1,06	-0,14	2,00	5,00	0,72	<0,001
Time of preparing the product for consumption	4,04	4,00	1,00	-0,80	-0,03	1,00	5,00	0,81	<0,001
Advertisement	3,03	3,00	1,19	-0,23	-0,64	1,00	5,00	0,89	<0,001
Ingredients	4,19	5,00	1,02	-1,17	0,73	1,00	5,00	0,76	<0,001

Source: own compilation.

The result of the Shapiro-Wilk test for all the variables entered proved to be statistically significant, meaning that their distributions are significantly different from the normal distribution. However, it should be noted that the skewness of the distribution of all variables does not exceed an absolute value of 2, which means that their distributions are slightly asymmetric. Therefore, it is reasonable to carry out the analysis based on parametric tests, provided that their other assumptions are met.

Then, the percentage distributions of the qualitative variables were verified. For this purpose, a frequency analysis was carried out together with a chi-square test to verify whether the resulting distributions are equal. Firstly, it was verified what proportion of the research group buys innovative food products for infants and young children. The results of the analysis are presented in Table 2.

**Table 2.**

*Percentile distribution of responses to the question on whether respondents purchase innovative food products for infants and young children*

		<i>N</i>	<i>%</i>	$\chi^2$	<i>p</i>
Purchasing innovative food products for infants and young children	No	96	21,8%	139,78	<0,001
	Yes	344	78,2%		

Source: own compilation.

The analysis showed that there were significantly more people in the study group who purchased innovative infant food products.

The following step of the analysis was to verify which products are most often chosen by people buying innovative food products for infants and young children. The results of the analysis are presented in Table 3.

**Table 3.**

*Percentile distributions of the frequency of choosing individual innovative foods for infants and young children*

<b>Which innovative food products for infants and young children do you buy?</b>		<i>N</i>	<i>%</i>	$\chi^2$	<i>p</i>
Gluten-free products	No	203	59,0%	11,17	0,001
	Yes	141	41,0%		
Vegan products	No	241	70,1%	55,36	<0,001
	Yes	103	29,9%		
Sugar-free products	No	212	61,6%	18,61	<0,001
	Yes	132	38,4%		
GMO-free products	No	142	41,3%	10,47	0,001
	Yes	202	58,7%		
Colour-free products	No	96	27,9%	67,16	<0,001
	Yes	248	72,1%		
Products without artificial flavourings	No	119	34,6%	32,66	<0,001
	Yes	225	65,4%		
Products without palm oil	No	155	45,1%	3,36	0,067
	Yes	189	54,9%		
BIO-certified products	No	205	59,6%	12,66	<0,001
	Yes	139	40,4%		
Others	No	344	100,0%	-	-
	Yes	0	0,0%		

Source: own compilation.

The obtained results indicated that a significantly higher proportion of the respondents purchasing innovative food products for infants and young children chose GMO-free, colouring-free, and artificial flavouring-free products. No statistically significant variation was recorded in terms of the frequency of choices concerning products without palm oil. For the other articles, it was found that a significantly higher proportion of respondents did not choose them.

The final stage of the frequency analysis was to find out what were the most frequently indicated predictors for not buying innovative food products for infants and young children. The results of the analysis are presented in Table 4.

**Table 4.**

*Percentile distributions of the frequency of indicating individual predictors of not buying innovative food products for infants and young children*

Why do you not buy innovative food products for infants and young children?		<i>N</i>	%	$\chi^2$	<i>p</i>
I do not trust these products	No	72	75,0%	24,00	<0,001
	Yes	24	25,0%		
I am not convinced	No	50	52,1%	0,17	0,683
	Yes	46	47,9%		
I am concerned about the child's reaction to the food	No	46	47,9%	0,17	0,683
	Yes	50	52,1%		
They are too expensive	No	67	69,8%	15,04	<0,001
	Yes	29	30,2%		
They are difficult to get	No	72	75,0%	24,00	<0,001
	Yes	24	25,0%		
Other reason	No	89	92,7%	70,04	<0,001
	Yes	7	7,3%		

Source: own compilation.

The analysis showed that the most identified predictor for not buying innovative food products for infants and young children was the fear of the child's reaction to the food and a lack of belief in this type of product. It also turned out that a significantly smaller proportion of respondents indicated the packaging and price, as well as other issues as the reasons for a lack of confidence in this type of product.

It was then examined whether those who buy innovative food products for infants and young children differ from non-buyers in terms of their opinion on whether innovative products are more desirable than traditional products and whether the current offer of innovative products is sufficient. The relationship regarding the frequency of purchasing individual products and the intensification of the indicated purchase predictors was also verified. For this purpose, a series of Mann-Whitney tests were performed, the results of which are presented in Table 5.

**Table 5.**

*Comparison of people buying innovative products and non-buyers of innovative products in terms of opinion on innovative products and buying habits*

<b>Purchasing innovative food products for infants and young children</b>									
<b>General questions</b>	<b>No (n = 96)</b>			<b>Yes (n = 344)</b>			<b>Z</b>	<b>p</b>	<b>η<sup>2</sup></b>
	<b>middle rank</b>	<b>M</b>	<b>SD</b>	<b>middle rank</b>	<b>M</b>	<b>SD</b>			
Opinion on whether innovative products are more desirable than traditional ones	179,69	3,48	1,08	231,89	3,93	0,85	-3,73	<0,001	0,03
Opinion on whether the current offer of innovative products is sufficient	188,84	3,50	0,85	229,33	3,77	0,89	-2,99	0,003	0,02
Most frequently purchased food products for infants and young children									
Fruit mousses in tubes	193,18	3,39	1,34	228,13	3,75	1,28	-2,49	0,013	0,01
Porridges	215,17	3,48	1,16	221,99	3,56	1,02	-0,48	0,629	<0,01
Freeze-dried fruit	176,98	2,72	0,95	232,64	3,20	1,25	-3,93	<0,001	0,04
Dinners in jars	207,11	3,22	1,35	224,24	3,42	1,15	-1,21	0,228	<0,01
Desserts in jars	227,66	3,51	1,41	218,50	3,46	1,23	-0,64	0,519	<0,01
Predictors of purchasing food products for infants and young children									
Price	201,08	3,38	0,97	225,92	3,52	1,07	-1,79	0,073	0,01
Packaging	194,17	3,53	1,20	227,85	3,90	0,93	-2,41	0,016	0,01
Brand	209,26	3,68	1,01	223,64	3,78	1,07	-1,03	0,303	<0,01
Opinion of others	199,40	3,58	1,00	226,39	3,80	1,03	-1,96	0,050	0,01
Child's preferences	214,73	4,28	0,96	222,11	4,35	0,89	-0,57	0,569	<0,01
Time of preparing the product for consumption	202,11	3,85	1,10	225,63	4,09	0,96	-1,70	0,090	0,01
Advertisement	215,50	2,94	1,30	221,90	3,06	1,16	-0,45	0,649	<0,01
Ingredients	209,21	4,10	1,06	223,65	4,22	1,00	-1,07	0,284	<0,01

Source: own compilation.

The analysis showed that people purchasing innovative food products for infants and young children were statistically significantly different than non-buyers in terms of both the analysed general questions, as well as in terms of the frequency of buying fruit mousses in tubes and freeze-dried fruit, as well as the significance of product availability and peer opinion. It turned out that respondents declaring that they buy innovative products were characterised by a significantly better opinion on whether innovative products are more desirable than traditional products and whether the current offer of innovative products is sufficient, compared to respondents who do not buy this type of products. Moreover, it turned out that respondents buying innovative products were significantly more likely to choose fruit mousses in tubes and freeze-dried fruit compared to non-buyers, and in terms of purchases took into consideration the availability and peer opinion. However, it should be noted that the observed effects were found to be weak ( $\eta^2 < 0.06$ ). In the case of the other analysed variables, there were no statistically significant differences. The results of the analysis are illustrated in figures 1-3.

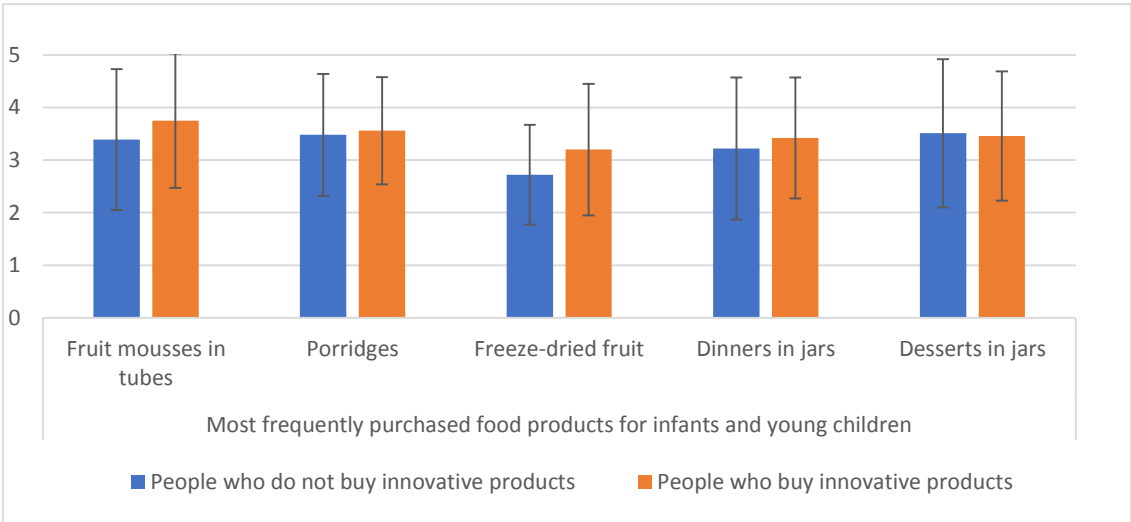


Figure 1. Most frequently purchased food products for infants and young children.

Source: own data.

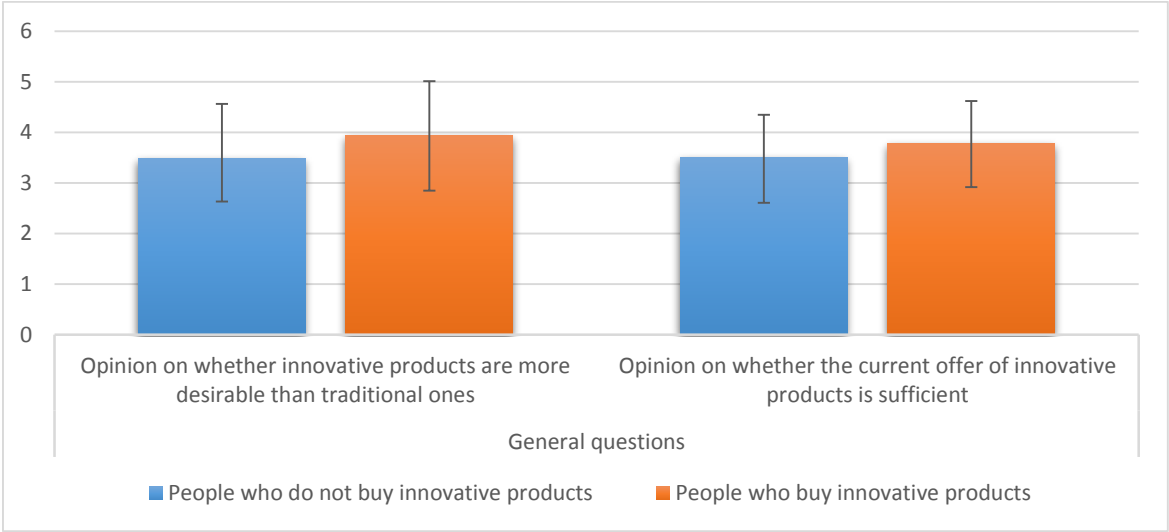
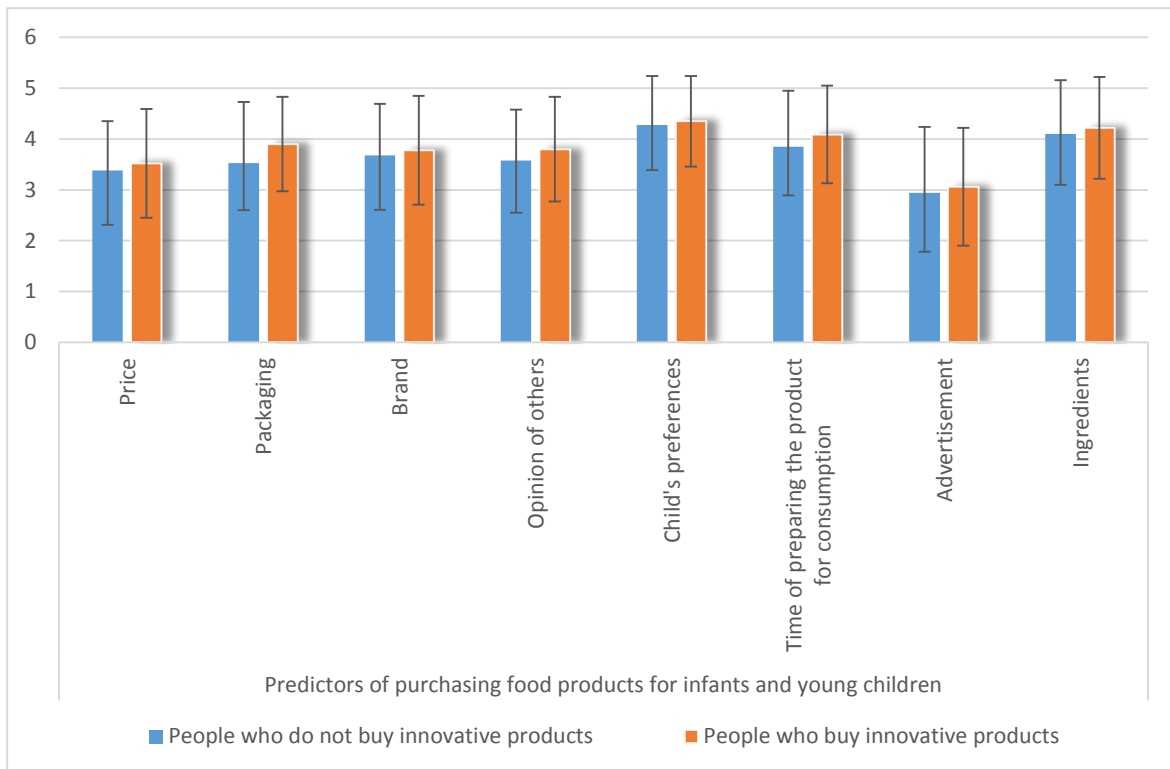


Figure 2. Purchasing innovative food products for infants and young children.

Source: own data.



**Figure 3.** Predictors of purchasing food products for infants and young children.

Source: own data.

During the following stage of the analysis, it was examined whether there is a correlation between buying products immediately after their introduction to the market and opinions on whether brand loyalty facilitates deciding to purchase and whether innovative products are more desirable than traditional ones. For this purpose, the Pearson's  $r$  correlation analysis was performed, the results of which are presented in Table 6.

**Table 6.**

*Correlation of the frequency of purchasing products immediately after introducing them to the market with an assessment of whether brand loyalty makes it easier to make a purchase decision and whether innovative products are more desirable than traditional ones*

		<b>Buying innovative nutrition products immediately after introducing them to the market</b>
Opinion on whether brand loyalty makes it easier to make purchase decisions	$r$ Pearsona	0,06
	significance	0,294
Opinion on whether innovative products are more desirable than traditional ones	$r$ Pearsona	0,13
	significance	<b>0,018</b>

Source: own compilation.

The analysis showed a statistically significant positive relation only between the opinion on buying products as soon as they are launched and the opinion on whether innovative products are more desirable than traditional ones. This means that, as buying products immediately after their introduction to the market increases, so does the respondents' belief that innovative products are more desirable than traditional ones. However, it should be noted that the observed relationship appeared to be weak ( $r < 0.30$ ).



It was then examined whether there was a correlation between the assessment of whether the current offer of innovative products is sufficient and the frequency with which individual products are purchased. For this purpose, the Pearson's  $r$  correlation analysis was performed, the results of which are shown in Table 7.

**Table 7.**

*Correlation of assessing the current offer of innovative products with the frequency of purchasing given products*

<b>Opinion on whether the current offer of innovative products is sufficient</b>		
Most frequently purchased food products for infants and young children		
Fruit mousses in tubes	$r$ Pearsona	0,11
	significance	<b>0,018</b>
Porridges	$r$ Pearsona	-0,05
	significance	0,301
Freeze-dried fruit	$r$ Pearsona	0,11
	significance	<b>0,022</b>
Dinners in jars	$r$ Pearsona	-0,06
	significance	0,224
Desserts in jars	$r$ Pearsona	-0,06
	significance	0,209

Source: own compilation.

The analysis showed statistically significant positive relations between assessing the current offer of innovative products and the frequency of buying fruit mousses in tubes and freeze-dried fruit. This means that as the assessment of the current range of innovative products increased, so did the frequency of the aforementioned products. However, it should be noted that the observed relationship appeared to be weak ( $r < 0.30$ ). In terms of the other correlated pairs of variables, there were no statistically significant relations.

## 5. Discussion

The results indicated above constitute the outcome of the literature research and the conducted empirical studies. The theoretical considerations carried out and the results of the empirical research have demonstrated the relevance of the set research hypotheses and enabled the scientific objective set in this thesis to be achieved.

The following conclusions concerning the verification of the set hypotheses result from the empirical studies:

- brand loyalty makes it easier to make a decision concerning buying innovative products as soon as they are launched,
- there is a correlation between buying products immediately after they are introduced to the market and whether innovative products are more desirable than traditional ones,
- there is a link between assessing whether the current offer of innovative products is sufficient and frequency.

Analysing the results of the conducted survey shows that Polish buyers are characterised by a wide range of perceiving and interpreting product innovation. The collected data confirms the relatively high level of accepting innovative food products for infants and young children, even immediately after their launch. Consumer expectations concerning the quality of a product, its composition, the production process, as well as the benefits of consuming it, are important for the success of a new food product. Lack of knowledge about a product can give rise to negative attitudes towards it and feelings of apprehension that do not work in favour of accepting it.

Polish consumers are open to new, innovative product categories. All these factors are driving the infant and young children food market, as manufacturers are constantly expanding their offers, tempting parents with new products.

In summary, the food market for infants and young children constitutes a good place for introducing innovations, both in terms of existing and new products. This allows expanding the range of products, creating new markets and thus attracting new customers with specific requirements and needs.

## 6. Conclusion

Presenting the contribution of the present manuscript to existing knowledge and the originality of the presented material in a synthetic manner, it should be pointed out that its essential scientific values are:

### **on a theoretical plane:**

- synthesizing customer attitudes in terms of product innovation,
- verifying consumer preference interdependence and acceptance of innovative food products for infants and young children;

### **on an empirical plane:**

- identifying customer attitudes towards traditional and innovative products for infants and young children in the FMCG sector;

### **on a practical level:**

- through disseminating research results, supporting managers operating in the FMGC sector in an aware and effective planning and implementing product innovations for infants and young children,
- identifying barriers that significantly impede implementing innovative foods for infants and young children.

However, the subject presented in the article concerning customer attitudes towards novel foods for infants and young children cannot be considered exhaustive, because the discussed topic constitutes a multifaceted and interdisciplinary research area.

In the conducted study, the respondents consisted only in parents from Poland, so in the future it would be worthwhile to carry out research in other European countries and compare the obtained results with regard to shopping behaviour. It should be also considered to verify the posed hypotheses and extend the research field to include a variety of innovative products from the FMCG sector and the process of implementing them on the market. The year 2020 in the market of fast-moving goods is considered to be the year of covid. Nevertheless, a lot of new products appeared on the FMCG market. The process of preparing an innovation, especially in large organisations, is a lengthy process. Most of the innovations were planned as far back as before the pandemic, and in many cases COVID-19 merely postponed the debut of new products on the market. The share of innovation has increased among products such as coffee, water and washing powders. In terms of the above, a research problem for the future that would be worth analysing consist in how COVID has influenced the significance of innovation particularly in categories with a high proportion of impulse purchases, often consumed outside (sweets, ice cream, or beverages).

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## SAFETY DURING MEDICAL WASTE TRANSPORT IN PRACTICE

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**Purpose:** The aim of the article is to provide objective information about the classification of medical waste and its storage and transport based on the Silesian waste transport company – Ekomed. Generally, waste is very marginalized by society, therefore the article aims to present the further way of dealing with medical waste.

**Design/methodology/approach:** The basic research methods were the analysis of literature on the safety of transport of medical waste, along with their categorization based on the BDO system, by example of Silesian waste transport company – EKOMED.

**Findings:** Disposing of medical or chemical waste is a unique responsibility. Leaving such a sensitive procedure to the wrong companies or people who do not have adequate technical and personal resources may not only have dangerous consequences, but also be severely punished by applicable law. Therefore, it is worth trusting certified companies that not only have many years of experience, but also perfectly understand the responsibility of waste producers.

**Research limitations/implications:** In the future, research will be continued in the field of medical waste transport in context of safety, especially during pandemic.

**Practical implications:** This article provides an overview of quantitative research and diversity of medical waste from medical facilities in Poland. This review shows the importance and scale of the problem and allows for further continuation of research to manage the generated waste. The author has also noted that people generally forget about waste when they get into the bin. The main aim is to get people's attention what is happening later with the medical waste.

**Originality/value:** Based on empirical research, the article shows the scale of the problem that, through the new EU directives on the recycling and sustainable development, will be a forward-looking and important issue. Additionally, the article presents concepts for medical waste transport based on a Silesian company EKOMED. It's twenty years of daily practice of transporting medical waste to the place of its disposal allowed the development of effective logistic solutions for its safe transport, which turned out to be of invaluable value during the SARS-COV-2 virus pandemic.

**Keywords:** medical waste, transport, safety.

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

## 1. Introduction

Very rapid economic and technological development has contributed to population growth around the world. As the population has increased, the amount of garbage they produce has also increased. Here we can distinguish municipal waste – originating from everyday human activities and industrial waste - coming from various types of companies, enterprises and production facilities or service facilities. Due to such a large diversity of companies and industrial facilities, a huge amount of waste is generated, differing in physical and chemical properties. The waste includes biodegradable waste, green waste, raw material waste (recyclable), mixed waste, waste electrical and electronic equipment, bulky waste, renovation waste and hazardous waste (Szołtysek, 2009; Kostecka, 2014). Hazardous waste is the most difficult to dispose of due to its toxic or infectious nature. In perspective of the large amount of waste generated and its different nature, the urgent issue is its transport for neutralization, recycling, or reuse.

The main goal of rational waste management is primarily to reduce the amount of waste generated, and in cases where its generation cannot be avoided, to minimize its negative impact on the environment or human and animal health. Proper waste disposal should lead to their neutralization (or - in certain cases - reuse of raw materials or energy) (Wąsowicz, 2018). Although the disposal and transport of any type of waste is a complicated process and involves many people, waste classified as hazardous, e.g., medical, chemical, or animal waste, is special. It should be noticed that this type of waste may pose a potential threat to health and the environment. For this reason, the collection and transport of e.g., medical waste is a big challenge. However, there are companies on the market that specialize in the transport and disposal of hazardous waste. One of such companies operating in the Silesian Voivodeship is EKOMED Gospodarka Odpadami Sp. z o.o.

## 2. Conceptual background

### 2.1. Medical waste

The Waste Act of 2022 defines the concept of medical waste as "waste generated in connection with the provision of health services and conducting research and scientific experiments in the field of medicine" (Dz.U., 2023). Therefore, medical waste will appear in hospitals (general, psychiatric), rehabilitation sanatoriums, addiction centers, hospices, medical and educational facilities, care and educational facilities, clinics, health centers, clinics, and individual medical and nursing practices. Medical waste can be divided into 2 groups: hazardous waste (infectious waste, special waste) and non-hazardous waste. These wastes may



occur as solid substances (syringes, needles, limbs), liquid substances (blood, plasma, vomit) and gaseous substances. Since medical waste encounters the patient's blood and secretions, it may be dangerous to human health. Primarily because the patient may be a carrier of various types of diseases or pathogens such as viruses, bacteria or fungi that may cause AIDS, hepatitis C or the plague (Topolska, 2017).

Hazardous medical waste is generated at virtually every stage of a medical facility's operations. During the admission and diagnosis of a patient, medical waste may appear, such as: dressing materials, surgical gloves, sponges, cotton swabs, sticks, spatulas, pharmaceuticals, syringes, and needles. At the stage of conducting research, including laboratory tests, medical waste appears in the form of e.g., needles, pipettes, human tissues, or blood. Most hazardous medical waste occurs during surgery. During and after surgery, waste such as used surgical equipment (needles, scalpels, etc.), human remains and tissues, and blood are generated (Zalewska, 2019).

In order to classify waste, not only medical waste, an online waste database (BDO) was established and launched in 2018. Its main goal was to seal the waste management system. The main tasks of BDO are (BDO, 2023):

- collecting information on packaging and products in packaging introduced in Poland,
- collecting information on the achieved levels of recovery and recycling of waste from packaging and products,
- obtaining information on cross- border movement of waste,
- waste classification,
- keeping waste records based on submitted reports,
- control of the waste management market.

According to the Regulation of the Minister of the Environment of January 2, 2020 on the waste catalogue (Dz.U., 2020) medical and veterinary waste was classified in group 18 in accordance with Table 1.

The waste catalog is a collection of all waste divided into groups, subgroups, and types of waste, depending on the source of their generation. Additionally, the catalog lists hazardous waste that poses a particular threat to human health and life and the environment, marked \* (Dz.U., 2020, item 10). According to the waste catalog, medical waste is classified in group 18 and subgroup 01 (waste from diagnosis, treatment, and medical prevention).

**Table 1.**

*List of medical and veterinary waste classified in the waste catalogue*

Waste code	Description
18 01 01	Surgical and treatment tools and their remains (except 18 01 03)
18 01 02*	Body parts and organs, as well as a container for blood and preservatives used to store it (except 18 01 03)
18 01 03*	Other waste that contains live pathogenic microorganisms or their toxins and other forms capable of transferring genetic material that are known or there are reliable grounds for believing that they cause diseases in humans and animals (e.g. infected diapers, sanitary pads, pads), except 18 01 80 and 18 01 82

Cont. table 1.

18 01 04	Waste other than those mentioned in 18 01 03
18 01 06*	Chemicals, including chemical reagents, containing hazardous substances
18 01 07	Chemicals, including chemical reagents, other than those mentioned in 18 01 06
18 01 08*	Cytotoxic and cytostatic drugs
18 01 09	Medicines other than those mentioned in 18 01 08
18 01 10*	Dental amalgam waste
18 01 80*	Used peloids after treatments performed as part of medical activities with infectious properties
18 01 81	Used peloids after treatments performed as part of medical activities, other than those mentioned in 18 01 80
18 01 82*	Leftovers from feeding patients in infectious diseases wards

Source: Waste catalog, Dz.U. 2020.

The specific nature of the work of medical facilities is related to constant contact with hazardous substances. Improper contact with blood or surgical waste may pose a risk of infection. Improper storage or transport of medical waste, or even worse, a complete lack of proper management of this type of waste, may lead to the release of potentially hazardous substances into the environment and, consequently, to contact with them by unaware third persons. In the event of improper storage of waste (e.g., in a common garbage container), hazardous compounds may spread even through animals, such as rats or cats, which is why it is so important to properly handle waste at the stage of storage. Due to the potentially dangerous impact of medical waste on the environment, it should be properly segregated and stored at the initial stage of its production. This is the first and very important step in the entire process of safe transport and waste disposal.

In the case of medical waste, its initial segregation and - more importantly - proper protection against the environment mainly concern waste such as:

- used dressings, syringes, surgical tools,
- waste from treatment and operating rooms,
- used and expired medicines.

To store medical waste (depending on the type of waste) plastic bags or hardened containers may be used. What type of container should be used depends primarily on the characteristics of individual medical waste. In the case of waste with sharp edges, e.g., needles or scalpels, hardened containers should be used. The proper selection of the agent and method of storage allows you to minimize the risk of potentially dangerous situations for the environment or for people who have direct contact with the waste, e.g., during its storage or transport. Hardened containers are resistant to most mechanical damage, moisture, and certain chemical reactions. Containers and bags for medical waste are delivered in different colors, depending on the target type of waste to be stored in them. Figure 1 shows examples of bags and containers for storing and transporting medical waste.



**Figure 1.** examples of bags and containers for storing and transporting medical waste.

Source: [https://www.seni24.pl/...](https://www.seni24.pl/)

The following types of containers can be distinguished (Regulation of the Minister of Health of October 5, 2017, on the detailed method of dealing with medical waste (Dz.U., 2017; EKOMED, 2023):

- **red containers** – intended for collecting waste with codes: 18 01 02\*, 18 01 03\*, 18 01 80\*, 18 01 82\*, e.g., residues from feeding people from infectious disease wards, blood, waste containing toxins or microorganisms,
- **yellow containers** – intended for collecting waste with codes: 18 01 06\*, 18 01 08\*, 18 01 10\*, e.g., chemical reagents – containing dangerous substances, cytotoxic drugs,
- **different colour containers e.g., blue** – intended for collecting waste with codes: 18 01 01, 18 01 04, 18 01 07, 18 01 09 18 01 81, e.g., surgical and treatment tools, dressings, including plaster casts, bedding.

It is important to note that the containers are not designed with reusability. After filling, each container should be tightly closed in a way that prevents it from being opened again without leaving a clear trace. Professional containers used by companies are created in such a way that once closed, the container guarantees the waste producer that it cannot be reopened by unauthorized persons. Containers should be filled with no more than  $\frac{2}{3}$  of their volume – this allows them to maintain appropriate properties of containers and resistance to damage, which is crucial for the safety of the waste producer due to his responsibility. An equally important element is the proper marking of the container or bag with waste – each of them should have an appropriate marking containing, among others: waste code or time of its closure.

It is worth remembering that the choice of a reliable company dealing with the transport and disposal of medical waste, which can provide and provide appropriate means of transport, is crucial for the safety of outsiders and the waste producer, because he is responsible for the waste generated.

## 2.2. Storage and transport of medical waste

Proper waste management is becoming particularly important in the case of hazardous waste (e.g., medical waste) that may contain dangerous substances or microorganisms that, if released into the environment, could lead to contamination of water, air, or soil. Medical waste may also contain infectious or genotoxic material, which - in case of direct contact - may contribute to the development of cancer or infectious diseases. Proper collection of medical waste and its proper disposal minimize the potential risks associated with it. In the case of non-hazardous waste, its management should primarily lead to effective recycling, i.e., recovery of secondary raw materials or energy. This not only reduces environmental pollution, but also reduces production costs and reduces the degree of exploitation of natural resources.

The first stage of medical waste management is its appropriate storage. Each medical facility should have its own procedure for dealing with medical waste. The key issues in effective waste management are (Topolska, 2017; Rosik-Dulewska, 2000):

- segregation of waste on an ongoing basis as it is generated,
- division of waste depending on the risk level,
- knowledge of the chemical and physical composition of waste, which will help in subsequent recovery or disposal waste,
- knowledge of the rules regarding waste allocation, quantity in a container and the arrangement and labelling of containers.

Instructions on waste segregation rules should be posted at workstations. The key is to recognize a type of waste and place it in the right bag or container. Disposable bags should be placed on racks with a closed flap or immediately in containers. The way the bag is placed in the container is also important, the upper part of the bag should be rolled up by approximately 20 cm so that it's outer space does not get contaminated.

Another important issue regarding medical waste is time and storage. Packaging, i.e., appropriate bags and containers, should be replaced as often as conditions allow, but - in accordance with generally applicable law - at least every 72 hours (in the case of highly infectious waste, this time has been shortened to 24 hours). As a rule, waste may remain at the place of its creation (e.g., a treatment room) for a maximum of 72 hours from the time of its production. A similar time was introduced by the Legislator for the initial storage of waste - it should be noticed that the place of waste generation and the place of initial waste storage are not the same places, as evidenced by regulation by the Legislator of the issue of internal transport of medical waste from the place of its generation to the place of its initial storage. It should be assumed that the period during which medical waste can be initially stored should be treated and counted regardless of the duration of storage of medical waste at the place of its generation. The period during which specific waste can be initially stored will depend largely on the place and conditions in which such a process will take place - this time, however, cannot be longer than 30 days. Due to the high cost of preparing a place for the initial storage of medical

waste (which will meet the stringent requirements set by the Legislator), the need to allocate space for such a room and the rising prices of energy carriers necessary to maintain the proper temperature inside, such action may turn out to be unprofitable in the long run. In such circumstances, choosing an experienced and reliable partner providing waste transport and disposal services becomes even more important. The guarantee of continuity and timeliness of collections, while maintaining the necessary safety measures, allows for comfort in minimizing the risk of liability for the waste generated (EKOMED, 2023).

Due to the nature of medical waste, especially its transport should be carried out in accordance with applicable legal regulations. The issue of hazardous waste transport is regulated, among others, by the European ADR agreement on the road transport of goods and dangerous cargo, and Polish law, which determines the method of transport of medical waste, which in a specific part is classified as hazardous waste. Appropriate marking of waste transport means is only one of the factors ensuring the safety of the entire process - equally important is their appropriate equipment and qualified personnel with specific training in the proper handling of medical waste during its transport.

Moreover, the regulations clearly specify that a vehicle intended for transporting medical waste should be closed. This means that medical waste cannot be transported on uncovered trailers. The previously mentioned special containers are also necessary, marked in accordance with applicable regulations and practice. Transport of certain categories of medical waste may take place in disposable bags, but they are still required to be properly secured and described aimed at increasing the safety of the entire process of their transportation and disposal.

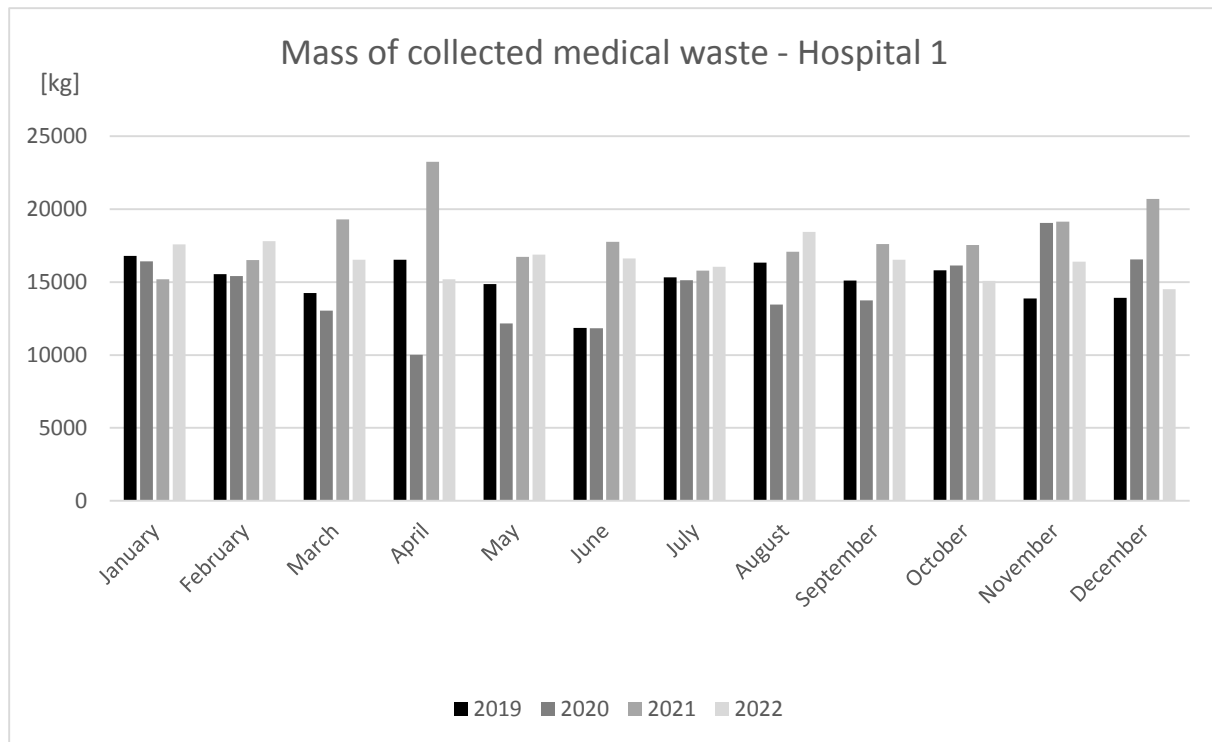
Medical waste management requires exceptional knowledge, care and safety of people working in its collection, transport, and disposal. The ecological aspect is also extremely important, which is why so much importance is attached to proper labeling and segregation of waste. It is therefore worth entrusting issues related to waste collection and disposal to experienced specialists who have the knowledge and permits required by law to conduct this type of activity. Ultimately, the safety of the entire waste transport and disposal process, and therefore the safety of its producer, depends on the proper selection of an entrepreneur specializing in the transport and disposal of waste (EKOMED, 2023; Siekierski, 2021).

### 3. Practice based on EKOMED experience

Over the last twenty years, the process of managing medical waste and other hazardous waste, especially the process of its transport, has become far-reaching professionalized. The daily practice of transporting medical waste to the place of its disposal allowed the development of effective logistic solutions for its safe transport, which turned out to be of invaluable value during the SARS-COV-2 virus pandemic. As indicated by the President of the Management Board of EKOMED Gospodarka Odpadami Sp. z o.o. – one of the leading companies in the field of transport of medical and hazardous waste in the Silesian Voivodeship – Mrs. Anetta Jędryczka, high standards introduced in the field of employee training, quality of packaging, protective measures used, appropriate human and material reserves, and finally technical facilities intended for direct waste transport enabled (and continues to enable) continuous and uninterrupted transport of waste to the place of waste disposal, even in the event of intensification of its production and volume, thus enabling medical facilities to operate uninterrupted - which was not an easy task at all. The increased hospitalization of the population was not only a test of the limits of endurance of medical staff, but also of the technical support and people responsible for the current transport and disposal of medical waste. In her opinion - as a practice - solutions introduced in recent years aimed at intensified recording of waste generated, both in terms of quantity and quality (including in the form of the BDO System), at the same time allow for far-reaching control of the entire waste management process, which in As a consequence, it resulted in its "tightening" and the elimination from the market of a significant number of entities whose activities consisted in disposing of hazardous waste in an illegal manner.

Research on the mass of collected waste was conducted in two hospitals in the Silesian Voivodeship, in the years 2019 to 2022, during the pandemic. The first hospital was a large district, general specialist hospital (Hospital 1). The second hospital was a Covid hospital - a district hospital, also a general specialist hospital (Hospital 2).

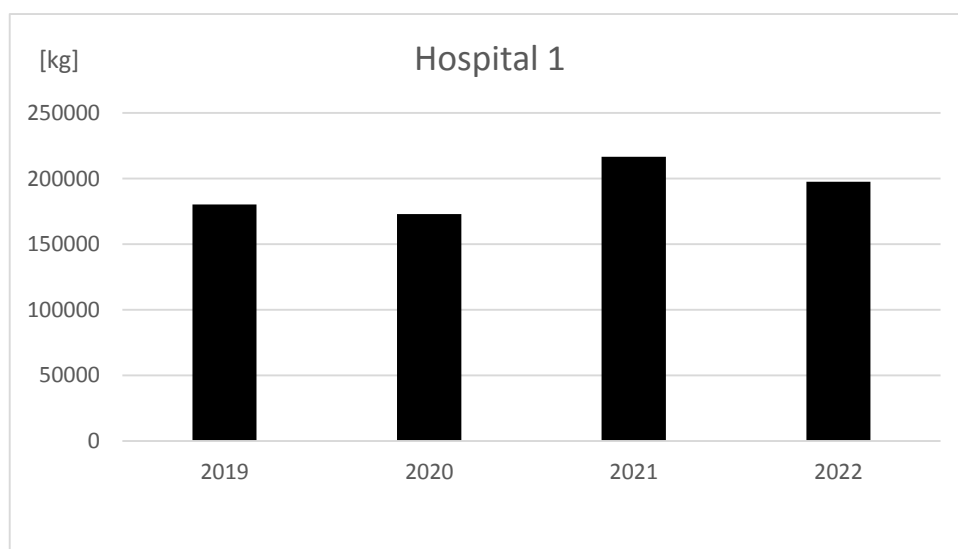
Medical waste was collected daily from both hospitals, taking all precautions. Figures 2 and 3 show the masses of medical waste collected from a large children's hospital, and Figures 4 and 5 from a large Covid hospital in all analyzed years, broken down by month.



**Figure 2.** Mass of collected medical waste from Hospital 1.

Source: own work.

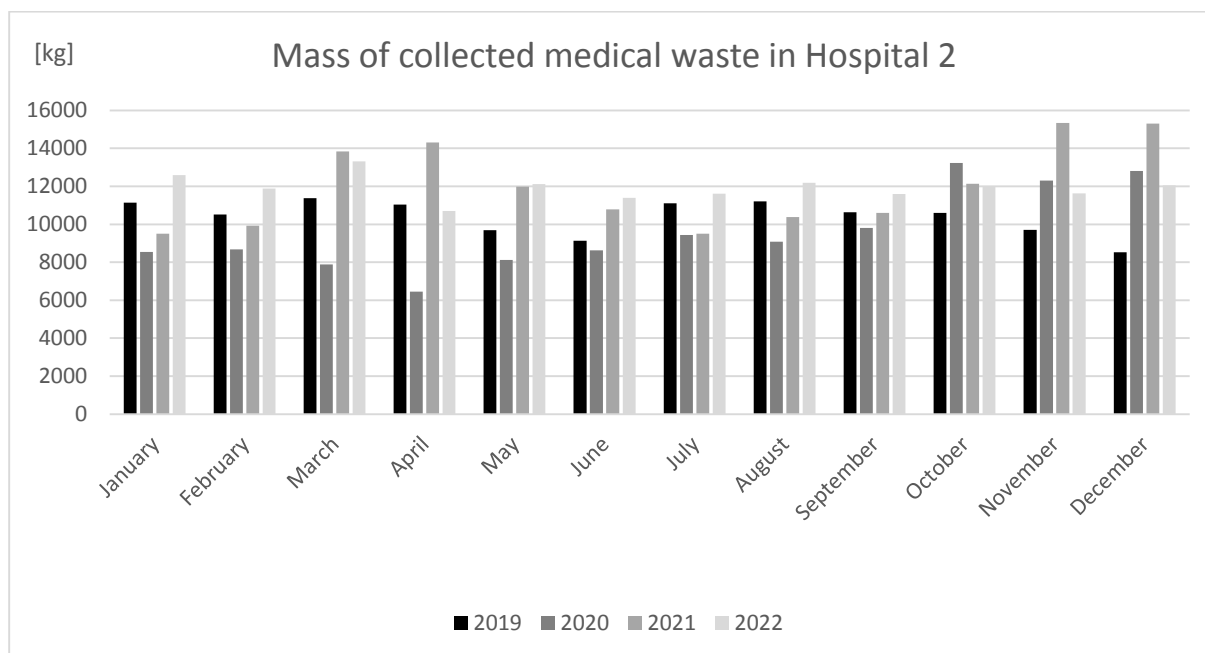
Analyzing the data obtained from the Hospital 1, the monthly amount of medical waste collected does not vary much. You can see the largest amount of waste collected in April 2021, which was probably caused by the wave of the pandemic that came in mid-March 2021. It can also be noted that, in general, the amount of medical waste collected during the pandemic years (2020-2022) was higher in almost every month than in 2019 - before the pandemic. The smallest amount of waste collected was recorded in April 2020. This was due to the lock down after the first wave of the pandemic in Poland.



**Figure 3.** Total mass of collected medical waste from Hospital 1.

Source: own work

Analysis of the graph of the annual collected mass of waste showed that the amount of waste during the pandemic increased, especially in 2021 and 2022. In 2020, a smaller mass of waste was collected than before the pandemic, which was probably related to the lock down, fewer patients, and therefore a smaller number of treatments, which resulted in less waste produced.

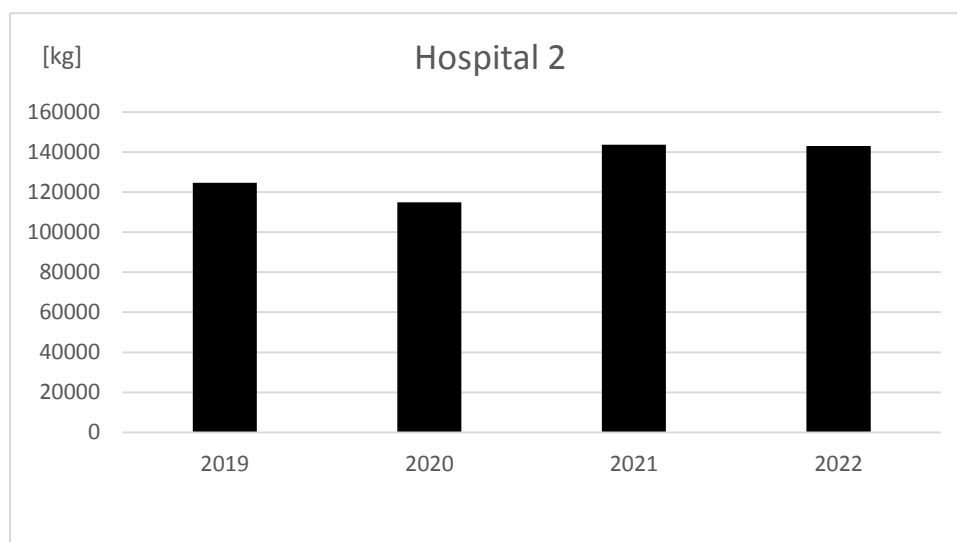


**Figure 4.** Mass of collected medical waste from Hospital 2.

Source: own work.

Interpreting the results obtained from the Hospital 2 - covid, it can be clearly seen a decrease in the amount of medical waste collected in the first quarter of 2020 compared to 2019. This decrease was most likely caused by the lock down and the beginning of the pandemic. In the later months of the year, there is a clear increase in the amount of waste (May 2020 – December 2020), which was caused by the further development of the pandemic. In 2021, there were three waves of the pandemic - in March, August, and December, which was, of course, reflected in the amount of waste collected - in March, April, November and December, the largest amounts of waste collected can be seen. After the December Covid wave, an increase in the amount of waste could be seen in January and March 2022. When the waves of the pandemic stopped, life slowly returned to its normal course, so patients appeared in the Hospital 1, and then medical waste also occurred.





**Figure 5.** Total mass of collected medical waste from Hospital 2.

Source: own work.

Analyzed data show that the total amount of collected medical waste during the pandemic increased, especially in years 2021 and 2022. In 2020, a smaller mass of waste was collected than before the pandemic, which was probably related to the lock down, fewer patients, and therefore a smaller number of treatments, which resulted in less waste produced.

#### 4. Summary and conclusion

The specific nature of the work of medical facilities is related to constant contact with hazardous substances. Improper contact with blood or surgical waste may pose a potential risk of infection. Improper storage or transport of medical waste, or even worse, a complete lack of proper management of this type of waste, may lead to the release of potentially hazardous substances into the environment and, consequently, to contact with them by unaware third parties. In the event of improper storage of waste (e.g., in an ordinary garbage container), hazardous compounds could spread even through animals, such as rats or cats, which is why it is so important to properly handle waste at the stage of storage. Disposing of medical or chemical waste is a unique responsibility. Leaving such a sensitive procedure to the wrong companies or people who do not have adequate technical and personal resources may not only have dangerous consequences, but also be severely punished by applicable law. Therefore, it is worth trusting certified companies that not only have many years of experience, but also perfectly understand the responsibility of waste producers. As emphasized by the Chairman of the Management Board of EKOMED Gospodarka Odpadami Sp. z o. o. constant supervision of the entire waste management process and the implementation of new solutions while consolidating the developed positive habits leads to increased safety of the entire process not

only for the producer himself, but above all for the general population and the natural environment. EKOMED Gospodarka Odpadami Sp. z o. o., constantly monitors the implementation of the latest solutions for the safety of his contractors. Obtained data showed, that the total amount of all collected medical waste in both hospitals were higher during and after the pandemic, than before it. It can be related with fact, that many people were treated and diagnosed for Covid in hospitals, so a lot of medical waste were produced.

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## ACCOUNTING PROFESSION TRANSFORMATION IN THE WAKE OF DIGITALIZATION – SURVEY RESULTS IN POLAND

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**Purpose:** The article aims to outline how digitalization has been contributing to the change in the role of accountants and present the professionally active accountants' perception of this transformation.

**Design/methodology/approach:** A literature review was conducted, followed by a survey carried out among accounting office employees and owners.

**Findings:** The accounting offices surveyed have shown inclination to utilize modern tools of digitalization. Employees report numerous benefits of digitalization, and most commonly consider the identified barriers to the implementation thereof to be of no significance. The greatest of these barriers is the lack of sufficient digital competence. The survey respondents, both the owners and employees, discern significant changes in the accounting profession, resulting from digitalization. The majority of respondents identify a new role assumed by accountants in the wake of digitalization, most prevalently that of a supervisor/controller and/or analyst.

**Research limitations/implications:** The empirical survey involved the use of the selection-by-convenience method, thereby the results obtained cannot be generalized to the entire population.

**Practical implications:** The article highlights the utmost relevance and indispensability of technological competencies in the accounting profession. By underscoring the increase in the importance thereof, the article can also contribute to greater focus on digitalization education among the students training to become accountants.

**Originality/value:** The article partially fills the research gap in empirical studies on the changing role of accountants in the wake of digitalization. It also serves as groundwork for the subsequent phase of empirical research on specialized studies graduates' awareness of the impact of digitalization on the role and profession of an accountant.

**Keywords:** digitalization, accounting profession, accounting office/firm, RPA, AI.

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

## 1. Introduction

The modern technologies and solutions associated with the digitalization and digital transformation processes taking place in business entities are becoming increasingly popular. Generally, businesses can opt to utilize elective digitalization tools, but in many cases, they are mandated to undertake this process by various legal provisions, including the tax and accounting regulations. The legislative changes were initiated by the implementation of the Directive 2012/17/EU of the European Parliament and of the Council (Directive 2012/17/EU), which imposed digitalization obligations in EU member states. As a consequence of the Directive implementation, amendments to the Tax Ordinance followed in Poland, which introduced a mandatory requirement to provide the tax authorities with the information contained in accounting books and accounting evidence in an electronic form compliant with the logical structure of the Standard Audit File for Taxes (SAF-T). Online fiscal cash registers have been made mandatory for all entrepreneurs making sales to non-business customers. Starting July 1, 2024, in turn, regulations mandating issuance and availability of XML-format structured invoices via the National e-Invoice System (KSeF) [PL: Krajowy System e-Faktur] will come into effect. These changes concern the tax aspects, but they have also affected the regulations governing the areas of business entity accounting. As of 2016, a requirement has been in force to submit the information reported to the National Court Register via the eKRS [PL: Krajowy Rejestr Sądowy] system, using electronic applications signed with electronic signatures. Changes to the Accounting Act, in turn, have introduced mandatory electronic financial statements.

In February 2021, the Polish Agency for Enterprise Development [PL: Polska Agencja Rozwoju Przedsiębiorczości] surveyed a group of 105 companies which had undertaken digitalization process projects. The concluding study (Zadura et al., 2021) detailed eight good practices, one of which involved the process of voluntary digitalization in an accounting office, encompassing automation of clerical, accounting and administrative processes. A number of benefits resulting from the implementation of this practice were observed, such as increased revenue, improved quality of work, and ongoing error correction, which eliminated year-end backlogs. The example of this accounting firm has inspired further in-depth research on digitalization in accounting offices and the impact it has had on the change in the role of accountants.

Undeniably, the accounting profession has transformed over the past few decades. Personnel Service experts indicate the accounting profession as one of the professions most threatened by the development of robotization and artificial intelligence (Jarco, 2023). This dynamic transformation is associated with the process of digitalization, and year after year further changes in the practice of accounting activities are noticeable.

A report by Symfonia<sup>1</sup> and the Association of Accountants in Poland [PL: Stowarzyszenie Księgowych w Polsce], titled “Doradca i analityk czy może jednak rachmistrz? [ENG: Advisor and Analyst or still an Accountant?],” further revealed that more than 56% of accounting sector employers consider knowledge of financial and accounting software to be a key skill in the careers of specialized studies graduates. This underscores how important digital skills are. The report's authors add that persons resisting digitalization may struggle to find employment. Moreover, Małgorzata Ściślak - a Symfonia product marketing and strategy expert - stresses that in the near future, repetitive activities, such as invoice data entry, are likely to be performed by dedicated systems. This means that the role of accountants will be limited to analysis, verification and conclusion drawing. These areas are where machines will not be able to replace humans, thus accountants will become business advisors (Cyfryzacja wchodzi do księgowości... [ENG: Digitalization makes its way into accounting...], 2022).

A. Lewandowski is of a similar opinion as regards the change in the role of accountants in the wake of automation. According to the author, the day-to-day tasks of an accountant will not consist of merely documenting past events. Accountants are tasked with analyzing, advising and suggesting directions for company optimization (Lewandowski, 2021).

The International Federation of Accountants (IFAC) has identified seven new roles within the accounting profession: that of a co-pilot (who introduces new strategies, influences people), a navigator (who guides toward the maintenance of profitability, by creating scenarios and identifying trends), a brand guardian (who protects the organization and its reputation), a narrator (who recounts the company's values and challenges to stakeholders), a perpetrator of digital and technological change (who is committed to the company's automation and digitalization, and persuades management to equip accounting with the right digital tools), a process and control expert (who ensures process efficiency), a trusted professional (who oversees the procedures ensuring protection against misconduct) (Wojtas, 2022).

The main objective of the article is to outline how digitalization has been contributing to the change in the role of accountants and present the professionally active accountants' perception of this change.

To achieve the objective, the following research questions were posed:

- In what scope do the surveyed accounting offices utilize voluntary digitalization in their operations?
- What is the surveyed accounting office employees' attitude toward digitalization?
- What is the employees' perception of the change in the role of accountants in the wake of digitalization?
- What benefits of and barriers to digitalization do the employees in the surveyed accounting offices identify?

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<sup>1</sup> Symfonia – business management software provider.

For the purpose of the article, a literature review was conducted using the Scopus and Web of Science databases, which were searched for positions describing digitalization in accounting. In the next step, the methodology of the planned empirical research was then detailed, and a survey was conducted among the owners and employees of selected accounting offices.

## 2. Literature review

The literature review was carried out between November 24<sup>th</sup> and December 20<sup>th</sup>, 2022, drawing on an Internet search of two electronic databases: Scopus and Web of Science. The main objective of the preliminary literature review was to search for items describing digitalization in accounting and the empirical research undertaken in this area. Two groups of keywords were used:

- digitalization, RPA, cloud computing, UiPath,
- accounting profession.

Individual search queries involved simultaneous use of keywords from both groups. A total of 81 articles were targeted. Considering the subject of the changing role of accountants as a result of digitalization, 14 articles from the Scopus database and 11 articles from the Web of Science database were selected for further research. In each category, the Authors identified the conclusions and main research areas common to the papers reviewed (Table 1).

**Table 1.**

*Primary research area and conclusions - literature review*

<b>Main research area</b>	<b>Conclusions /Authors</b>	<b>Number of publications</b>
Accountants' response to digitalization	- reaction to the digitalization-effectuated change – Stoica, Ionescu-Feleaga, 2021 - reluctance to implement RPA can occur at any stage of the process – Sarilo-Kankaanranta, Frank, 2022	2
Change in working conditions	- RPA positively changes and improves career prospects – Cooper et al., 2022 - the evolution of information technology poses challenges for accounting, but improves the quality of work and creates more value – Weng et al., 2014	2

Cont. table 1.

The course for the accounting profession	<ul style="list-style-type: none"> <li>- the insights set the course for the accounting profession as it increases its use of RPA – Cooper et al., 2022</li> <li>- research on the impact of new technologies (RPA, cloud computing, AI), and the process of accounting firm and profession transformation – Tiron-Tudor et al., 2022; Langmann, Kokina, 2021; Dimitriu, Matei, 2014; Mihai, Dutescu, 2022; Sytnik et al., 2022, Stancu, Dutescu 2021</li> <li>- main predictors of the accounting profession development and digitization in the country are the size of the population and the competitiveness of the national economy – Ionescu-Feleagă et al., 2022</li> <li>- Industry 4.0 will significantly affect the duties of accountants and the changes in the accountant profession – Bakarich, O'brien, 2021; Onyshchenko et al., 2022; Meiryani et al., 2022; Fulop et al., 2022</li> <li>- professional accountants with a strong understanding of the digital age do play a role in challenging the systems and mechanisms supporting the acquisition, management, sharing and distribution of information – Ciurea, Man, 2020</li> <li>- stages of accounting robotization: organizational and informational, robotic data processing, reporting and analytical, account management – Bakulina et al., 2020</li> <li>- the evolution of information technology presents accounting with challenges which call for a new set of skills to be acquired by professionals in order to improve the quality of their work and create more value – Moore, Felo, 2022</li> </ul>	15
Digitalization-effectuated change in the role of an accountant	<ul style="list-style-type: none"> <li>- accountants become the liaison and “voice of reason” between enthusiastic IT departments and skeptical management – Mangiuc, 2016</li> <li>- the emotional intelligence, ethical and moral values characterizing experienced accountants cannot be replaced by digitalization – Boutellis-Taft, 2019</li> <li>- the role as identifiers, explainers, trainers, supporters, analyzers, qualified strategic business consultant, decision-makers and financial supervisors – Kokina et al., 2021; Frolova et al., 2021; Knihova, 2019; Andreassen, 2020</li> </ul>	6

Source: own elaboration.

The literature review conducted allowed for the systematization of publications on the digitalization-effectuated change in the role of accountants into four research areas. The first represents the accountants' response to the very process of digitizing and digitalization - different reactions have been indicated, showing that resistance to digitalization-related changes can occur at any stage of the process. The second area entails presentation of the changes in the working conditions of accountants, brought about by digitalization. The process has been emphasized to improve the quality of work. The last two research areas cover the directions of change and the related evolution of the accountant's role. Publications indicate that the role of accountants has been transforming due to the ongoing processes of mandatory and voluntary digitalization within accounting systems. Such new technologies and digitalization tools as RPA or AI have influenced the transition from the classic role of accountants to, inter alia, that of analysts or controllers. As emphasized, however, not all skills can be replaced by digitalization.

The literature review revealed a research gap consisting of a scant number of empirical studies on digitalization in accounting offices. The Authors aim to partially fill this gap through this article.

### 3. Empirical research methodology

The literature review carried out, the analysis of the legal acts in force in Poland, as well as the empirical survey conducted on February 9, 2023 via a semi-structured interview with the owner of an accounting office in the Pomeranian Voivodeship indicated ample research opportunities in the field of digitalization in accounting. The findings of the study on accounting office digitalization (Kotowska, Sikorska, 2023) show that, in addition to the obligations imposed by legal regulations, the surveyed accounting office also leverages such voluntary digitalization tools as OCR, bank transfer automation, as well as upload of bank statements in the form of MT 940, VPN or Power BI Desktop files. The digitalization process itself is also valued highly, and the benefits thereof are emphasized, with some of the highest rated including: increased productivity, ongoing access to data, improved service quality, and the flexibility to work remotely from any location. The owner of the surveyed office additionally stressed during the interview that accountants need to be IT literate and adept at technological innovations. This view prompted the Authors of the article to plan research in areas that had not yet been addressed. The research was designed to be carried out in three stages, divided into eight phases (Table 2).

**Table 2.**  
*Planned empirical study*

Research stage/study	Task	Study sample	Method
<b>STAGE 1</b>			
1) Preliminary study	Presentation of voluntary digitalization tools and the associated benefits and barriers	Case study	Semi-structured interview
2) Literature review - preliminary	Scopus, Web of Science	-	Literature analysis
3) Law regulation	Digitalization obligation under the law	-	Law analysis in Poland
<b>STAGE 2</b>			
4) Questionnaire 1	Digitalization-effectuated change in the role of accountants	Accounting firm owners	Questionnaire - MsForms
5) Questionnaire 2	Digitalization-effectuated change in the role of accountants	Accounting firm employees	Questionnaire - MsForms
6) Result analysis	Study summary and conclusions	-	Synthesis, deduction



Cont. table 2.

STAGE 3			
7) Questionnaire 3	Survey of final-year accounting students' knowledge and awareness of the changing role of accountants in the wake of digitalization	Students – Poland, Romania	Questionnaire - MsForms
8) Result analysis	Study summary and conclusions	-	Synthesis, deduction

Source: own elaboration.

The first stage of the research has already been carried out, and the results are presented in B. Kotowska, M. Sikorska (2023).

This article presents the conclusions of the survey conducted as part of the second stage with the use of questionnaires designed and developed for accounting office owners and employees.

An assumption was made that, to achieve the research objective set and obtain answers to the research questions posed, the method of selection by convenience, in which the researcher determines the quickest and easiest method of selection under the given conditions, would prove the most feasible for the selection of the sample population units (Kozłowski, Szreder, 2020). This unfortunately prevents generalizations to the entire population; nevertheless, such a measure does provide advantages, as it allows inclusion of willing and readily available entities in the study, yielding empirical data necessary to verify the research questions posed (Kowal, 1998).

#### 4. Empirical research – conclusions

The survey was divided into two parts: the part designed for accounting office owners and the part designed for accountants, i.e., employees of these offices. The survey characteristics are presented in Table 3.

**Table 3.**

*Characteristics of the surveys conducted*

	<b>Specification</b>
Survey objective	Outline of how digitalization contributes to the changing role of accountants, and how professionally active accountants perceive this change
Object of survey	1) Accounting firm owners 2) Accounting firm employees
Subject of survey	Digitalization-effectuated change in the accountant's role
Survey time horizon	From April 15, 2023 to June 10, 2023, using a Microsoft MsForms questionnaire
Survey method	Selection by convenience
Size of the survey sample	Survey sample: 1) 22 accounting office owners 2) 59 accounting office employees

Source: own elaboration.

#### 4.1. Questionnaire - accounting office owners

As part of the metric, questions regarding the number of employees working in accounting positions (Table 4), the number of clients served and the approximate monthly volume of documents in the office were asked (Table 5).

**Table 4.**

*Accounting position employment structure*

Number of employees	1-5	6-10	11-15	16-20	Over 20
Number of accounting offices	11	4	2	1	4

Source: own elaboration.

Of the 22 owners, 11 employ between 1 and 5 persons in accounting positions, two employ from 11 to 15 such specialists, whereas only one of the surveyed owners employs 16 to 20 accountants. Four of the surveyed accounting offices are staffed with 6 to 10 accounting position employees, and four with over 20 accountants.

**Table 5.**

*Number of clients served by accounting office*

Number of clients	Under 20	20-50	51-100	101-150	Over 150
Number of accounting offices	2	2	9	3	6

Source: own elaboration.

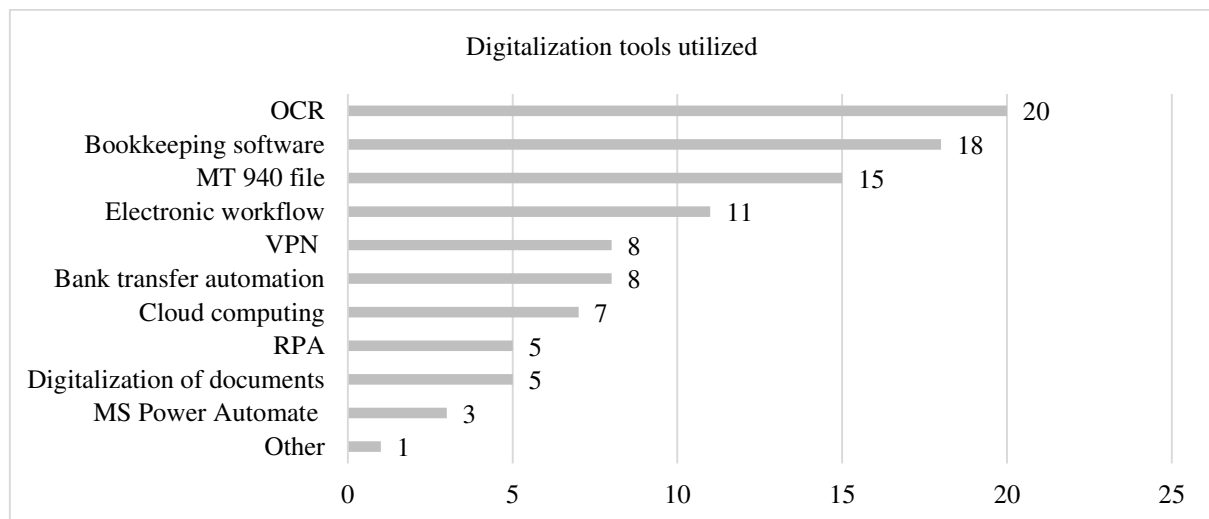
Most of the surveyed accounting firms, i.e., nine, serve 51-100 clients. Three offices serve between 100 and 150 clients, and as many as six accounting offices provide accounting services to more than 150 clients. Four accounting offices are smaller service providers delivering services to less than 20 clients (2 offices) and 20-50 clients (2 offices).

The majority of the surveyed offices specified the monthly number of documents as exceeding 6000, with five offices indicating 2000-3000 and three under 2000. A value in the range of 3000-4000 and 4000-5000 was reported by two office owners.

In all accounting offices participating in the survey, electronic workflow is already in place, but paper versions of documents are also used by the vast majority (18 offices). In 14 accounting offices, at least 50% of the documents are generated in electronic form. Five owners specified the share of electronic form in the total number of documents at 20-30%. Three of the surveyed offices indicated that electronic documents account for 15% or less of total documents.

The responses to questions regarding the areas subject to digitalization indicate that in more than half of the accounting offices surveyed, not only accounting, but also HR or clerical departments are subject to digitalization.

Figure 1 shows the responses relative to the tools utilized as part of digitalization in the accounting offices surveyed (selection of multiple answers was possible).



**Figure 1.** Digitalization tools utilized.

Source: own elaboration.

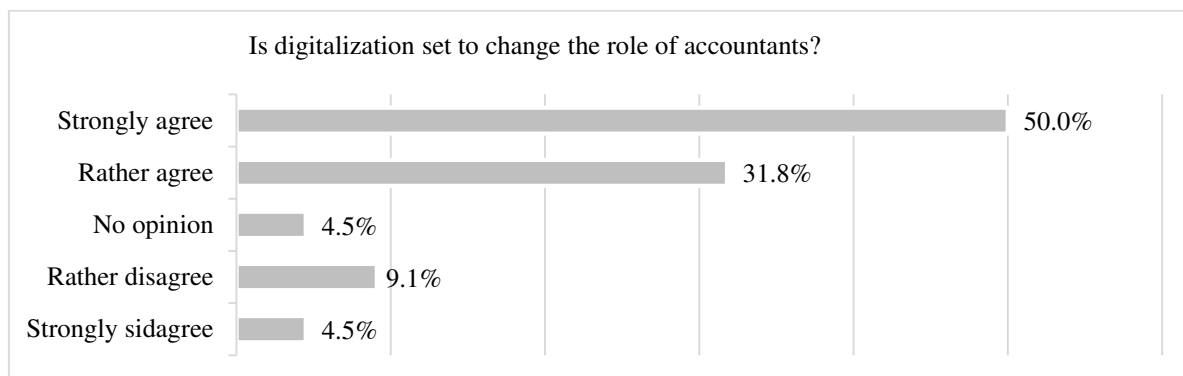
Bookkeeping software and Optical Character Recognition (OCR) are in greatest demand when it comes to digitalization. As many as 20 of the 22 surveyed owners utilize OCR in their offices. Bank statement loading is also very popular - 15 of the 22 surveyed offices operationalize this function. Half of the offices participating in the survey have introduced electronic workflow. Document digitalization, robotics and MS Power Automate, in contrast, are the least popular.

The respondents were also asked what services they have used/are using as part of their digitalization implementation process - external consultants and in-house training were most commonly indicated. UiPath Academy as well as other training courses and webinars were also utilized.

The survey participants were also asked about their customers' reception of digitalization. Half of the respondents reported that most of their clients showed a positive attitude in this regard, but as many as seven owners indicated a very mixed customer reaction. Resistance on the part of customers was indicated by one office, and three owners reported that this aspect was of little importance to customers, as only the end product is what matters.

One very important part of the survey administered to the owners consisted of questions regarding employee attitudes toward digitalization. The majority of respondents (12 indications) stressed that their employees' attitude to digitalization is mostly positive, although some resistance to implementing new technologies has been noted. Eight respondents, in turn, indicated that their employees' attitude is mostly highly positive, and is characterized by eagerness to become familiar with new tools and employ new technologies. Two respondents indicated a very mixed pattern, with attitudes toward digitalization contingent on experience and other factors. Significantly, none of the respondents described their employees' attitudes toward digitalization as negative.

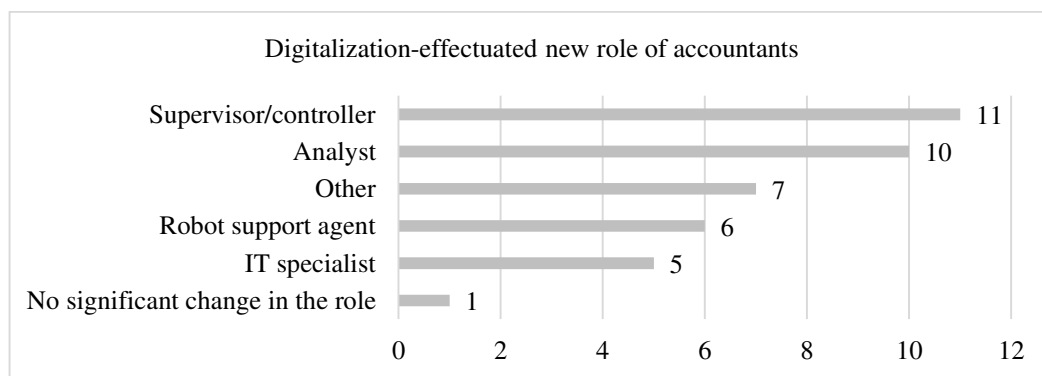
Half of the respondents strongly agree with the statement that digitalization is set to change the role of accountants. Less than 32% rather agree with this position, whereas only 4.5% of the respondents strongly disagree with such a stance. The results are shown in Figure 2.



**Figure 2.** Impact of digitalization on the change in the role of accountants.

Source: own elaboration.

A question regarding the direction of the digitalization-effectuated role of accountants was also included in the survey, with several answers available for selection. The results are shown in Figure 3.



**Figure 3.** The new role of accountants according to accounting office owners.

Source: own elaboration.

The answer most commonly identified was that of a supervisor/controller, selected by half of the respondents. Slightly fewer respondents felt that the new digitalization-effectuated role of an accountant would be that of an analyst. The role of a tax advisor (provided under the answer "other"), IT specialist or robot support agent was indicated by less than half of the respondents.

Importantly, from the perspective of the accounting profession and its future, however, the vast majority of respondents (19 office owners) stressed, when asked whether they thought digitalization could lead to a scenario in which the job of an accountant would not require a degree in the field, that no such possibility existed.

## 4.2. Questionnaire - accounting office employees

The employee survey was completed by 51 female and 8 male respondents. Most of the surveyees (12) aged between 36 and 40, with slightly fewer, i.e., 11 respondents, under 25 years of age. The fewest number of surveyees (5) were between 46 and 50 years of age. The data on work experience (Table 6) shows that the same number of respondents (14) reported professional experience ranging from 11-15 years and over 20 years. Experience of 16-20 years was indicated by the least number of surveyees. 10 respondents reported work experience of less than two years.

**Table 6.**

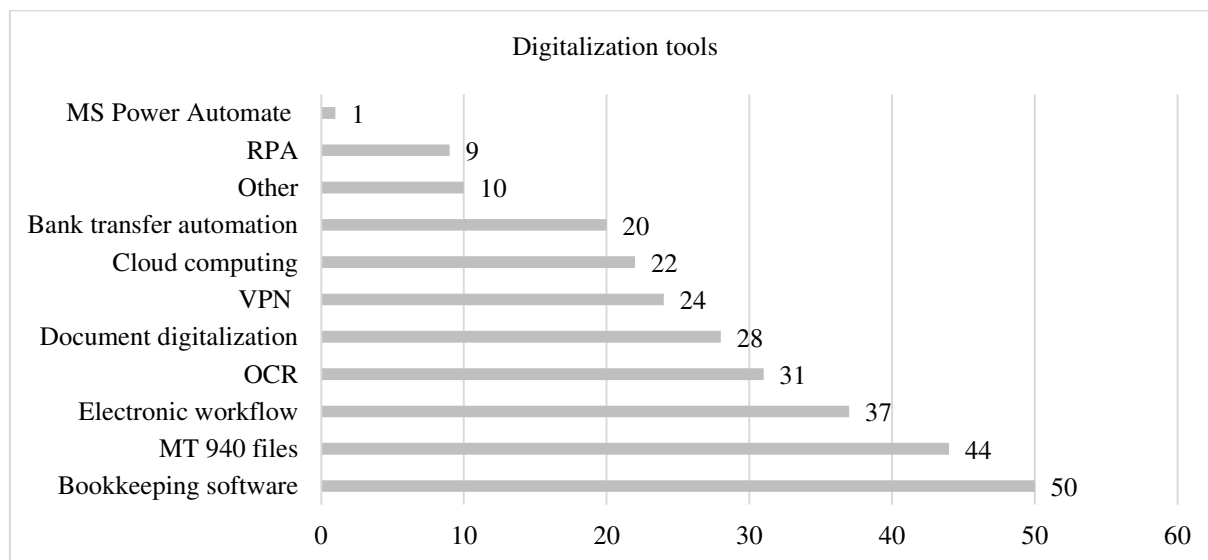
*Professional experience of accounting office employees*

Professional experience	0-2 years	3-5 years	6-10 years	11-15 years	16-20 years	Over 20 years
Number of answers	10	12	7	14	2	14

Source: own elaboration.

A vast majority of the surveyed employees (47 indications) hold a master's degree in specialized studies. Slightly fewer, i.e., 32, have completed dedicated courses. No specialized education was declared by four respondents; five marked the answer "other". The survey sample also included one PhD graduate and one chartered accountant.

As part of the survey, the respondents were asked to select the most practical digitalization tools they use in performing their work. The results are shown in Figure 4.



**Figure 4.** Digitalization tools.

Source: own elaboration.

Bookkeeping software, with 50 responses, and bank statement loading in the form of MT 940 files, with 44 indications, are the most popular tools. Electronic workflow, OCR and document digitalization are also widely employed (37, 31 and 28 indications, respectively). Slightly less popular, but still widespread, is the use of VPN - 24, cloud computing - 22,

and bank transfer automation - 20. Robotization, other than document uploading, and MS Power Automate are the least widely utilized.

The questionnaire also included questions regarding the benefits of digitalization and the barriers to its implementation. Both the benefits and barriers were rated on a Likert scale, with the following scores assigned to individual responses: 1 - strongly disagree, 2 - rather disagree, 3 - no opinion, 4 - rather agree, 5 - strongly agree. The benefits of digitalization are shown in Table 7.

**Table 7.**  
*Benefits of digitalization according to accounting office employees*

Benefit/scale	1	2	3	4	5
Increase in productivity			8.5%	39.0%	52.5%
Reduction of work time	1.7%		13.6%	40.7%	44.1%
Increase in digital competence	1.7%	1.7%	16.9%	40.7%	39.0%
Ongoing access to data		1.7%	5.1%	28.8%	64.4%
Reduction of errors		11.9%	28.8%	32.2%	27.1%
Improved speed of processes		3.4%	11.9%	37.3%	47.5%
Greater control over processes		5.1%	22.0%	30.5%	42.4%
Higher quality of data (accuracy, consistency)		3.4%	20.3%	42.4%	33.9%
Feasibility of continuous operation		5.1%	13.6%	33.9%	47.5%
Feasibility of remote work from any location	1.7%	1.7%	5.1%	25.4%	55.1%
Reduced environmental impact	1.7%	5.1%	15.3%	28.8%	49.2%

Source: own elaboration.

More than 50% of the respondents rated the benefits associated with increased productivity, ongoing access to data and the feasibility of remote work from any location at "5," which indicates their strong agreement that a given benefit does arise as a result of digitalization. With regard to four benefits, namely the reduction of work time, higher digital competence, feasibility of remote work from any location, and reduced environmental impact, a number of respondents were found who strongly disagree, which indicates that they do not discern any benefits in those areas. Reduction of errors, in turn, elicited the most "No opinion" ratings among all the respondents. Three respondents additionally provided their own examples of benefits:

1. *Process streamlining, assignation of steps to be performed by inexperienced personnel lacking substantive accounting/tax knowledge.*
2. *Optimization of customer communication (customers do not, so to speak, bother the personnel, as all information and documents are available to them).*
3. *Paperless work environment*".

The Likert scale rating of digitalization-resultant barriers is presented in Table 8. Habituation to traditional solutions as a barrier to the implementation of digitalization was rated with a score of "5" by 15.3% of the respondents. The largest barrier, in terms of combined respondent ratings of "4" and "5," however, is the lack of sufficient digital competence. The majority of respondents disagree or strongly disagree on a barrier consisting in the

prevalence of digitalization-related responsibilities over the benefits, thus not identifying it as an obstacle to the implementation of digitalization.

**Table 8.**

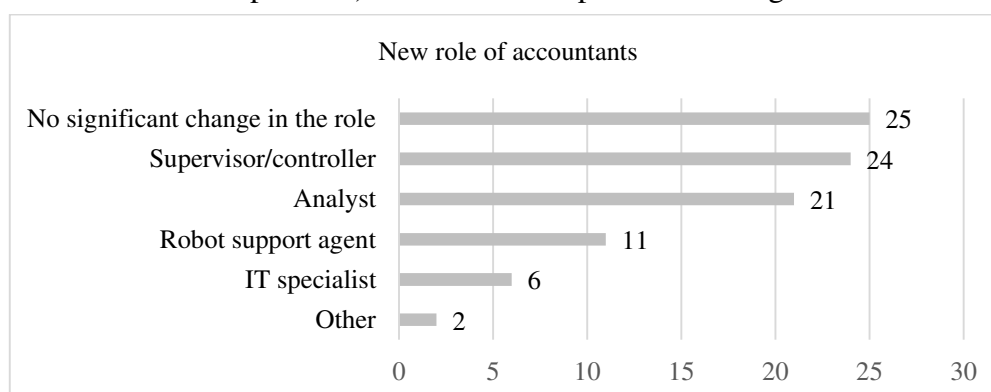
*Barriers to digitalization according to accounting office employees*

Problem/Scale	1	2	3	4	5
Anxiety towards/fear of new solutions	16.9%	30.5%	10.2%	33.9%	8.5%
Lack of sufficient digital competence	13.6%	22.0%	15.3%	47.5%	1.7%
Reluctance associated with additional responsibilities	22.0%	27.1%	18.6%	23.7%	8.5%
Habituation to traditional solutions	22.0%	13.6%	20.3%	28.8%	15.3%
Prevalence of digitalization responsibilities over the benefits	32.2%	25.4%	27.1%	13.6%	1.7%

Source: own elaboration.

The survey revealed that 88% of the respondents (52 surveyed) do consider the accounting profession to be changing as a result of digitalization. Furthermore, 53 respondents (89%) reported that, as a result of digitalization, accountants are faced with the need to acquire new competencies in technology and prefer digitalization solutions to traditional ones.

The employees surveyed were also asked to indicate, from a range of possible answers, the direction in which the role of accountants is heading in the wake of digitalization (selection of more than one answer was possible). The results are presented in Figure 5.



**Figure 5.** The new role of accountants according to accounting firm employees.

Source: own elaboration.

In response to the question regarding the digitalization-effectuated role of accountants, 25 of the respondents answered that their professional role would not change significantly. 24 surveyees opined that the role of accountants is moving toward that of supervisors/controllers, while 21 indicated the role of analysts. Only one respondent specified the role of a tax specialist. The question was open for multiple responses.

The results of the survey show that 48 of the 59 respondents (81%) believe that digitalization will not lead to a scenario in which professional education would not be required for an accounting position. Eleven people are of the opposite opinion.

### 4.3. Survey summary

All of the accounting offices surveyed employ electronic workflow, which indicates that digitalization is widespread, regardless of the office size. Digitalization processes involve such areas as accounting, HR and clerical work, which means that digitalization is not only implemented under the regulatory requirements, but also in voluntary areas.

Both groups of the respondents (accounting office owners and employees) indicated that the most widespread digitalization tools used were bookkeeping software, OCR and the MT 940 file loading of bank statements.

None of the office owners surveyed reported negative employee attitudes toward digitalization, which bodes well for the future.

The employees surveyed indicated increased productivity, ongoing access to data and the feasibility of remote work from any location as their perceived benefits of digitalization implementation. The greatest barriers to the implementation of digitalization indicated in the survey are habitual use of traditional solutions and lack of sufficient digital competence. Interestingly, the employees expressed their preference for digitalization solutions over traditional ones in their responses.

Both the accounting office owners and employees agree that the accounting profession is undergoing transformation as a result of digitalization. As a consequence, accountants need to acquire new competencies in technology. The vast majority of the owners surveyed note the new nature of the accountant's role - supervisor/controller and/or analyst. A somewhat different picture emerges for the responses provided by the accounting office employees. Among this group of the respondents, some believe that their professional role will not change significantly as a result of digitalization, while others discern a new direction for the accounting profession - supervisor/controller and/or analyst. The objective set in this article, namely, to outline how digitalization has been contributing to the change in the role of accountants and how professionally active accountants perceive this change, has been achieved.

It is also worth noting that the vast majority of the accounting office owners and employees surveyed believe that digitalization is unlikely to lead to a scenario in which accounting personnel will not be required to hold a degree in accounting.

## 5. Conclusions

Analysis of current Polish legislation shows that, in many areas of business operation, digitalization constitutes an element mandatory, both in tax-related and accounting aspects. Some businesses, however, also utilize voluntary digitalization tools, as exemplified by accounting firms.



The literature review conducted has revealed a research gap in the field of accounting office digitalization, more specifically, the scant number of empirical studies conducted in this area. The research gap indicated has been partly filled by the Authors of this article.

The main objective of the article was to demonstrate how digitalization contributes to the change in the role of accountants and present the perception of professionally active accountants in this regard, based on a survey of selected accounting offices. The survey yielded answers to the research questions posed. The surveyed accounting offices, in addition to their legally imposed duties, also implement digitalization within a voluntary scope. The owners emphasize their readiness to utilize modern digitalization tools, including OCR, bookkeeping software, MT 940 file loading of bank statements, electronic workflow, VPN and bank transfer automation. The surveyed employees, in turn, emphasize their use of bookkeeping software, but also MT 940 files, electronic workflow, OCR, document digitalization or VPN. The most substantial benefits of digitalization, noted by the surveyed employees, are increased productivity, ongoing access to data or the feasibility of remote work from any location. The most substantial barriers, indicated by the surveyed employees, include the lack of sufficient digital competence, as well as anxiety towards modern solutions and habituation to traditional solutions. The last of the research questions referred to the perceived new role of accountants. The owners of accounting offices in vast majority indicated the role of a supervisor/controller or analyst. They additionally have identified their new professional role with that of a tax advisor and a robot support agent. Only one owner expressed an opinion that the role of accountants would not change significantly. The employees' opinions, by contrast, were more disparate. The answer stating that the professional role of accountants will not change significantly received 25 indications. The roles of a supervisor/controller and analyst received 24 and 21 indications, respectively. The role of a robot support agent also showed to be a relatively common choice (11 responses).

The conclusions drawn from the literature review and the survey research confirm the need to undertake further in-depth empirical research on digitalization in accounting offices, accounting departments and the very system providing education for future employees whose professional life will entail accounting. The respondents emphasize in their answers the need for professional education covering the aspects of digitalization. This provides impetus for the subsequent, third stage of the research, which will be carried out by means of a questionnaire designed for students, with the aim of examining the level final-year accounting students' familiarity with and awareness of the change in the role of accountants in the wake of digitalization.

A comprehensive review of accounting regulations is currently underway, with the aim of identifying areas in need of possible refinement, simplification, harmonization or introduction of new solutions, in order to adapt those solutions to the current practice, the legal and economic reality, and the opportunities offered by digitalization-related advances. The work on this part of the report is expected to be completed in April 2024 (Huczko, 2023).

It is also worth noting that one survey respondent expressed an opinion that artificial intelligence (AI) will either cause a drastic change or extinction of the accounting profession within 10 years, and simple accounting systems such as lump sums and tax ledgers will be handled by AI and corporations (e.g., banks). This somewhat outlines the possible future of the accounting profession.

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## MANAGEMENT SYSTEMS IN THE AUTOMOTIVE INDUSTRY – ASSESSMENT OF AWARENESS OF THE MANAGEMENT STAFF REGARDING THEIR IMPLEMENTATION AND APPLICATION

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**Purpose:** The article presents the results of research on the assessment of awareness of middle-level employees in the field of their implementation and use in a company from the automotive industry.

**Methodology:** Assessment of the management staff's awareness of the implementation and use of management systems in the automotive industry using a survey. Assessment of the management staff's awareness of the implementation and use of management systems in the automotive industry using a survey. The survey was addressed to middle management (90 employees). The number of respondents was indicated by top management. A four-stage research methodology was developed, including: development of survey questions (first stage), determination of the research group (second stage), determination of the minimum number of respondents using the PQStat tool (third stage), analysis of survey results (fourth stage).

**Findings:** The results of the survey research obtained in the work can be considered as a contribution to the statement that the awareness of the mid-level staff regarding the management systems used in the surveyed company, the implemented systems supporting the optimization of all production and production-related processes. Determining the type of impact of the implementation of management methods and tools used in the company affect the improvement of OHS, determine the type of impact of the implementation of management methods and tools used in the company that improves the organization of production, how employees acquire knowledge and skills in the field of OHS Management System and what are the most effective sources of knowledge should be a priority.

Making employees at all levels, including the middle level, aware of the importance of training and with what frequency it should take place, as well as the involvement of middle-level employees in the implementation of management systems, has a significant impact on the employees' work efficiency.

**Research implications:** The survey research was limited to examining the awareness of only one group of respondents (mid-level management) of the surveyed enterprise. This survey can also be conducted among other employees of the enterprise in order to obtain full information on the use of management systems in the audited entity. This industry is developing intensively and there is a need for greater awareness of employees about the applicable management systems.

**Practical implications:** The conducted research may provide important information for the management staff in terms of improving competences within the applied management systems.

**Originality:** The purpose of the publication was to present survey results concerning the assessment of awareness among middle-level employees regarding the implementation and utilization within a company in the automotive industry. In today's business world, the research problem holds significant importance. This industry is developing intensively and there is a need for greater awareness of employees about the applicable management systems.

**Keywords:** automotive management system, Lean Manufacturing, awareness.

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

## 1. Introduction

Nowadays, the challenge in the automotive industry is more demanding due to the increase in dynamicity and complexity of environmental changes in the external business environment (Purwanto, Ashari, Anggoro, Nasution 2023). The automotive industry is an important element of the global economy and is constantly undergoing changes and transformations, and in the last decade, the Polish automotive industry has recorded a 100% growth measured by sold production. This considerable success makes the automotive industry the second-largest industrial sector in Poland (10.1% share) (Dąbrowski, 2019) for maintained jobs and new investments. There are significant links between the automotive industry and other sectors of the economy related to the maintenance of vehicles, the business sector, road transport, the sale of propellants, or even the broadly understood construction of road infrastructure. Management systems such as WCM, EFQM, Toyota Production System and certified: PN EN ISO 9001, PN EN ISO 14001, PN ISO 45001, ISO/IEC 27001, ISO 28001, IATF 16949 have been used in this industry for years, contributing to better management, greater savings and the development of labor and production standards. Undoubtedly, the knowledge and awareness of employees regarding the use of systems is the main element of implementation and success.

In a manufacturing company, employees are considered a valuable resource against which goals related to the company's strategy are defined. Then the tasks and responsibilities in the process are specified. The role assigned to each employee separately causes each of them to be a clearly defined element of the system. This definition is expressed in defining the required competencies that are necessary for the proper performance of the entrusted tasks. The degree of compliance of the competencies possessed with the desired competencies proves the level of quality of human resources in the enterprise. It can be achieved when an employee is hired or



developed in parallel with the commencement of the employment relationship. Full employee involvement increases the ability to create value for stakeholders. Top management should, through their leadership, create and maintain a shared vision, shared values, and an internal environment where people can fully commit to achieving the organization's goals. These changes result from the understanding that most of the factors that improve work efficiency depend on the social and emotional nature of employees (Lindebaum, Cartwright, 2002; Santarek, Duda, Oleszek, 2020; Zeguo, Jiang, Zhicheng, Xueli, 2023). It can be concluded that the commitment and awareness of employees is, next to professionalism, availability of resources and proper organization of work, one of the basic conditions for high quality activities and, as a result, products (Hamrol, 2017; Hamrol, Mantura, 2005; Minh, Kien, 2021; Oana, Popescu, Gabor, 2023; Garg, Mahajan, Ghosh, 2023; Kelly, Wellington, Pimentel, Almeida, Juventino, 2023). Awareness is a complex concept. It may concern various categories (e.g. ecology, marketing, market, etc.). Attempting to define consciousness, a certain generalization is introduced and it is treated as the knowledge that a person has about his existence, his actions and the external world in given working conditions (Berkowska, Drzewiecka, Mrugalska, 2014; Vuppalapati, Roohi, Kursheed, Dasharath, Reddy, Prasada, 2023). Employees are motivated, dedicated engaged, eager to contribute to problem solving, and take part in improvement activities because they feel responsible for their performance.

The key benefits of employee engagement are:

- motivated and committed employees of the organization,
- innovation and creativity in promoting the company's goals,
- a responsibility of employees for their actions,
- willingness to participate and contribute employees to continuous improvement.

In every enterprise where product manufacturing processes are carried out, it is necessary to design, efficiently implement and maintain a system that should meet all the requirements set for it in terms of production flow control, planning, quality and customer service. Particularly in the automotive industry, management systems are necessary to maintain production continuity and high quality of manufactured products (Kuczyńska-Chałada, Poloczek, 2020).

## **2. Management systems used in the automotive industry**

The number of enterprises included in the automotive industry means that it is treated as the main pillar of the Polish and European economies (Karlikowski, Karlikowska, Plezia, 2010). The automotive industry includes, among others:

- production of motor vehicles,
- manufacture of trailers and semi-trailers, excluding motorcycles,
- production of motor vehicles,
- manufacture of bodies for motor vehicles,
- manufacture of parts and accessories for motor vehicles,
- production of car tires,
- production of car windows,
- production of car batteries.

The implementation of management systems in the automotive industry requires technical, organizational, and mental preparations among employees (Oana, Popescu, Gabor, 2023). Management systems are not only the recording and application of procedures but also demonstrating positive behavior towards the customer and for the quality of the product, which prevail in the company regardless of the functioning system. It is based on knowledge in the field of technology of the selected industry, machine operation, maintenance, metrology, logistics, statistics, human resource management, finance, etc.

Because the issues are so numerous, the entrepreneur, implementing the selected management system, must take the necessary actions to adjust the current state of functioning of individual areas to the desired state. Changes may be required that are not easy or impossible in the realities of a given enterprise. What is important here are the necessary financial resources, technological capabilities, and technical conditions, but also cultural (mentality, habits of employees and management/owners) and qualifications. Table 1 characterizes selected management systems used in the automotive industry.

**Table 1.**

*Characteristics of management systems, including certified ones, used in the automotive industry*

Management system	Characteristic
Toyota Production System	The Toyota Production System is one of the most interesting concepts of production management. This method is a combination of unique Japanese management methods and the characteristic feature of the company is its specific organizational structure, the way of perceiving reality, and conducting business activity. The essence of TPS is based on the proper organization of production and logistics as well as mutually beneficial relations between the company and its suppliers and customers. The overriding objectives of the Toyota Production System are activities such as: providing products and services of the highest quality standards, developing employees' potential through mutual trust and cooperation, and reducing costs by eliminating waste. TPS is one of the most efficient production systems in the world and has been implemented in various forms by many large enterprises. The Toyota Production System is a long-term and never-ending improvement, which is manifested in continuous growth productivity, and production quality. TPS is the foundation of the Lean Manufacturing concept.

Cont. table 1.

<p>WCM system (World Class Manufacturing)</p>	<p>World Class Manufacturing (WCM for short) is an integrated management system. The basic assumptions of WCM are the absence of losses, failures, defects, and accidents. World Class Manufacturing is based on the lean manufacturing philosophy, Total Quality Control, and Total Productive Maintenance concepts as well as the Just in Time philosophy. Just in time assumes the complete elimination of waste of time, energy, materials, and overproduction by providing each production process with the exact number of needed elements at the right time. The main objectives of World Class Manufacturing include maximizing the results of the production system while maintaining quality standards and complying with logistics programs. The aim of WCM is also the development of a production system aimed at improving competitiveness. For success in implementing World Class Manufacturing, it is equally important to meet the assumptions that make up the group of managerial pillars. In the management area, it is considered crucial to develop the involvement of the management board, clearly define goals in the form of KPIs (Key Performance Indicators), create a framework project implementation plan, and define the target level we are aiming for. Next, it is important to allocate the necessary human resources, define deadlines and budget, gain acceptance for changes and commitment of the entire staff, and shape the motivation for continuous improvement.</p> <p>It is worth noting that the implementation of each of the pillars is a multi-stage process. There are 7 steps for each pillar, and the degree of their implementation is assessed during internal and external audits. WCM provides 4 levels of certification - bronze, silver, gold, and world class. Depending on the results of the control audits carried out, the auditors award the appropriate level of certificate. The bronze certificate is dedicated to companies that have already started the process of implementing WCM and this has translated into observable effects. The silver certificate has been provided for plants that have already implemented a complete set of WCM assumptions and function better on this account. The gold certificate is awarded to entities considered exemplary in terms of improving the functioning and innovativeness of solutions. The highest possible award is a world-class certificate confirming the model implementation of the WCM methodology.</p>
<p>Model of Excellence EFQM</p>	<p>The EFQM (European Foundation for Quality Management) Excellence Model is a comprehensive and advanced organizational improvement tool. It covers all the most important areas of the organization's functioning and precisely defines what requirements should be met in these areas. Thanks to this, the Model serves as a comprehensive self-assessment tool and at the same time a model of excellence to be pursued by taking appropriate action in each of the highlighted areas. Self-assessment makes the organization aware of its strengths and allows to identify areas that need to be improved. The EFQM Excellence Model does not impose or suggest ready-made solutions, but allows for many approaches to achieving sustainable excellence in all aspects of the organization's operations. The management approach suggested by the Model is based on the following assumption:</p> <p>Excellent results in terms of business performance, customers, employees and social impact are achieved through leadership that drives policy and strategy formulation, people management, partnership and resource management and processes.</p> <p>The EFQM Excellence Model covers the following business areas:</p> <ul style="list-style-type: none"> <li>- Leadership - how the board and all managers behave and act to inspire and bring about a change in the culture towards a quality mindset;</li> <li>- Policy and Strategy - whether the policy and strategy are formulated, verified, and improved by the EFQM management concept;</li> <li>- Personnel management - how the company unleashes the full potential of its staff;</li> <li>- Resources - how financial, information, material resources, and applied technologies are effectively used to support the implementation of the company's policy and strategy;</li> <li>- Processes - how critical processes are applied and controlled to ensure continuous improvement of the enterprise;</li> <li>- Customer satisfaction - how the customer evaluates the quality of products and services;</li> <li>- Employee satisfaction - how the employee assesses the benefits of employment in the company and their contribution to its development;</li> <li>- Impact on the environment - what are the company's relations with the local community and its impact on the natural environment;</li> <li>- Activity results - to what extent the company achieves its planned goals.</li> </ul>

Cont. table 1.

Norma PN EN ISO 9001	<p>The ISO 9001 standard contains requirements for a quality management system applicable to any organization, regardless of its size and type, which needs to demonstrate the ability to consistently provide products that comply with customer requirements and applicable regulations and strives to increase customer satisfaction (according to ISO 9001, a product is also service).</p> <p>The international ISO 9001 standard is one of the most popular standards, compliance with which is confirmed by external certifications.</p>
PN EN ISO 14001	<p>ISO 14001 contains requirements for an environmental management system, the fulfillment of which can help organizations achieve environmental and economic goals. The basic task of the standard is to support environmental protection and prevent pollution. The standard is intended for all organizations regardless of type and size.</p> <p>The benefits of environmental management system certification are:</p> <ul style="list-style-type: none"> <li>- Positive perception of the company on the market by customers and the public.</li> <li>- Minimizing emergencies in the company by using the best available technical solutions.</li> <li>- Reducing the costs of using the environment.</li> <li>- Better position when undertaking new ventures and raising capital.</li> <li>- Increased competitiveness in the market.</li> </ul>
PN ISO 45001	<p>“Occupational health and safety management systems. Requirements and application guidelines” is a standard issued in March 2018 by the International Organization for Standardization. The standard characterizes the requirements relating to the occupational health and safety management system (i.e. OHS). Its scope includes both a practical approach that translates into the safety of people and the company, as well as guidelines for its use so that it can be continuously monitored and optimized in the area of OHS. Thanks to such activities ensuring safety in the workplace, enterprises increase their competitiveness in the market and improve their image "in the eyes" of employees and customers.</p>
ISO/IEC 27001	<p>The ISO/IEC 27001 standard presents a model of an information security management system and defines the requirements for establishing, implementing, operating, monitoring, reviewing, maintaining and improving the system.</p> <p>Information, which is a valuable resource for every company, has a measurable value and is constantly exposed to many threats. Therefore, ensuring the security of information held should be a priority in managing the organization.</p> <p>Information security management is not only related to the protection of IT systems. It also serves to ensure the security of personal data, commercial information and other information constituting a business secret.</p> <p>Protection against loss of information is also a legal obligation of all entities conducting business activity, for non-compliance with which there are serious criminal sanctions.</p> <p>With the accession to the European Union, many legal acts appeared, among which the Act on the protection of personal data is of particular importance. IT systems and procedures used in the organization should be adapted to its requirements. You should also take all measures to ensure maximum protection of the processed information.</p> <p>Implementation of an information security management system raises employees' awareness, helps in risk management as well as in establishing information security goals and principles.</p>

Cont. table 1.

ISO 28001	<p>The supply chain security management system to identify and manage revealed threats focuses on identifying the risks associated with the physical movement of goods. ISO 28001 provides requirements and guidance for organizations in international supply chains to:</p> <ul style="list-style-type: none"> <li>- develop and implement supply chain security processes;</li> <li>- establish and document a minimum level of security in the supply chain(s) or segment of the supply chain;</li> <li>- assist in meeting the relevant Authorized Economic Operator (AEO) criteria set out in the World Customs Organization's Standards Framework and line with national supply chain security programs.</li> </ul> <p>In addition, ISO 28001 establishes certain documentation requirements that allow for verification.</p> <p>ISO 28001 users will be required to:</p> <ul style="list-style-type: none"> <li>- define the part of the international supply chain where they have established security;</li> <li>- conduct security assessments in this part of the supply chain and develop appropriate countermeasures;</li> <li>- develop and implement a supply chain security plan;</li> <li>- train security personnel in their security duties.</li> </ul>
IATF 16949 – Quality Management System in the automotive industry	<p>The IATF 16949 standard was published on October 1, 2016, and replaced the former ISO / TS 16949 standard. It is an extension of the ISO 9001 standard - apart from its general guidelines, it contains elements related only to the automotive industry. The quality management system according to the IATF 16949 standard applies to such aspects of activity as the design, production, assembly, and service of automotive products.</p> <p>The implementation of the IATF 16949 standard eliminates the need for multiple certifications when dealing with different foreign clients. Unification of international standards in the quality management system of the automotive industry is therefore a very convenient solution in this situation.</p>

Source: Own elaboration based on (Liker, 2005; Monden, 2011; Skojett-Larsen, 2012, ISO 28001:2007. 2007; Grzelakowski, 2011; Kosutic, 2022; Drzewiecka-Dahlke, 2020; Abdoul, 2022; Małysa, 2023; PN-EN ISO 14001:2015; PN-EN ISO 9001:2015; PN-ISO 45001:2018; Furman, Kuczyńska-Chałada, 2019; Piątek, 2022).

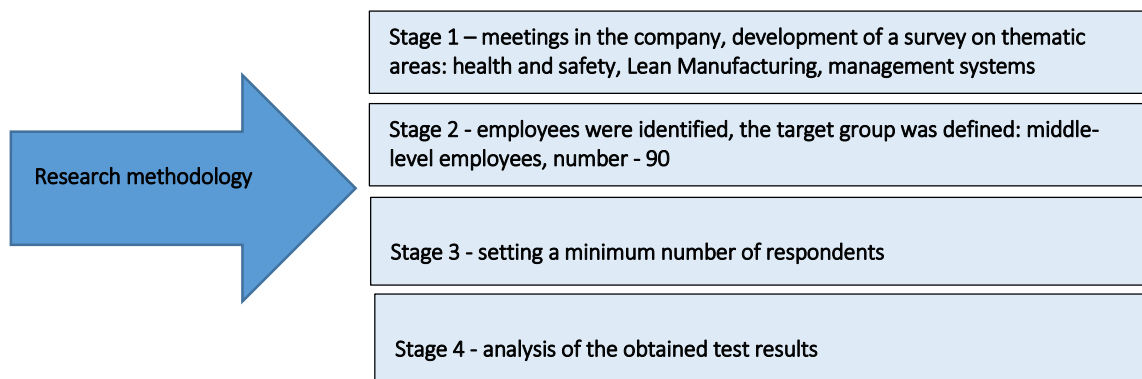
### 3. Metodology

The research on the awareness of automotive industry employees in the field of applied management systems was carried out based on surveys conducted in the first quarter of 2023. The questionnaire contains forty questions, including ten questions related to the management systems used in the company. The research was addressed to 90 middle-level employees employed in the following departments: production (23 employees), logistics and warehouse (18 employees), administration (11 employees), quality assurance (17 employees), production maintenance technology (13 employees), and maintenance (8 employees). The group of respondents consisted of employees aged 41-50 with 16-20 years of work experience. The subject of analysis as part of the work was the area related to the implementation of management systems and the awareness of middle-level employees in this regard. As part of the questionnaire, the issues related to occupational health and safety, the use of Lean Manufacturing concept tools, and applied management systems (first stage) were addressed.

In the second stage of own research, the employees to whom the survey was addressed were identified - the research group consisted of 90 middle-level employees, indicated by the top management of the surveyed company (working in two plants in a two-shift system). Two plants where survey respondents belonging to one company work. The results are analyzed for the company and not for each independent device (according to the management executive substances).

In the third stage, the minimum number of respondents was established. For this purpose, the PQStat statistical analysis tool was used. With the assumptions of the significance level of 0.05 and the estimation error of 0.02, it was estimated that the necessary number of questionnaires should be 87. The assessment of awareness was a subjective assessment based on the analysis of the results of each question individually.

In the fourth stage, the obtained research results were analyzed and areas for potential improvement were indicated. The step-by-step approach is graphically presented in Figure 1.



**Figure 1.** Methodology of own work.

Source: own elaboration.

As part of the survey questionnaire, 10 single- and multiple-choice questions were distinguished from the following research areas:

- awareness of the middle-level staff in the field of management systems used in the audited enterprise,
- awareness of the implemented systems supporting the optimization of all production and production-related processes,
- determination of the type of impact of the implementation of management methods and tools used in the Company that improve OHS,
- determination of the type of impact of the implementation of management methods and tools used in the company that improves the organization of production,
- how employees acquire knowledge and skills in the field of OHS Management Systems and what are the most effective sources of knowledge.

Table 2 lists the survey questions that will be used to assess the awareness of middle-level employees in the field of implementing management systems, which in turn will allow them to take further actions in the field of development for the development of organizational culture in the company.

**Table 2.**

*Survey questions. Number of respondents. Number of responses*

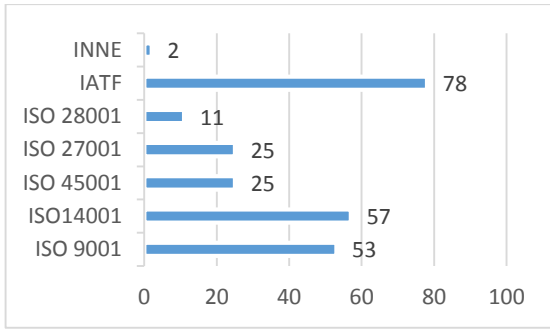
Specification	Number of respondents	Number of responses
What certificates does the company have? (more than one answer possible)	90	89
What systems are implemented in your company to support the optimization of all production and production-related processes? (you can select more than one answer)	90	89
As part of the implemented systems, what tools are used in the daily functioning of the Company? (more than one answer possible)	90	89
How long have you known and used the tools selected above? (choose one answer)	90	89
Which of the listed tools caused the least difficulty in implementing in your company, in your opinion? (more than one answer possible)	90	90
Please specify the type of impact of the implementation of management methods and tools used in your company on the improvement of occupational health and safety. (choose one answer)	90	90
Please specify the type of impact of the implementation of management methods and tools used in your company on the improvement of production organization. (choose one answer)	90	90
How many hours does it take to train a new employee? (choose one answer)	90	90
How do you acquire knowledge and skills in the field of OHS Management Systems? (more than one answer possible)	90	89
Choose three, in your opinion, the most effective sources of knowledge:	90	88

Source: own elaboration.

#### 4. Analysis of survey results - employee awareness survey

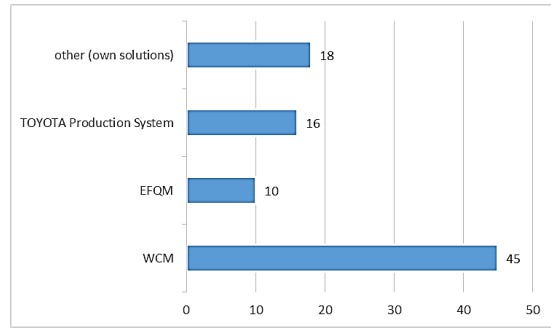
As a result of the analysis, based on the answers given by the respondents regarding the implemented systems supporting the optimization of all production and production-related processes, it can be concluded that the WCM system is the most recognizable among this group of employees (45 respondents answered), followed by the Toyota Production System (16 respondents). Awareness of the IATF standard is the highest (78 responses). In the case of WCM, visibility is related to the fact that awareness is raised every day through the dissemination of visual information in the workplace.

Figure 2a, 2b shows employees' awareness of the company's management systems and certifications.



**Figure 2a.** The results of the survey regarding the awareness of the mid-level staff what certificates the company has.

Source: own elaboration.

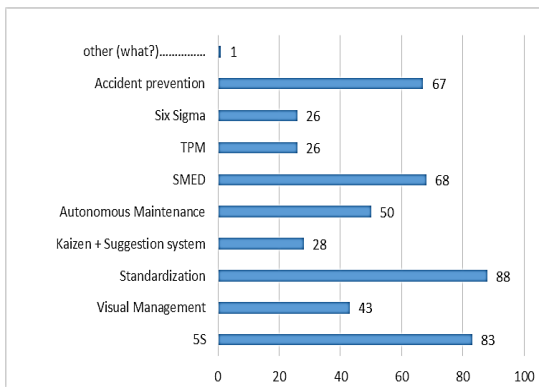


**Figure 2b.** The results of the survey in terms of awareness of the implemented systems supporting the optimization of all production and production-related processes.

Source: own elaboration.

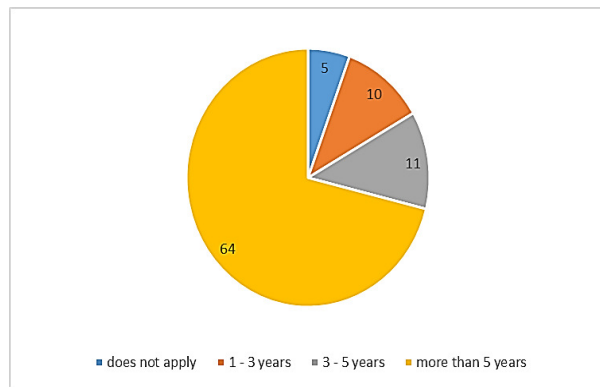
Figures 3a and 3b show the results of surveys in terms of awareness within the implemented management systems, what tools are used in the daily functioning of the company, and awareness of how long selected tools have been used (Six Sigma, TPM, SMED, Kaizen+Suggestion System, Standardization, visual).

The respondents replied that standardization (88) and the 5S method (83) are known and commonly used at work. Perhaps the period in which they are used plays an essential role here. Employees need time to get used to the changes. In this case, the most frequently marked answer in terms of awareness of how long these tools have been used, the employees answered that more than 5 years (65 persons).



**Figure 3a.** The results of the survey in terms of awareness within the implemented systems, what tools are used in the daily functioning of the company.

Source: own elaboration.



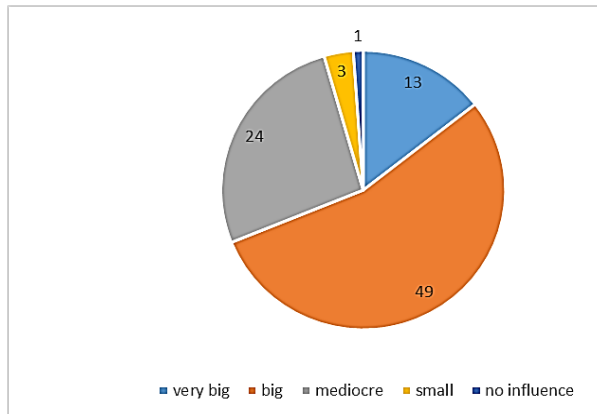
**Figure 3b.** The results of the survey in terms of awareness of how long selected tools are used.

Source: own elaboration.

Middle-level employees, when asked about the use of methods and tools (e.g. Six Sigma, TPM, SMED, Kaizen+Suggestion System, Standardization, visual management) to improve safety in the workplace, see the impact of selected methods and tools of the management system on improving safety. They assessed it as: large (49 respondents), medium (24 respondents), very large (13 respondents). Responses such as little or no impact were chosen by a total of

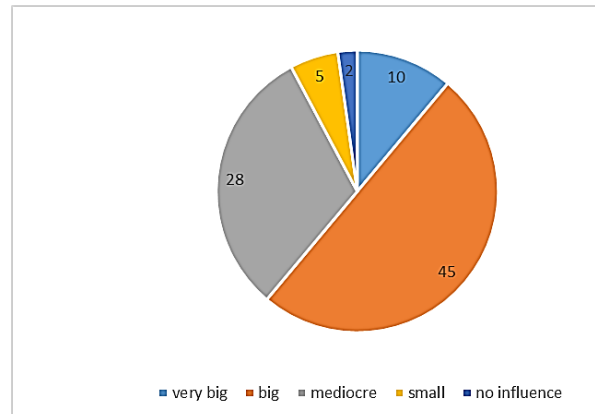


4 respondents (Fig. 4a). Awareness of middle-level employees in the field of health and safety is an essential element in improving working conditions. They have a real impact on improving safety at workstations that are directly under their control. Employees similarly assessed the impact of the tools used on improving the organization of production: 49 respondents decided that it had a large impact on the organization of production, 28 employees had a large impact, 10 medium, 5 small and 2 that it had no impact.



**Figure 4a.** Awareness of middle-level employees regarding the type of impact of the implemented management methods and tools on improving OHS.

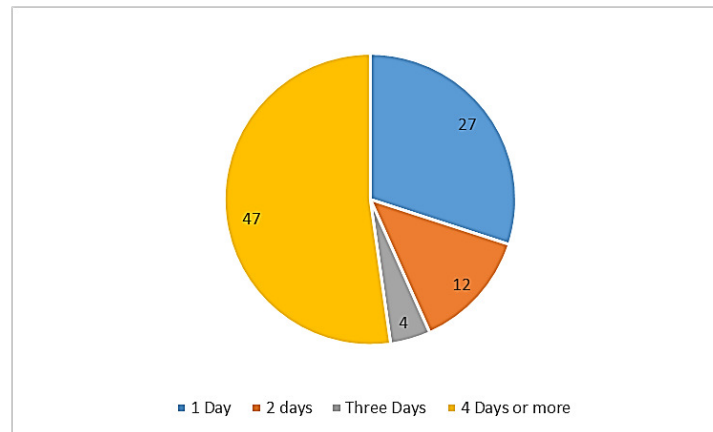
Source: own elaboration.



**Figure 4b.** Awareness of middle-level employees in the field of tools that have the greatest impact on improving the organization of production.

Source: own elaboration.

The time in which employees are trained provides the basis for better, safe and effective work, as well as information on management systems in the enterprise. Introducing changes is also associated with complex reactions of employees, and above all with resistance to the upcoming "new order". Time is needed for this stage to be successful and for everyone to become convinced of the proposals and duties that will improve their work. In each company, the implementation period is determined individually: sometimes it lasts a year, but in other cases it can be, for example, five years. One thing is certain, it must be used primarily for employee training, which will step by step introduce new arrangements, indicate their purpose, outline the perspective of effects. Employees need time to personally believe in the change, to work on new habits, and in the transition phase - to make mistakes. In building the competitive potential of the company using the Lean Manufacturing concept, the priority of the middle-level staff should be primarily to create a system of efficient information about changes, to take care of trainings that transfer specific knowledge and skills, to involve all employees who participate in company processes and to constantly motivate them to development. The results of the survey shown in Figure 5 show that 47 people are aware of how long it takes to train a new employee (4 days), 27 employees answered that one day, 12 employees specified 2 days, and 4 employees 3 days.

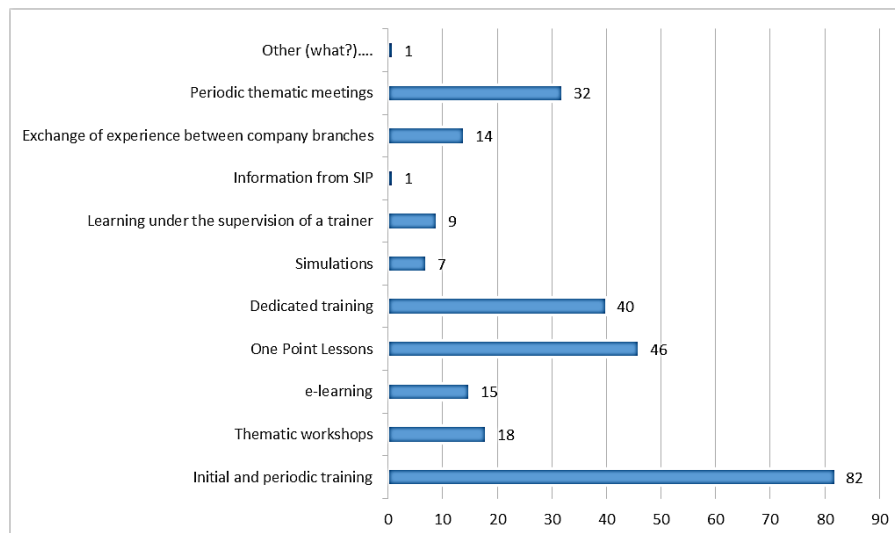


**Figure 5.** The results of a survey on the awareness of mid-level employees regarding the training time of a new employee.

Source: own elaboration.

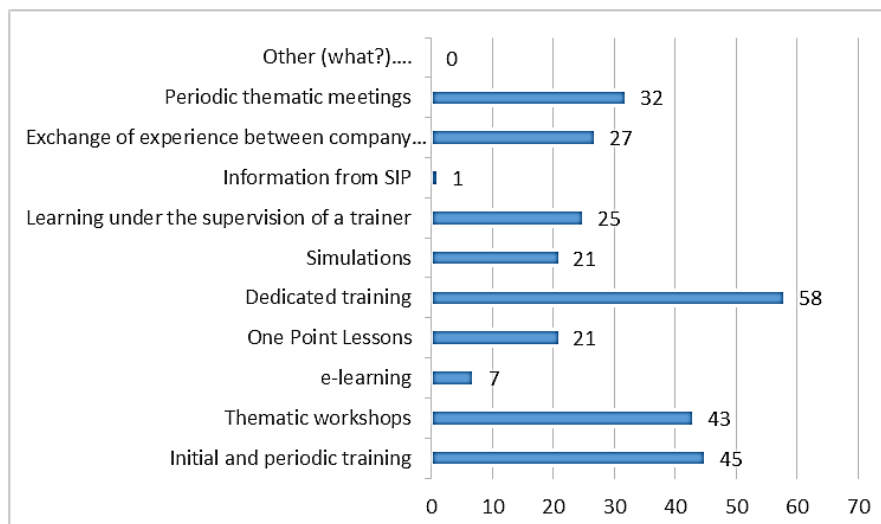
According to the requirements contained in the legal provisions (Section X of the Labor Code), an employee must not be allowed to work for which he does not have the required qualifications or skills, as well as sufficient knowledge of the regulations and principles of occupational health and safety. How to pass on knowledge, in the most effective way and at the same time make the employee aware that compliance with the rules at work is related to his safety and ensures continuity of production. To the question (Figure 6) on how middle-level employees acquire knowledge and skills in the field of OHS Management Systems, the largest number of answers (82) concerned thematic and periodic training, OPL (46), and dedicated training 40.

When asked what, according to middle-level employees, are the most effective sources of knowledge (respondents could indicate more than one answer), they chose: dedicated training (58), thematic and periodic training (45), and thematic training (43). Such a choice depends on the acquisition of specialist knowledge during such training on the use of methods and tools for the functioning of the management system in the enterprise. They are the most valuable to increase employee competencies in this area.



**Figure 6.** The results of the survey on the acquisition of knowledge and skills in the field of OHS Management System.

Source: own elaboration.



**Figure 7.** Survey results - the most effective sources of knowledge.

Source: own elaboration.

## 5. Conclusion

Implementation of management systems is a multi-stage process in a production company and requires careful planning and preparation of all persons involved in it. In the era of increasing competition in production markets, enterprises should continue to strive for perfection, introduce modern management methods and improve the quality and efficiency of production.

The results of the survey research obtained in the work can be considered as a contribution to the statement that the awareness of the mid-level staff regarding the management systems used in the surveyed company, the implemented systems supporting the optimization of all production and production-related processes. Determining the type of impact of the implementation of management methods and tools used in the company affect the improvement of OHS, determine the type of impact of the implementation of management methods and tools used in the company that improves the organization of production, how employees acquire knowledge and skills in the field of OHS Management System and what are the most effective sources of knowledge should be a priority. The answers rated the highest by the respondents, which prove the awareness of middle-level employees in the field of management systems in the company, are:

- obtaining specialist knowledge through dedicated training - 58 respondents answered 58,
- duration of the training - 47 respondents,
- how long selected tools of the management system have been used (Six Sigma, TPM, SMED, Kaizen+Suggestion System, Standardization, visual management) – respondents replied that standardization was 88 and the 5S method - 83 answers,
- the impact of the tools used on improving the organization of production - 49 respondents,
- what systems are implemented to support the optimization of all production and production-related processes - the WCM management system is the most recognizable among this group of employees (45 respondents answered), and the IATF (78 answers).

Making employees at all levels, including the middle level, aware of the importance of training and with what frequency it should take place, as well as the involvement of middle-level employees in the implementation of management systems, has a significant impact on the employees' work efficiency.

The increase in performance assessment can be attributed to their involvement in management systems such as WCM, EFQM, Toyota Production System and certified: PN EN ISO 9001, PN EN ISO 14001, PN ISO 45001, ISO/IEC 27001, ISO 28001, IATF 16949, because process owners have purposeful roles and functions in deployment. They are exposed to a variety of capacity-building activities such as training, thematic workshops, seminars, and focus group discussions that deepen their functional knowledge of these systems. As such, their involvement and awareness play a key role in governance throughout the company.

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## TOOL FOR SELF-ASSESSMENT OF PRODUCTION-ORIENTED ORGANISATION'S ENVIRONMENTAL MATURITY

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**Purpose:** The aim of the research was to build a tool designed to perform a self-assessment of the level of environmental maturity of a production-oriented organisation, which was not previously available. An attempt was made to arrive at an answer to the following question: what competences of an organisation determine a high level of its environmental maturity?

**Design/methodology/approach:** The targets set were achieved by: conducting an analysis of literature on the subject, which was necessary to identify self-assessment criteria, carrying out survey research covering experts and using the resulting self-assessment tool in a given organisation.

**Findings:** Based on the results obtained, it was found that the key competences that determine an organisation's environmental maturity include the ability: to accept responsibility for a product throughout its whole life cycle, to observe circular economy rules or to deploy energy consumption control systems. It was demonstrated that the level of environmental maturity in an organisation can be measured by using the proposed self-assessment tool.

**Research limitations/implications:** The study presents the process of creating a tool for manufacturing organizations. It was conducted in southern Poland in a very narrow telecommunications industry, it is difficult to find other works on the selected topic in this specific market area. As a result of the research, it was also found that the tool should be created adapting it to a specific organization - limited universality. The tool created in this article can only be used to examine the environmental maturity of an enterprise.

**Practical implications:** Examining the environmental maturity of an enterprise gives senior management an opportunity to create a detailed strategy for the development of the organization in a selected area. Additionally, the organization receives an easy-to-use method for self-diagnosis and for comments from lower management staff.

**Social implications:** A company's awareness of its environmental weaknesses allows it to eliminate them from its processes. The environmental maturity diagnosis allows the organization to react "here and now", thanks to which it can eliminate emissions and impact on local communities even before the legal obligation.

**Originality/value:** Based on the literature and their own research, the authors created a new, simple tool for examining environmental maturity.

**Keywords:** organisation's environmental maturity, self-assessment, Industry 4.0.

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

## 1. Introduction

Globalisation, the development of new technologies, emerging crises lead to the great volatility and complexity of environments, and this fact must be accepted by organisations to ensure they are competitive. Contemporary consumers pay attention not only to the quality of a product, but also to the method it is manufactured or the way it affects the environment. This means that the development of an organisation's competences has grown in importance. An organisation's technological transformation requires that a strategy be changed, innovativeness be increased, which allows for generating profits (Węgrzyn, 2009; Marciniak, 2010).

Aware stakeholders expect managers to be socially responsible, e.g. to eliminate the emissions of harmful and noxious compounds. A quality-oriented approach (e.g. the implementation of a quality management system according to the ISO 9001 standard) or taking eco-friendly actions (e.g. the implementation of an environmental management system according to the ISO 14001 standard) was already very common in the last century, which popularised integrated management systems (Węgrzyn, 2007). Nowadays, a decisive factor behind the competitiveness of an organisation is associated with its competences that determine the use of a variety of interactions in cyberspace, cognitive thinking (utilising artificial intelligence). What has gained popularity today is, among other things, a SMART WORLD concept based on the Internet of Things (IoT), which requires an organisation's quality- and ecology-oriented development (Adamik, 2020), enhancing the effectiveness of raw material consumption management in a process, or of the control of emission levels (Polska Cyfrowa, 2020).

A contemporary organisation must pay attention to technological aspects related to the environment, ecology and society. In the global economy, an organisation's competences started to be considered the intangible building blocks of values (Urbanek, 2011). Hence the concept of competences is associated with the maturity of organisations, the level of their orientation towards the excellence of existing solutions (Skrzypek, 2014). Greater and greater importance is being attached to knowledge and other resources that determine the efficiency of an organisation's operations, but also the effectiveness of limiting its negative impact on the natural environment (Jabbour, 2015).

The following hypothesis was formulated in this paper: the level of environmental maturity of an organisation can be measured by performing a self-assessment of existing solutions. The principal aim of the research was to build a tool designed to perform a self-assessment of the level of environmental maturity of a production-oriented organisation. What is of relevance is to arrive at an answer to the following question: what competences of an organisation determine a high level of its environmental maturity? The targets set were achieved by: conducting an analysis of literature on the subject, carrying out survey research covering experts

(scientists involved in the issue being examined) and using the resulting self-assessment tool in a given organisation.

## 2. An overview of the literature

Environmental maturity of an organisation is a component of its quality maturity (Łukasiński, 2015). Due to a dynamically changing and complex environment, an organisation is required to shape the solutions that determine permanent and sustainable development, taking into account the needs of the natural environment and society. This means that organisations are expected to be orientated towards ensuring the solutions that determine the implementation of the cleaner production concept, the development of infrastructure necessary to achieve that, personnel competences (Adamik, 2020). Organisations take various actions with a view to improving the eco-friendliness of their processes, often relying on ecological benchmarking (Chen, 2022). An organisation's eco-friendly approach enables it to increase the level of its maturity, understood as the effectiveness and efficiency in perfecting the competences that determine ecological security, which is achieved by pursuing a sustainable development policy (Łukasiński, 2015). Reaching environmental maturity entails investment in technologies, changing a mindset, making a strategy eco-friendly. Collaboration with stakeholders, including clients' participation in a product designing process, or treating competitors as partners for co-operation, is also of key relevance. Consequently, an organisation can become the best in its class, be the leader, setting trends and defining the norms of environmental policy.

Table 1 shows the areas which, based on the literature review, must be considered vital in the process of an organisation's environmental maturity development.

**Table 1**

*Description of Areas that Determine Organisation's Environmental Maturity*

<b>Specification</b>	<b>Justification</b>
Eco-friendly strategies (an environmental management system, e.g. ISO 14001, EMAS, a Cleaner Production strategy)	It is important that an organisation is orientated towards developing solutions that eliminate emissions, minimising a waste of resources, reducing costs. This can be achieved through monitoring, the control of an organisation's impact on the natural environment (Preisner, Pindór, 2014; Bordun, 2020). The control of raw materials consumption has a bearing on: the optimisation of manufacturing costs, the elimination of inefficiency and ensuring the effective response to deviations from the norm. Bottlenecks need to be identified (Stojadinovic, Majstorovic, Gaška, Śladek, Durakbasa, 2021; Reschke, Gallego-García, 2021; Won, Kim, Park, Eun, 2021; Denkena, Bergmann, Stiehl, 2021; Lawrenz et al., 2021; Martínez-Cámara, Santamaría, Sanz-Adán, Arancón, 2021).

Cont. table 1.

Circular economy – responsibility for a product throughout its whole life cycle	Implementing an LCA enables an organisation to foster its awareness of the consumption of resources. What needs to be considered as early as at the designing stage is the consumption of secondary raw materials and what will happen to a product after it is worn out (Borys, 2015; Biernacki, 2018; Ciechan-Kujawa, Sychta, 2018). Waste which is generated must be managed reasonably, most preferably, when it is processed and used for production (Wengierek, 2014). A socially responsible organisation should be capable of recovering components from worn-out products and managing them properly (Woynarowska, Żukowski, 2012). Using recycles for a process input reduces the amount of waste to be managed (Pietrzyk-Sokulska, 2016; Białasz, 2018).
Energy from alternative sources, using cleaner fuels, saving water and energy	Own energy sources lower costs, reducing an organisation’s detrimental impact on the environment, being a determining factor behind reaching zero emissions by it (Kuziemska, Pieniak-Lendzion, Trębicka, Wieremiej, Klej, 2015; Bieńkowska-Gołasa, 2016). Using biofuels is recommended. It is necessary to change the technology used to propel, e.g. material handling industrial trucks, from LPG to hydrogen or electricity (Fidos, 2017). Controlling the consumption of energy or water makes it possible not only to reduce organisation’s costs, but also results in lower environmental costs (Szczepaniak, 2014).
Competences of leaders and employees – co-operation, minimising the importance of human errors, the ability to imitate perfect solutions	Competent personnel allow for streamlining processes identified in an organisation, are orientated towards designing cleaner processes (Pabian, 2011; Kacak, 2015). Co-operating with universities and research institutes provides an organisation with improved access to knowledge of the subject that is interesting to it, which determines the development of human resources, is conducive to changes in the mindset, encourages creativity (Nazdrowicz, 2017). Nowadays, it is essential to use computer systems that aid process designing and are able to focus employees’ attention on what and how should be done (Podostek, 2022). In practice, there is a variety of useful management concepts, e.g. benchmarking which allows for applying best practices and technologies in an organisation (Jabłoński, Chodyński, Jabłoński, 2005).

Source: Own elaboration based on the literature on the subject shown in the table.

The ecology of production is based, to a large extent, on creating a closed-loop material flow, which requires selecting a proper supplier of components. According to Kuen-Suan Chen et al, this should enhance the quality and availability of products, as well as ensure that modifications, defects or scrapping during the production process occur less frequently. Selecting a proper supplier may reduce the frequency of maintenance of machinery or replacement of components after purchase. This is conducive to the reduction of CO<sub>2</sub> emissions, hence it fits in with the Cleaner Production concept (Chen, 2022). The use of the blockchain technology is rising in importance, e.g. in the management of the national power grid, which is based on distributed renewable energy resources (Juszczuk, Shahzad, 2022). Environmental maturity of an organisation is manifested through its ability to employ innovative, but also cost-effective methods, e.g. for reducing CO<sub>2</sub> emissions at plants. One of them includes an amine flushing method, which is implemented to “flush” gases emitted by a company (Afif, 2022).

### 3. Research methods

This paper attempts to identify criteria for a self-assessment of an organisation's competences that determine its environmental maturity. The aim was to develop a tool for a self-assessment of an organisation's environmental maturity. A self-assessment is a tool used during the evaluation of an organisation's potential and performance, allowing for the identification of its strengths and weaknesses. A self-assessment is useful during the planning, organisation and monitoring of actions aimed at improving and correcting organisational solutions. The following self-assessment functions deserve mentioning: diagnostic (obtaining information about an organisation), verifying (carrying out appraisals of employees, analysing, compiling a report and assessing) or comparative (benchmarking against other entities). Its implementation makes it possible to initiate changes, providing an environment conducive to an organisation's growth (Gabryelczyk, 2016). Table 2 shows what actions determining the accomplishment of the objective were taken.

**Table 2**  
*Actions Performed*

Partial Objective	Description
Literature Analysis	To define the criteria determining the self-assessment of an organisation's environmental maturity
Building a database that contains contact details of scientists involved in the issue being examined	Purposive selection of respondents was used, experts had to have at least a PhD degree and operate in the scientific field related to production and management. 500 people were selected from among employees of Polish universities (searched on university websites) to participate in the study. These people were then asked via e-mail to participate in the study. Ultimately, 60 responses were collected.
Preparing a questionnaire, conducting the research, determining the weights of criteria	Developing a survey questionnaire, sending emails with invitations to take part in the research. The survey was distributed between April and May 2022. Eventually, the survey questionnaire was filled in by 60 experts.
Developing a self-assessment tool	Knowledge gained made it possible to determine the weights of individual criteria. A tool was created, and it could be used by a selected organisation in order to perform a self-assessment.

Source: Own elaboration.

In the 1st stage, a survey questionnaire was prepared for experts-scientists. Based on an extensive literature review, 22 criteria were defined. Experts' task was to select 10 criteria which they believed to be the most important of those defined. Weights for individual criteria were determined, taking into account how many times a given criterion was chosen. The sum of answers was referred to the number of all possible selections. This stage involved 60 scientists (holding at least a PhD degree) from all around Poland.

Once the self-assessment tool was built, it was used in a selected organisation. To this end, after securing consent for the research, management was asked to designate specialists and a link to the self-assessment tool was sent out. In total, 10 persons participated in the research, whose task was to assess the level of environmental maturity of the organisation they worked for, using the criteria determined and a scale ranging from one to five. The meaning of individual maturity levels was communicated to the respondents (Table 3).

**Table 3.**  
*Levels of Organisation's Maturity*

Level 1 Initial Phase	The organisation operates, however, it is not oriented towards the improvement of existing solutions.
Level 2 Orientation Towards Improvement of Existing Solutions Phase	The organisation starts to evaluate the flow of processes and mechanisms that determine its operation. It is willing to assimilate knowledge, nevertheless it lacks competences necessary to use that knowledge. A budget is allocated for investments designed to improve existing solutions.
Level 3 Systemic Approach Phase	The organisation is aware of actions being taken and starts to decide on itself, to adopt a systemic approach to the improvement of existing organisational solutions, investments are made to develop identified processes.
Level 4 Active Maturity Shaping Phase	The organisation knows how to ensure the effectiveness of processes. It is able to self-develop, there are opportunities for carrying out projects ensuring its sustainable development, social responsibility.
Level 5 Excellence Phase	The organisation's competences enable it to become the best in its class, it introduces innovations, develops and helps others.

Source: Own elaboration.

To measure the level of the organisation's environmental maturity, the products of weights and maturity levels for respective criteria were added up.

#### 4. Results of the research

The self-assessment was carried out at an organisation operating in the telecommunications sector, based in the southern part of Poland, with a headcount of more than 250 staff. The self-assessment process involved representatives of the following units: Production Management Team, Production & Supplies Quality Control Team, Production Process Team (three people from each unit) and the Warehouse Management Specialist. The representatives were selected based on their seniority in the organisation and taking into consideration the fact that they managed the organisation (participated), which translated into the level of knowledge about the issues being examined.

The environmental maturity of the organisation being examined was assessed at 2.174. To calculate that score, the products of weights (determined on the basis of the scientists' selection) and marks (an arithmetic mean of 10 answers given by the organisation's representatives for the level of maturity relating to a criterion being examined) received for individual criteria were added up. The score obtained indicates level 2 of maturity, namely the organisation's orientation towards the improvement of existing solutions. This may give cause for concern, however, the willingness to take part in the evaluation of the present state must be seen as the first step of the organisation towards improvement. Detailed information is shown in Table 4.

**Table 4.***Self-Assessment Tool – Level of Environmental Maturity of Organisation Being Examined*

<b>Criteria</b>	<b>mark</b>	<b>weight</b>	<b>score</b>
Responsibility for a product throughout its whole life cycle	2.8	0.08	0.224
Observing circular economy rules	1.7	0.07	0.119
Using energy consumption control systems	1.9	0.07	0.133
Implementing environmental management system, e.g. ISO 14001, EMAS	3.9	0.06	0.234
Developing technologies supporting the reduction of waste, the utilisation of resources	1.6	0.06	0.096
Developing competences of employed staff (e.g. designing eco-friendly products and processes)	2.2	0.06	0.132
Employing the Cleaner Production strategy	2	0.06	0.12
Using “green” energy sources – the ability to generate electricity, e.g. a photovoltaic farm, wind turbines	1.3	0.06	0.078
Optimal utilisation of resources, cost minimisation	2.2	0.06	0.132
Ecological reviews, regular environmental audits at the organisation	3.7	0.05	0.185
Developing the technology that determines the processing of production waste at a plant	1.6	0.05	0.08
Using recycled components for the manufacturing of a product	1.4	0.05	0.07
Organising waste collection, e.g. for electronic waste	2.9	0.04	0.116
Ecological education of local society (e.g. classes at schools)	2.7	0.03	0.081
Ecological benchmarking, co-operation with universities, research institutes	1.9	0.03	0.057
Sewage treatment capacity (e.g. own sewage treatment plant)	1.2	0.03	0.036
Developing ecological initiatives among employees	3	0.03	0.09
Arranging mass transport for employees, promoting the concept of travelling by car together	1.5	0.03	0.045
Using the Industrial Internet of Things technology	1.4	0.03	0.042
Developing human-machine integration systems to eliminate errors, avoid a waste of raw materials	2.3	0.02	0.046
Employing big-data technologies for data processing and analysis	1.5	0.02	0.03
Applying the Blockchain technology (tracking raw materials and a product throughout their life cycle)	1.4	0.02	0.028
<b>Level of environmental maturity</b>			<b>2.174</b>

Source: Own elaboration based on own studies.

The basic indicator for an ecologically mature organisation is responsibility for a product throughout its whole life cycle. According to the experts, that area – as it is now, received a mark of 2.8. This level demonstrates that actions in this regard are being performed, e.g. the identification of the cause of complaint. The information obtained will allow for introducing corrective and preventive measures. Attention is focused on components used for production, e.g. the control of suppliers, using recycled materials, the separation of waste and engaging specialist waste collection companies to collect waste. Responsibility for a product requires that the material loop within a plant be closed. The level of solutions in this regard was assessed at 1.7, which means that waste separation needs to be addressed as a matter of utmost urgency. It is recommended that trainings be provided and instructions for employees be drawn up in order to reduce the percentage of products which have been incorrectly manufactured. The closed loop will make it possible to initiate co-operation with a company having waste processing capacity. Own recycling technologies and the ability to use waste for manufacturing a product were assessed at 1.6 and 1.4. The implementation of such solutions needs to be considered, as preventive measures and waste processing are conducive to the reduction of

a company's emissions. In the future, financial penalties contingent on emission levels might be imposed, hence it is well worth developing own infrastructure. Own waste processing technologies may be the key to success. The current level of solutions in that area was assessed at 1.6. The scarcity of optical fibre processing plants creates an opportunity for the development of waste recycling, which, at the same time, will contribute to closing the waste loop. Waste processing capacity should result in the possibility of making extra profits on the collection of waste from others and processing them for own purposes.

The organisation operates on many foreign markets. Having the ambition of being competitive, it implemented the ISO 14001 environmental management system. According to the respondents, the system works well (a mark of 3.9). Its implementation entails performing an audit and certification. The mark obtained in this regard was 3.7. Its further development based on the existing competences is required. Nowadays, considerable importance is attached to the Cleaner Production Strategy. The mark scored was 2.0, which implies that it is worth taking appropriate actions, especially because the experts considered it the key competence that determines environmental maturity.

Contrary to appearances, controlling the consumption and waste of energy is easy to introduce. In the course of the self-assessment process, the mark of 1.9 was given. The mark of 2.2 for the criterion called optimal utilisation of resources, cost minimisation is also a matter of concern. In the future, it will be necessary, for example, to fit taps and light switches with timers so as to ensure that water or light is turned on only when required. Room ventilation needs also to be standardised (windows must not be opened when air conditioning is switched on). Water consumption can be controlled with sensors fitted on taps and light switches. The capacity of using "green" energy sources in the organisation was assessed merely at 1.3. The company is planning to install photovoltaic panels in the future. In addition, it may decide to erect energy storage systems.

Proper competences of leaders and employees enable the organisation to expand. The level of personnel training stood at 2.2. This means that appropriate professional development paths for employees need to be built. An emphasis laid on ecology may bring notable economic benefits, because by reducing the consumption of resources, without affecting the production capacity, it is possible to cut down production costs and increase the percentage share of a margin. The utilisation of resources can be minimised by choosing proper trainings for employees, drawing up detailed instructions.

The other criteria were regarded by the experts as less significant. The scores achieved are shown in Table 4. The organisation being examined reached level 2 of environmental maturity, meaning that it is only learning the processes and mechanisms based on which it operates. Therefore the organisation is focused on gaining knowledge by employing new specialists, or by relying, for instance, on benchmarking, consulting. What requires attention is the fact that the present state of affairs was evaluated and the future plans of the organisation were not taken into account. The low level of environmental maturity may imply that there are no eco-friendly



solutions that could be applied in the sector in which the organisation operates. A narrow circle of component manufacturers can limit waste treatment opportunities.

## 5. Discussion

The available literature portrays a self-assessment of an organisation as an effective and comprehensive method of self-development (Skrzypek, 2012). Striving to increase the effectiveness of existing organisational solutions is of relevance. An organisation's success is conditional on the ability to perfect the flow of processes, optimise the utilisation of data. The results of P. Sliz's research revealed that the maturity of an organisation operating in the automotive industry is categorised as level 2 (37%) or level 3 (41%) (Śliz, 2016). The organisation examined in this paper is also classified between maturity level 2 and 3. This means that there is clear willingness to implement solutions which are nowadays seen as necessary. Hence the organisation being examined is in the group of approx. 70% of organisations which reached a relatively low maturity level (2 and 3).

An interesting alternative in the form of an assessment of environmental maturity of an organisation operating in the industry based on the level of carbon footprint reduction was presented in the Czech Republic in 2021. After analysing 35 maturity models, authors (Zoubek, Poor, Broum, Basl, Simon, 2021) developed their own tool for environmental maturity assessment. In aggregate, 6 levels (0-5) were defined for the tool, which are expressed as a percentage reduction of carbon footprint. Subsequently, they implemented it in several stages in an organisation being examined. The organisation was assessed by external experts during four meetings. In the course of the study, none of the areas being investigated achieved a level higher than level 2 on the scale proposed by the authors. This means that the plant only partially implemented technical solutions in production processes, which allowed it to reduce a carbon footprint by 30%. A comparison between the organisation being examined and the one evaluated in the Czech Republic demonstrates that both industrial plants are at a similar level of environmental maturity, since there is environmental awareness of the organisation and attempts have been made to improve the situation and reduce the impact (Zoubek, Poor, Broum, Basl, Simon, 2021).

The optical fibre sector, in which the organisation being examined operates, is struggling with the environmental transformation. Research conducted in 2017 in the USA sought to determine a carbon footprint generated by the optical fibre sector, and more precisely, the manufacture of cables. The whole process was reviewed, from the extraction of raw materials, through supplies, to a finished cable product. Next, an attempt was made to carry out an organisation assessment process, with attention being focused on the reduction of a CO<sub>2</sub> footprint over several years. It was found that in aggregate the general carbon footprint

increased slightly, compared to a substantial growth of production volumes. Authors emphasise that OFC should focus on selecting better raw materials and streamline the processes which are based on natural gas, i.e. high temperature processes, such as combustion (Inakollu, Morina, Keefe, 2017).

In its report called “Best Environmental Management Practice in the Telecommunications and ICT Services sector”, the European Commission presents instruments that support organisations operating in the telecommunications sector in carbon footprint reduction. The production plant being examined, which operates in the optical fibre sector, should read that document and choose solutions which are available to it in terms of complexity and implementation costs (Paolo, Pierre, Ioannis, Marco, 2020).

## 6. Conclusions

The environmental maturity level of an organisation improves its competitiveness. Focus must be on gaining knowledge and obtaining financial resources which will be utilised for reducing a carbon footprint an organisation generates. Most organisations will have to address the need for the development of competences that determine an increase in the level of their maturity. The fact that approx. 70% of companies is at a similar level of development should encourage them to take on competitive leadership.

To this end, the research was performed, as a result of which the tool for a self-assessment of environmental maturity was developed, however, the possibility of its configuration to adapt to a sector to be examined requires consideration. The limitation of the study is the need to take into account individual characteristics of an organisation and the market on which it operates. The questionnaire was prepared based on an analysis of literature and an examination of the experts' opinions, which allowed for determining the criteria for a self-assessment of an environmentally mature organisation. The most important of them were deemed to include: responsibility for a product throughout its whole life cycle, observing circular economy rules, or using energy consumption control systems. The hypothesis put forward was proved successfully. It was demonstrated that environmental maturity of an organisation can be measured by performing a self-assessment of existing solutions. It can be claimed that the application of the tool proposed:

- Contributes to determining the level of development of an organisation's competences necessary for reaching a high level of environmental maturity;
- Makes it possible to obtain information ensuring that development activities are undertaken effectively, a strategy being pursued can be updated;
- Is orientated towards creating an organisational structure, implementing organisational solutions that determine the effective execution of a strategy.

It is difficult to find a similar study in the literature. This can be an indication that managers at organisations do not know that method or there are certain limitations which hinder their self-assessment of an organisation's environmental maturity. Perhaps there are problems with the preparation and utilisation of the tool determining the effective evaluation of the present situation. In the future, it will be required to continue the research, in order to prove the possibility of the generalisation of results obtained and the improvement of the tool proposed. Before beginning the development of a self-assessment tool, it is necessary to consider the sector in which an organisation being examined operates and what area of its operations requires an evaluation. This method may be applied also to the evaluation of technical and technological, or economic maturity of an organisation. This creates an opportunity for building a flexible, multidimensional tool, which has a very broad scope of application.

## 7. The contribution of the authors

Wiesław Łukasiński – concept, description of the method, interpretation of results, substantive supervision – 50%.

Wiktor Lis – literature review, conducting research, interpretation of results – 50%.

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## METHOD OF ESTIMATING THE EXPENDITURES REQUIRED TO CARRY OUT THE LIQUIDATION PROCESSES OF A MINING SITE

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**Purpose:** This paper proposes a new method for the initial estimation of expenditures necessary to carry out mine decommissioning processes.

**Design/methodology/approach:** A tool for preliminary estimation of the expenditures necessary to carry out the designed liquidation process was used, based on selected estimated component costs of coal mine liquidation. In designing the method, a certain functional similarity of the analyzed mining plants was assumed.

**Findings:** Estimation of liquidation costs at the preliminary stage of design work is important support for the company designing the mine liquidation process. The method described is based on a statistical evaluation of costs and allows an analysis independent of the scale of the liquidation task. A forecast can be obtained once the costs of at least one of the liquidation component processes have been correctly determined. Adding each additional cost improves the accuracy of the estimation.

**Practical implications:** A key issue for the Polish energy sector is to meet the requirements of the European Green Deal to achieve climate neutrality by 2050. A Just Transition is a process of moving away from coal mining and consumption, considering the needs and concerns of communities living in coal regions. It involves the liquidation of the coal sector in the Polish economy, which, in accordance with the adopted Sectoral Agreement, assumes that the last mine will be closed by 2049. The decommissioning of hard coal mines is a complex and lengthy process, but above all one that requires large economic outlays.

**Originality/value:** A new method of preliminary estimation of mine liquidation costs has been proposed. The proposed method can be used as a tool in the possible processes of designing the liquidation of other mines or parts of mines. The proposed method is a useful auxiliary tool in engineering work and preliminary design work for the restructuring of post-mining assets.

**Keywords:** cost management, restructuring of mining companies, liquidation of a hard coal mine, decision-making, multi-criteria analysis.

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

## 1. Introduction

Spółka Restrukturyzacji Kopalń S.A. (SRK S.A., Mines Restructuring Company) is a mining company referred to in Article 8(1) of the Act of 7 September 2007 on the functioning of the coal mining industry (Polish Journal of Laws 2018, item 1374, as amended). The Company's core business is to conduct mine liquidation, protect neighboring mines from water, gas and fire hazards, effectively develop, rehabilitate and revitalize the acquired post-mining areas, protect cultural and industrial heritage sites from destruction, restructure employment through the creation of new jobs and care for the environment.

In line with market conditions, the hard coal mining industry is carrying out restructuring activities (Bluszcz, Smoliło, 2021; Dragan, Zdyrko, 2023; Krzemień et al., 2023; Prusek, Turek, 2018; Urych et al., 2021). As a result of the European Union's policy to achieve climate neutrality, member states must prepare to withdraw from burning fossil fuels, including coal (Kozioł, Kozioł, 2019; Midor et al., 2021; Riesgo Fernández et al., 2020; Salom, Kivinen, 2020; Tokarski et al., 2021). For the mining industry, the transition is a complex and lengthy process. Despite this, little space in the literature related to the industry is devoted to issues related to mine liquidation and decommissioning activities (Biały, Midor, 2021; Biały et al., 2020; Bluszcz, Smoliło, 2021; Bluszcz, Manowska, 2021). Restructuring, revitalization or decommissioning activities of the mining sector in Poland are spread over many years and result from the policy of the European Union. The European Green Deal document is a kind of road map for the transformation of the European Union towards achieving climate neutrality by 2050 (Prakash et al., 2022; Schotten et al., 2023; Smith, Underwood, 2000). One form of restructuring the mining industry is the closure of permanently unprofitable mines. Mine closure is the final, natural and inevitable stage of mining operations. Rational disbursement of funds for the effective management of post-mining areas has not been the subject of any comprehensive scientific research to date (Badakhshan et al., 2023; Chmiela, Smoliło, 2023; Turek, Lubosik, 2008). The available studies in this area are few and cover only selected issues (Biały, Cymler, 2015; Fernandez et al., 2020; Gajdzik et al., 2022; Shavarskyi, et al., 2000; Wrona, 2017).

Due to the large scope of work required, the mine liquidation is complex and costly undertaking. One of the reasons limiting improvements in decommissioning efficiency is the lack of instruments and tools to support cost management (Chmiela, Smoliło, 2023; Kaczmarek, et al., 2022; Kaczmarek, 2022; Kustra, Sierpińska, 2013; Różański, 2018a; 2018b; Segeth-Boniecka, 2017). This work presents a method for estimating liquidation costs based on a volume analysis of selected sub-costs.

The task of decommissioning a mine is a lengthy process, difficult to implement and requiring significant support from the state budget. This is due to the large volume of work required to be carried out during the task. Estimating the expenditures required to abandon

a mine is a lengthy process due to the complexity of the processes involved in abandoning a coal mine. The traditional methods of valuing a business are the income method, the comparative method, and the asset method. In the case of the income method, the valuation of a company boils down to an analysis of the company's development potential and the potential to generate future income. It is possible to use the discounted cash flow method or the free cash flow method. In the case of the comparative method, the method of stock market multiples and comparable transactions is used. In other words, the value of the company is estimated based on the value of comparable companies. The last method is the asset method, which uses the adjusted net asset method or the liquidation method. The expenditure required to carry out liquidation varies greatly; for example, the cost of liquidating the largest mines is several tens of times higher than the cost of decommissioning the smallest mines. Each case of mine liquidation is an individual case, but important regularities can be distinguished (Smith, 2000; Smoliło et al., 2021a; 2021b; Smoliło, Chmiela, 2021). The aim of this research was to develop and propose a tool for preliminary estimation of the expenditures necessary to carry out the designed liquidation process based on selected estimated component costs of mine liquidation. In designing the method, a certain functional similarity of the analyzed mining plants was assumed. It was assumed that each of the analyzed mines has a similar set of facilities, differing only in scale (Panahi Borujeni, Gitinavard, 2021).

## 2. Materials and methods

The research plan was carried out based on the analysis of programs and plans for the liquidating of coal mines carried out by the company from 2015 to 2023. After analyzing the available literature and collecting the documentation discussed, a statistical method for estimating the final cost of mine liquidation was proposed. The intention of the method was to statistically estimate mine decommissioning costs based on knowledge of selected component costs. Finally, a survey of experts (liquidation planners and liquidation managers) carried out at the end of the study allowed the validity of the estimation carried out according to the proposed method to be verified.

The research began with an analysis of the literature thematically related to the restructuring of industrial sites and facilities. Unfortunately, the literature in this area is extremely scarce. The analysis of the literature showed that in the design of future liquidation processes, it is possible to approximate the magnitude of the expenditures for the individual component processes and the total cost by knowing the costs of the selected component process(es) possible to determine already at the initial stage of the design work for a new mine liquidation task.

The next stage of the research was to determine the costs, knowledge of which would allow the most accurate estimation of the remaining component costs and the total cost. The correctness of the proposed assessment tool was verified by comparing the estimated costs for the actual mine liquidation processes carried out with the actual costs. The research was concluded by conducting a survey of the Company's engineering and technical staff involved in practice in the processes of liquidating and management of post-mining assets. The research verified an unconventional statistical method for preliminary cost assessment. The survey research made it possible to propose potential innovative measures for reducing the capital intensity of liquidation and post-liquidation processes carried out by the Company. Consultations in the form of face-to-face interviews with experts in charge of liquidating processes, confirmed the validity of the results and allowed the causes of more significant deviations from expected values to be clarified.

### 3. Results and discussion

#### 3.1. The method for the preliminary assessment of mine liquidation time and costs

Mine liquidation processes are broad concepts so it would be difficult to treat them as just one process. According to the principles of process management (Chmiela et al., 2022; Chmiela, 2022; Noor Salim, Prasetia, 2022) and the practice at the company, mine liquidation processes are divided into 10 smaller sub-processes. Each of the processes shown in Table 1 includes its characteristic operations and activities.

**Table 1.**

*Mine liquidation processes at SRK S.A.*

1.	Decommissioning and securing mine workings
2.	Decommissioning and securing fore-shafts and shafts
3.	Protecting neighboring mines from water, gas and fire hazards
4.	Liquidation of mine infrastructure
5.	Land reclamation
6.	Maintenance of facilities to be decommissioned in order to ensure safe liquidation of a mining site
7.	Carrying out safety work and risk prevention measures in connection with a decommissioned mining site
8.	Preparation of required projects, documentation, opinions, expertise and analyses related to mine liquidation
9.	Repair of damage caused by the motion of a mining plant
10.	General management of the tasks performed during mine liquidation

Processes nos. 1, 2, 4, 6, 7, and 10 are carried out in every mine liquidation case. The conduct of the remaining processes (nos. 3, 5 and 9) is optional and results from the specifics of the liquidation task being carried out. Mine liquidation usually follows one of two options. These options are related to the construction of the target mine model. Due to the protection of neighboring mines, the mine can be decommissioned in its entirety or with the

pumping station remaining. The liquidation process is slightly different in each of these cases (Smoliło et al., 2023).

In the case of mine liquidating without leaving the mine wastewater pumping stations, the liquidation process ends with the transfer of the assets remaining after decommissioning to the Coal Mines in Full Liquidation or to a possible end user. The entire underground infrastructure (workings and shafts) is decommissioned. In this model, the process of decommissioning the workings (Process no. 1), and if the process of securing the neighboring mines (Process no. 3) is also carried out, must end before the process of decommissioning the last two shafts under Process no 2 begins (Pach et al., 2018). If a land reclamation process (Process no. 5) is to be carried out, it can only start after the processes of the liquidation of the mine infrastructure (Process no. 4) and maintaining the facilities to be liquidated (Process no. 6) have been completed. The remaining processes (Processes nos 7, 8, 9 and 10) are carried out throughout the entire mine liquidating period. If there is a need to conduct Process no 9 then this is also conducted throughout the mine decommissioning task.

In the case of liquidation with the pumping station remaining, the liquidation process ends with the transfer of the assets remaining after liquidation to the Coal Mines in Full Liquidation, and the prepared pumping station to the Central Mine Dewatering Plant. The entire underground infrastructure is being decommissioned, with the exception of the necessary shafts and workings being converted to a pumping station (Bondaruk et al., 2015; Chmielewska et al., 2020; Łabaj et al., 2020; Wysocka et al., 2019). In this case, the process of securing the neighboring mines is carried out (Process no. 3) and must continue until the end of mine liquidation. The timing of the start of this process is determined by the mine liquidation schedule (it does not have to start as soon as the liquidation process starts). The decommissioning of the shafts to be liquidated (Process no. 2) can proceed independently of the decommissioning of the workings (Process no. 1), the decommissioning of which can be carried out with the shafts remaining to service the pumping stations even until the end of the mine liquidation processes. As in the first case, if it is necessary to carry out the land reclamation process (Process no. 5), this process can only start after the processes of the liquidation of the mine infrastructure (Process no. 4) and maintenance of the facilities to be decommissioned (Process no. 6) have been completed, while Processes nos. 7, 8, 9 and 10 are carried out throughout the entire mine decommissioning period. The process no 9 is optional and if it is carried out it is done throughout the mine decommissioning period (Łupieżowiec et al., 2022; Mhlongo, Amponsah-Dacosta, 2016; Mhlongo, 2023; Rubio et al., 2019).

To increase the consistency of the component structure of liquidation costs, it was proposed to divide liquidated mines into 5 groups. To determine the reference groups, the analysis of the variation structure of the component process costs was analyzed using the coefficient of variation (Chmiela et al., 2022). The mines were divided into Very Large Mines (VLM), Large Mines (LM), Medium Mines (MM), Small Mines (SM) and a group of Very Small Mines (VSM) (Smolilo et al., 2021; Smoliło, Chmiela, 2021a; 2021b).

A tool has been prepared for the proposed method. The design interface of the tool is presented in Fig. 1. The interface contains fields with a white background. These fields are descriptive fields excluded from editing. The fields highlighted in yellow are the input fields, i.e. the estimated values of the components of the liquidation processes and the decision field, where the approximate size of the mine to be decommissioned should be determined. In the field highlighted in light blue, the method provides the suggested reference group most likely to the amount of the liquidation task component cost(s) entered. The boxes highlighted in grey are the resulting boxes, where the method gives the estimated size of the component costs of the liquidation process. In the same column, the last line in dark red gives the estimated total value of the liquidation process of the mine under analysis.

	Thousand PLN	assessed cost mln PLN
Process 1 (decommissioning of workings)		0,000
Process 2 (decommissioning of shafts)		0,000
Process 3 (securing neighboring mines)		0,000
Process 4 (liquidation of mine infrastructure)		0,000
Process 5 (land reclamation)		0,000
Process 6 (maintenance of decommissioned facilities)		0,000
Process 7 (safety work and risk prevention measures)		0,000
Process 8 (projects, expert opinions, etc.)		0,000
Process 9 (mining damage)		0,000
Process 10 (general management)		0,000
	<b>Total cost</b>	<b>0,000</b>

**Figure 1.** Interface model of a tool for estimating the expenditures required to carry out the liquidation processes of a mining site.

In the method, the user enters between one and nine estimated component costs of liquidation processes into the calculations. It has been assumed that the entered costs will be given in thousands of PLN and the estimated costs will be presented in millions of PLN. To the entered value of the component cost, the method assigns the same entered value in the result field, which remains unchanged in further calculations. The user can enter from 1 to 9 known component process costs out of a possible 10. While it is technically possible to enter ten component costs, such a case does not lead to a cost forecast. On the basis of the entry of each value, the method statistically estimates the size of the remaining component liquidation costs beyond those already entered. The average value of the estimated values is reported as the result. In the last line, the value of the total mine liquidation cost, which is the sum of the entered costs and the averaged estimated values of the remaining component costs, is given in dark red. The introduction of each successive component process value increases the accuracy of the estimation of the remaining component costs and the total cost.

The proposed method, on the basis of the entered values, statistically determines the most probable membership of the analyzed mine to one of the reference groups. After the first value is entered, a probable reference group is determined using single-criteria analysis for the analyzed size of the liquidation cost component. The introduction of the next or subsequent liquidation cost component values results in the determination of the membership of one of the reference groups already being carried out by multi-criteria analysis (Aleskerov et al., 2003; Chmiela, 2023; Chmiela et al., 2023; Smolilo, Chmiela, 2021). This increases the correctness of the assignment of the liquidation task to the correct reference group. The user's identification of the correct reference group helps to ensure correct cost estimation. Each of the reference groups, due to the different scope of activities carried out, has a slightly different cost structure. The user may disagree with the result of the reference group estimation and ask for the calculation of what he/she believes to be the correct scope of the liquidation process as defined by another reference group (Stankevich, 2017).

### **3.2. Verification of the proposed method and discussion**

The verification of the method took place in three phases. In the first phase, all 19 mines analyzed were examined for compliance of the calculated results with the values obtained in liquidation practice. As there is only one example of a liquidation carried out in the group of very small mines (VSM), which is also the benchmark, 100% conformity of the forecast with reality was achieved for this mine. To ensure that this example did not distort the verification with too perfect results, it was considered that it should not be taken into account in further analyses. The verification of the method in the first stage consisted of entering one of the component processes into the analysis and each time preparing a forecast of the amount of the remaining costs of the component processes and the total cost. A full study was carried out for the remaining 18 examples of the processes of the completed and decommissioned mining plant. For each forecast, a comparison with the actual results was prepared. In two cases out of 18, results differing from reality were obtained. The analysis of the documentation (liquidation plans and programs), the statistical evaluation and the interviews with the experts (persons in charge of the liquidation processes) indicated that these 2 cases were cases that were not in line with the other examples. According to the experts, their non-conformity was due to the specificity of the decommissioning processes carried out due to the atypical scope of the activities carried out. In the case of other mining sites, the inconsistencies obtained were due to the atypical nature of the liquidation component process itself. Good cost estimation results were associated with the component processes that were carried out in all cases analyzed, and the best for those representing the largest percentage of the total cost (processes 6, 7 and 10). Estimation on the basis of processes that can only occur during mine liquidation (optional processes 3, 5 and 9) gave the largest discrepancies with reality, and in some cases it was not possible to prepare a forecast. This occurred, for example, when the entered value of the process liquidation cost was equal to "0". After excluding these cases from the verification of the

method, according to the experts, the results of estimating the component and total liquidation costs based on a single value were satisfactory.

In all cases of cost projections, the actual value was subtracted from the estimated value and the deviation expressed as a percentage was calculated from the resulting difference. For the deviations, the median for the whole group of mines and the median for the reference group were determined. In Tables 2 and 3, analyzing the median deviation from the actual value, values not exceeding 20% are highlighted in yellow. Table 2 shows the results of the liquidation cost estimation derived from the analysis of the process no. 10. The process no.10 is one of the processes that estimates liquidation costs well. In contrast, Table 3 shows the estimation based on process 3, which is one of the processes optionally carried out in decommissioned mines and therefore its use as a benchmark gives poorer estimation results.

**Table 2.**

*Median deviations of estimated liquidation costs from actual value when estimating based on process no. 10*

	TOTAL	VLM	LM	MM	SM
Process 1 (decommissioning of workings)	-67%	-8%	-36%	-66%	-75%
Process 2 (decommissioning of shafts)	-44%	-53%	-263%	3%	2%
Process 3 (securing neighboring mines)	0%	-102%	59%	70%	0%
Process 4 (liquidation of mine infrastructure)	-8%	17%	-11%	-52%	12%
Process 5 (land reclamation)	0%	-254%	21%	70%	0%
Process 6 (maintenance of decommissioned facilities)	10%	-39%	12%	18%	-12%
Process 7 (safety work and risk prevention measures)	-16%	-7%	-57%	-9%	-5%
Process 8 (projects, expert opinions, etc.)	3%	3%	5%	2%	7%
Process 9 (mining damage)	4%	-2%	-11%	-212%	29%
Process 10 (general management)	0%	0%	0%	0%	0%
<b>Total cost</b>	<b>-5%</b>	<b>-13%</b>	<b>-3%</b>	<b>-1%</b>	<b>9%</b>

The method rather slightly overestimates liquidation costs. In most of the reference groups, the median deviation does not exceed 30% "up" and "down". The best estimation was obtained for the analysis of all mines as one group and for the group of small mines (SM).

**Table 3.**

*Median deviations of estimated liquidation costs from actual value when estimating based on process no. 3*

	TOTAL	VLM	LM	MM	SM
Process 1 (decommissioning of workings)	-94%	-94%	-283%	-30%	-61%
Process 2 (decommissioning of shafts)	-46%	39%	-403%	-106%	-4%
Process 3 (securing neighboring mines)	0%	0%	0%	0%	0%
Process 4 (liquidation of mine infrastructure)	-30%	4%	-63%	-52%	-7%
Process 5 (land reclamation)	0%	4%	-33%	0%	0%
Process 6 (maintenance of decommissioned facilities)	-17%	38%	-17%	-173%	-26%
Process 7 (safety work and risk prevention measures)	-68%	-89%	-80%	-229%	7%
Process 8 (projects, expert opinions, etc.)	-67%	-82%	-85%	-67%	2%
Process 9 (mining damage)	-8%	-47%	12%	-143%	27%
Process 10 (general management)	-25%	-15%	-64%	-23%	-11%
<b>Total cost</b>	<b>-15%</b>	<b>-14%</b>	<b>-21%</b>	<b>-20%</b>	<b>-2%</b>



In the second verification phase, a similar analysis was already carried out for two component processes. As expected, adding another component process to the analysis improved its accuracy. The unpublished part of the study shows that each time an additional data in the form of the cost of another component process was added, the accuracy of the estimation improved. According to the preliminary results of the analysis from the first stage of verification, the best results were obtained for the component cost pairs accounting for the largest part of the total cost and also conducted in all cases of liquidation. The best estimation results were obtained for the combined analysis of process 6 and 7 (Table 4).

**Table 4.**

*Median deviations of estimated liquidation costs from actual value when estimating based on processes nos 6 and 7*

	<b>TOTAL</b>	<b>VLM</b>	<b>LM</b>	<b>MM</b>	<b>SM</b>
Process 1 (decommissioning of workings)	-37%	17%	-76%	-24%	-28%
Process 2 (decommissioning of shafts)	-11%	-17%	-217%	28%	2%
Process 3 (securing neighboring mines)	0%	-62%	66%	68%	0%
Process 4 (liquidation of mine infrastructure)	2%	1%	7%	-13%	-31%
Process 5 (land reclamation)	0%	-172%	34%	68%	0%
Process 6 (maintenance of decommissioned facilities)	0%	0%	0%	0%	0%
Process 7 (safety work and risk prevention measures)	0%	0%	0%	0%	0%
Process 8 (projects, expert opinions, etc.)	0%	-8%	11%	-30%	0%
Process 9 (mining damage)	-33%	-13%	-18%	-133%	7%
Process 10 (general management)	1%	-11%	9%	-6%	-20%
<b>Total cost</b>	<b>3%</b>	<b>2%</b>	<b>7%</b>	<b>-6%</b>	<b>1%</b>

Also as expected, the worst liquidation cost estimation results were obtained for the component processes which were optionally carried out during decommissioning. Table 5 shows the decommissioning cost projection based on component process nos 3 and 5. Due to the lack of input data, for small mines (SM) the method was not able to determine the total cost for some of the mines, as indicated in Table 5. According to the experts, the accuracy obtained was again considered sufficient for this stage of potential design work.

**Table 5.**

*Median deviations of estimated liquidation costs from actual value when estimating based on process nos 3 and 5*

	<b>TOTAL</b>	<b>VLM</b>	<b>LM</b>	<b>MM</b>	<b>SM</b>
Process 1 (decommissioning of workings)	-71%	0%	-363%	-30%	-61%
Process 2 (decommissioning of shafts)	-45%	-59%	-164%	-106%	-4%
Process 3 (securing neighboring mines)	0%	0%	0%	0%	0%
Process 4 (liquidation of mine infrastructure)	-47%	-148%	-41%	-52%	-7%
Process 5 (land reclamation)	0%	0%	0%	0%	0%
Process 6 (maintenance of decommissioned facilities)	-63%	-61%	-81%	-173%	-26%
Process 7 (safety work and risk prevention measures)	-26%	3%	-89%	-229%	7%
Process 8 (projects, expert opinions, etc.)	-44%	-42%	-57%	-67%	2%
Process 9 (mining damage)	-31%	-49%	-31%	-143%	27%
Process 10 (general management)	-36%	-46%	-52%	-23%	-11%
<b>Total cost</b>	<b>-63%</b>	<b>-21%</b>	<b>-63%</b>	<b>-236%</b>	

In the third verification step, a hypothetical example of mine liquidation was analyzed. The average value of the liquidation costs for all analyzed examples carried out since 2015 and ongoing mine liquidation processes was used as comparative data. The projection was based on the two largest liquidation component processes (process nos 6 and 7) assigning the analyzed mine consecutively to all reference groups. Tables 6 and 7 show selected estimates for the different reference groups.

**Table 6.**

*Forecast of the amount of liquidation costs based on process 6 and 7 for the group of medium-sized mines (MM)*

	Thousand PLN	assessed cost, mln PLN
Process 1 (decommissioning of workings)		5,790
Process 2 (decommissioning of shafts)		20,951
Process 3 (securing neighboring mines)		25,876
Process 4 (liquidation of mine infrastructure)		20,641
Process 5 (land reclamation)		15,497
Process 6 (maintenance of decommissioned facilities)	83,618.73	83,619
Process 7 (safety work and risk prevention measures)	159,110.92	159,111
Process 8 (projects, expert opinions, etc.)		2,990
Process 9 (mining damage)		24,648
Process 10 (general management)		63,432
<b>Total cost</b>		<b>422,553</b>

Despite using the same values of processes nos 6 and 7, a difference in the amount of estimated costs is observed in Tables 6 and 7. The difference of more than PLN 100 million between the projected costs is due to the fact that in the case of medium-sized mines (MM), the assumed cost values of processes nos. 6 and 7, which are too high for the reality of this reference group, correspond to much higher costs of the component processes and, at the same time, to the total cost.

**Table 7.**

*Forecast of the amount of liquidation costs based on process 6 and 7 for the medium-sized (MM) group of mines*

	Thousand PLN	assessed cost, mln PLN
Process 1 (decommissioning of workings)		2,583
Process 2 (decommissioning of shafts)		21,277
Process 3 (securing neighboring mines)		0,627
Process 4 (liquidation of mine infrastructure)		20,507
Process 5 (land reclamation)		11,630
Process 6 (maintenance of decommissioned facilities)	83,618.73	83,619
Process 7 (safety work and risk prevention measures)	159,110.92	159,111
Process 8 (projects, expert opinions, etc.)		4,970
Process 9 (mining damage)		105,914
Process 10 (general management)		112,375
<b>Total cost</b>		<b>522,613</b>

As in the second stage, the percentage deviation from the baseline value was calculated. Table 8 shows the deviation of the estimated liquidation costs from the baseline calculated after the analyzed hypothetical mine was classified successively into all reference groups. The forecast was most accurate for large mines (LM) and very large mines (VLM), and worst for small mines (SM) and very small mines (VSM). The forecast for the smallest mines was particularly unfavorable. This was due to the overly high value of the introduced process costs 6 and 7 and, according to their amount, the method estimated results corresponding to other larger reference groups. The most favorable results were obtained for the group of large mines (LM), which was consistent with the mine size suggested by the method (see Table 6). In this case, deviations from the baseline value did not exceed 30%.

The method best estimated the total decommissioning cost and the costs of carrying out processes 2, 4, 5 and 8 especially for the groups of medium (MM), large (LM) and very large (VLM) mines.

**Table 8.**

*Deviation of estimated liquidation costs from the mean value when estimating based on process 6 and 7 for different reference groups*

	VLM	LM	MM	SM	VSM
Process 1 (decommissioning of workings)	-33%	2%	56%	-1%	98%
Process 2 (decommissioning of shafts)	13%	-1%	-3%	-160%	74%
Process 3 (securing neighboring mines)	-88%	24%	98%	100%	100%
Process 4 (liquidation of mine infrastructure)	-23%	11%	11%	-66%	95%
Process 5 (land reclamation)	2%	-26%	6%	100%	100%
Process 6 (maintenance of decommissioned facilities)	0%	0%	0%	0%	0%
Process 7 (safety work and risk prevention measures)	0%	0%	0%	0%	0%
Process 8 (projects, expert opinions, etc.)	-24%	23%	-28%	-79%	54%
Process 9 (mining damage)	-5%	28%	-209%	25%	100%
Process 10 (general management)	-1%	11%	-58%	-96%	92%
<b>Total cost</b>	<b>-8%</b>	<b>6%</b>	<b>-17%</b>	<b>-15%</b>	<b>43%</b>

A hypothetical example of mine liquidation was presented for evaluation to persons in charge of SRK S.A. branches. The interviewed experts (persons managing the liquidation processes), in a face-to-face interview, confirmed the compatibility of the results with past practice. The experts confirmed the correctness of the method with the accompanying software.

The method performs best in estimating the total cost and the liquidation cost components (process 6, 7 and 10). These are the processes most influencing the total cost, and their sum is about 70% of the total cost. By correctly estimating the total cost and the cost of these largest component processes, the estimated results are close to the real ones. The difference between the projected cost and the real amount of processes 1, 2, 3, 4, 5, 8 and 9 expressed as a percentage appears to be large. However, it should be borne in mind that their total impact on the total cost is small and amounts to only about 20%. In view of this, the differences expressed in PLN will not be so high and, according to experts, such a small discrepancy, when the large components are correctly estimated, ensures correct coverage of expenditures for the entire mine liquidation process.

## 4. Conclusions

The method described is based on a statistical evaluation of costs and allows an analysis independent of the scale of the liquidation task. A forecast can be obtained once the costs of at least one of the liquidation component processes have been correctly determined. Adding each additional cost improves the accuracy of the estimation.

It has been established that, for the validity of the estimation, relying on the costs of optionally conducted processes should be avoided. Their analysis can sometimes lead to an indeterminate situation, which can make the estimation impossible. Relying the estimate on the processes carried out in each case of the liquidation of a mine site, usually leads to satisfactory results of the forecast carried out.

The method performs best in estimating the large components of the liquidation costs (processes nos 6, 7 and 10) and the total liquidation cost. The correct estimation of these large components, even with significant variations for the other small components, ensures adequate inputs for the correctness of the overall mine liquidation process.

The method proposed for the preliminary assessment of mine liquidation costs can be used as a tool in the eventual processes of designing the liquidation of further mines or parts of mines. With some modification and adaptation, the method can be applied by any company dealing in the liquidation of mines.

An unresolved problem is the estimation of liquidation costs, taking into account cases of abnormalities in the main mine liquidation processes. There applies only the unstructured knowledge of practitioners.

The proposed method requires further research, but already in its present form it can be a very useful auxiliary tool in engineering work and in preliminary design work for the restructuring of post-mining assets.

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## SAFETY OF MACHINERY REGARDING THE REQUIREMENTS OF THE REGULATION 2023/1230/EU

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**Purpose:** The purpose of the study is to present the changes resulting from the publication of Regulation 2023/1230/EU in the field of essential requirements for machinery.

**Design/methodology/approach:** As part of the conducted analyses, the changes resulting from the publication of the new Machinery Regulation 2023/1230/EU were summarized and the manufacturers' obligations regarding the conformity assessment process were summarized, as well as the possibilities of supporting work in the field of essential requirements using computer software.

**Findings:** Based on the analyzes carried out, differences in the scope of legal acts were summarized. It was also found that the new regulation's requirements include an additional group of products that the Machinery Directive did not explicitly cover.

**Research limitation/implications:** The conducted analyzes were limited to EU law requirements specified in the Machinery Directive and the regulation.

**Practical implications:** The research carried out may provide important information for manufacturers and employers regarding the changes resulting from the publication of the Machinery Regulation 2023/1230/EU, also adapted to the evolving technological changes. The study also summarizes additional aspects resulting from, among others, taking into account: new definitions, the introduction of a new conformity assessment procedure, third-party participation in the conformity assessment process, and digital instructions.

**Originality/value:** The article refers to the changes resulting from the 2023/1230/EU machinery regulation.

**Keywords:** machinery safety, machinery regulation, machinery, legal requirements.

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

## 1. Introduction

Every day, technological machines are used in production enterprises, which should meet the requirements set out in legal regulations. According to the concept of security, in EU countries there are two types of requirements dedicated to employers or producers. From a practical point of view, each of the entities should limit all kinds of risks associated with the use of machinery in the enterprise. The employer is at the stage of installation and use, while the manufacturer is at the stage of design and production. Therefore, both the employer and the producer will be obliged to limit the risk by using solutions that reduce the risk (technical solutions, organizational solutions).

Effective preventive care allows you to reduce the accident risk, and thus reduce the costs incurred by enterprises in this respect. Therefore, manufacturers and employers should comply with applicable legal regulations in order to meet and maintain machines in terms of essential and minimum requirements. Legal regulations are changing; therefore, employers and producers should be aware that legal acts should be analyzed and their validity assessed. In the case of producers, this element is relatively important, because failure to meet the requirements of the acts of the applicable legal act may result in failure to meet the requirements set out by the legislator. Failure to comply with legal requirements may result in both practical and financial consequences.

The purpose of the study is to present changes resulting from legal regulations in the field of essential requirements set out in the machinery regulation 2023/1230/EU and to present the possibilities of supporting the work of manufacturers in relation to applicable legal regulations.

## 2. Literature review

Reducing the risk associated with manufactured and operated machines is the primary duty of manufacturers and employers providing technological machines in enterprises. The requirements of the legal provisions have been addressed to these entities and according to them, employers and manufacturers should take measures to reduce the risk at every stage of the machine's life. According to the applicable regulations, there are two types of requirements for machines, i.e., minimum requirements and essential requirements (Dyrektywa..., 2009; Dyrektywa..., 2006; Rozporządzenie 2023/1230/UE; Łabanowski, 2012; Nowak, 2008; Lis, 2007; Rączkowski, 2018; Małysa, 2020, Małysa et al., 2023).

The minimum requirements are set out in Directive 2009/104/EC (Directive..., 2009) and are addressed to employers - machine users. Due to the fact that these requirements were specified in the directive, the national legislator was obliged to implement them effectively into

national legislation. In Polish law, the minimum requirements for broadly understood work equipment are specified in the Regulation of the Minister of Economy (Regulation..., 2002). Other legal acts also refer to minimum requirements, such as the Labor Code (Act, 1974) and the Regulation of the Minister of Labor and Social Policy on general health and safety regulations (Regulation..., 1997). In accordance with applicable law (Directive..., 2009; Regulation..., 2002; Act..., 1974; Regulation..., 1997), it is the employer who is obliged to ensure safe and hygienic working conditions to protect against the risks associated with their operation. It is therefore the employer's responsibility to meet and maintain the machines throughout their life in terms of minimum requirements.

The essential requirements for machines are set out in the Machinery Regulation 2023/1230/EU (Regulation..., 2023), and due to the transition period and manufacturers' adaptation to the requirements of the new regulation, the Machinery Directive 2006/42/EC (Directive..., 2006) applies. Regulation 2023/1230/EU, on January 20, 2027, will replace the Machinery Directive 2006/42/EU and establishes a legal framework for placing on the EU market machines that are safe for users. The Machinery Regulation 2023/1230/EU does not require implementation into national law, it is directly applicable (GOV, 2023). In the case of the Machinery Directive 2006/42/EC, legal acts such as the Act on Conformity Assessment Systems and the Regulation of the Minister of Economy on the essential requirements for machines (Act..., 2002; Regulation..., 2008) were in force in national law, implementing the directive into national law. Therefore, the Directive needed to be transposed into the relevant provisions of national law (Hamrol, 2013). In terms of essential requirements, the provisions of the Labor Code (Act..., 1974) and the regulation on general health and safety regulations (Regulation..., 1997) also apply.

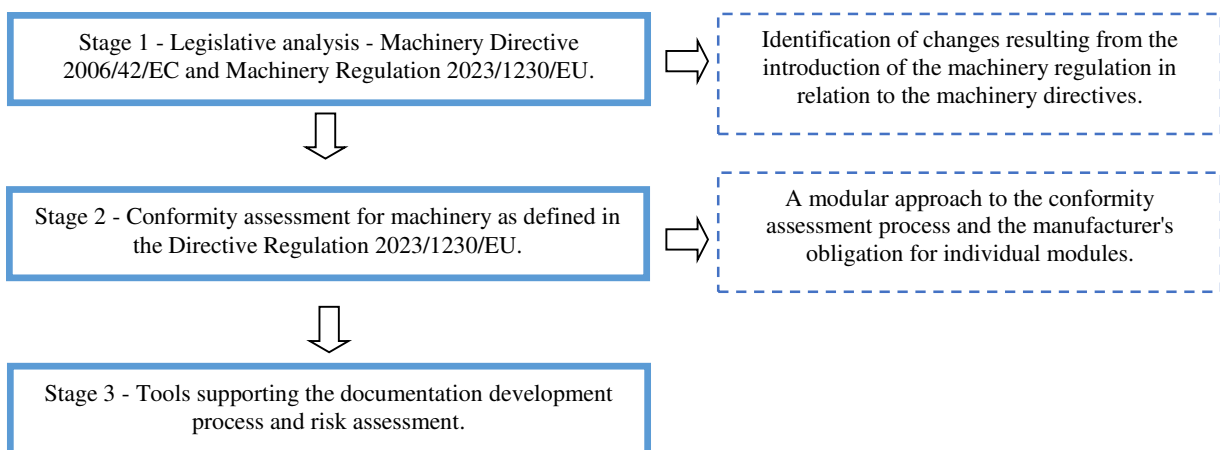
The issue of machine safety is an important issue where manufacturers and employers should reduce all types of risks associated with machinery. In the risk mitigation process, harmonized standards can be helpful, which contain technical details that are missing from legal regulations. Therefore, manufacturers and employers use the achievements of standardization, supporting themselves with the provisions of standards that contain technical details that allow risk reduction. As of the date of the machinery regulation, there is no list of standards harmonized with this legal act. The European Commission plans to issue harmonized standards by standardizes, in particular for the new areas covered by the regulation, before the date of its full application, i.e., January 20, 2027 (GOV, 2023).

### 3. Own work method

The implementation of the assumed goal of the work was possible with the developed method of own work. As part of my own work, legal acts such as the Machinery Directive 2006/42/EC and the Machinery Regulation 2023/1230/EU (first stage) were analysed. As part of this stage, changes resulting from the publication of the machinery regulation were identified in relation to the scope of application, selected definitions, the form of the operating manual, declaration of conformity, conformity assessment procedures, and the emergence of new technologies (Internet of Things, artificial intelligence, and robotics).

The second stage of the developed method of own work consisted in listing the manufacturer's obligations resulting from the conformity assessment for machines. The introduced changes include an additional conformity assessment module relating to the unit verification of the product.

As part of the third stage, an analysis was made of the possibility of using programs supporting work related to meeting the formal requirements resulting from legal regulations, including risk assessment.



**Figure 1.** Own work method.

Source: Own elaboration.

## 4. Directive 2006/42/EC and Machinery Regulation 2023/1230/EU

### 4.1. Changes resulting from the introduction of the machinery regulation

Machine safety is an important topic from the point of view of occupational health and safety, due to the number of registered accidents (Statistic Poland, 2023; Wilaczarska, 2012). The key element is its reduction, which is why machine manufacturers apply the achievements

of science and technology in the field of risk reduction. The development of new technologies and products that meet the definition of a machine, in accordance with the Machinery Directive (Directive, 2006), was constantly developing, which is why the adaptation of legal regulations to changes appearing on the market became an important element. The new Machinery Regulation 2023/1230/EU applies to machinery and related products, i.e., interchangeable equipment, safety components, lifting accessories, chains, belts, ropes, detachable mechanical transmission devices, and partly completed machinery. The Machinery Directive 2006/42/EC, on the other hand, referred to machines, but the term related products did not appear (Table 1).

The Machinery Regulation 2023/1230/EU introduces new definitions as well as supplements and changes existing ones, e.g., machines, by the manufacturer (Table 1). An important definition introduced in the Machinery Regulation is the definition of a significant modification (Table 1), which has not yet appeared in the Machinery Directive. This term means a change to a machine or related product, physically or digitally made after it has been placed on the market or put into service, which was not foreseen or planned by the manufacturer and which affects the safety of the machine or related product, creating a new risk or increasing an existing one a risk that requires the addition of guards or protective devices to that machine or related product, the operation of which requires the modification of an existing safety-related system or the application of additional protective measures to ensure the stability or mechanical strength of that machine or related product (Regulation..., 2023).

The regulation distinguishes two concepts concerning harmonized standards and technical specifications. In the case of the Directive, only the definition of a harmonized standard was mentioned (Directive..., 2006), which referred to the specification. This distinction is important due to the fact that harmonized standards are developed by European standardization organizations, to which the definition set out in the Machinery Regulation also applies. On the other hand, the technical specification was defined as a document specifying the technical requirements that must be met by products falling within the scope of the Machinery Regulation. Technical specifications may be developed by the manufacturer himself, taking into account the standardization output.

The notion of a user's manual has also been introduced (Table 1), which can be made available in a digital version. However, if the user expresses a desire to have a paper version at the time of purchase, then the manufacturer provides it free of charge within a month.

**Table 1.**

*Selected changes resulting from the introduction of the Machinery Regulation 2023/1230/EU*

No.	Machinery Directive 2006/42/WE	Machinery regulation 2023/1230/UE
	Scope of application	
1	The Directive applies to the following products, i.e., machinery, interchangeable equipment, safety components, lifting accessories, chains, ropes, belts, removable mechanical transmission devices, and partly completed machinery.	The regulation applies to machinery and related products, i.e.: interchangeable equipment, safety components, lifting accessories, chains, belts, ropes, detachable mechanical transmission devices, and partly completed machinery.

Cont. table 1.

Selected definitions	
2	<p>Machinery means:</p> <ul style="list-style-type: none"> <li>- an assembly, fitted with or intended to be fitted with a drive system other than directly applied human or animal effort (...);</li> <li>- an assembly referred to in the first indent, missing only the components to connect it on-site or to sources of energy and motion;</li> <li>- an assembly referred to in the first and second indents, ready to be installed and able to function as it stands only (...);</li> <li>- assemblies of machinery referred to in the first, second and third indents or partly completed machinery referred to (...);</li> <li>- an assembly of linked parts or components, at least one of which moves and which are joined together, intended (...).</li> </ul>
	<p>Machinery means:</p> <ul style="list-style-type: none"> <li>- an assembly fitted with or intended to be fitted with a drive system other than that directly applied human or animal effort (...);</li> <li>- an assembly referred to (...), missing only the components to connect in on-site or to source of energy and motion;</li> <li>- assembly referred to (...) ready to be installed (...);</li> <li>- assemblies of machinery referred in (...) or of partly completed machinery (...);</li> <li>- an assembly of linked parts or components, at least one of with moves (...);</li> <li>- <i>an assembly referred to (...) only uploading of the software intended for the specific application foreseen by the manufacturer.</i></li> </ul>
3	-
	<i>Substantial modification means a modification of machinery or a related product, by physical or digital means after that machinery or related product has been placed on the market or put into service, which is not foreseen or planned by the manufacturer, and which affects the safety of that machinery or related product, by creating a new hazard, or by increasing an existing risk (...).</i>
4	<p>Manufacturer means the natural or legal person who designs or manufactures machinery or partly completed machinery covered by the Directive and is responsible for the compliance of the machinery or partly completed machinery with the Directive with a view to its being placed on the market under his name or trademark or for his own use (...).</p>
	<p><i>Manufacturer means any natural or legal person who:</i></p> <ul style="list-style-type: none"> <li>- <i>manufactures products within the scope of the Regulation or who has those products designed or manufactured, and markets those products under its name or trademark; or</i></li> <li>- <i>manufactures products within the scope of Regulation, and puts those products into service for its own use.</i></li> </ul>
5	A harmonized standard means a non-binding specification adopted by a standardization body (...).
	<p><i>Technical specifications mean a document that prescribes technical requirements to be fulfilled by products within the scope of the Regulation.</i></p> <p><i>Harmonized standard means a European standard adopted on the basis of a request by the Commission for the application of Union harmonization legislation.</i></p>
6	-
	<i>Instructions for use means the information, provided by the manufacturer when the machinery or related product is placed on the market or put into service, to inform the user of the machinery or related product, of the intended and proper use of that machinery or related product (...).</i>
User manual and its form, the content of the user manual	
7	<p>The content of the instruction manual, p. 1.7.4.2</p>
	<p><i>Manufacturers shall ensure that the machinery or related products are accompanied by an instruction manual (...). The instruction manual may be provided in digital form. However, at the user's request expressed at the time of purchase, the manufacturer provides a manual in paper form free of charge within one month. The content of the manual, p. 1.7.4.2.</i></p>

Cont. table 1.

Declaration of Conformity		
8	EC declaration of conformity for machines (Annex II)	Manufacturers shall ensure that the machinery or related product is accompanied by an EU declaration of conformity (...), alternatively, provide the website address or machine-readable code for accessing that declaration (...). Digital EU declarations of conformity shall be made available online during the intended life cycle of the machinery or related product, and in any case for at least 10 years after the machinery has been placed on the market or put into service (...). EU Declaration of Conformity for machinery and related products (Annex V).
Conformity assessment		
9	- module A - internal production control (Annex VIII); - module B - EC type examination (Annex IX) + internal manufacturing control (VIII) - module H - full quality assurance (Annex X).	- module A - internal production control (Annex VI); - module B - EU-type examination (Annex VII) followed by conformity to type based on internal production control - module C (Annex VIII); - module H - full quality assurance (Annex IX); - <i>module G - conformity assessment based on unit verification (Annex X).</i>
The division into machine categories (high-risk machines)		
10	Annex IV	Annex 1 - part A Annex 1 - part B
Artificial intelligence, the Internet of Things, and robotics		
11	-	The emergence of new digital technologies such as artificial intelligence, the Internet of Things and robotics poses new challenges for product safety (...). The Regulation should therefore cover security risks arising from new digital technologies.

Source: Own study based on: Directive 2006/42/EC, Regulation 2023/1230/EU (Directive..., 2006; Regulation..., 2023).

The introduced changes also concern the marking of the declaration of conformity. In the Machinery Directive 2006/42/EC and the regulation of the Minister of Economy implementing it, the declaration of conformity is marked with the symbol "WE", in the case of a regulation it is the symbol "EU".

As regards the essential requirements, the manufacturer carries out the conformity assessment of the product within one of the modules (Regulation..., 2008; Directive..., 2006; Regulation..., 2023; Hamrol, 2008; Engel et al., 2009). Within the scope of the Machinery Directive 2006/42/EC, the legislator has provided for the following modules: A – internal production control; B+C type examination + internal production control and module H, full quality assurance. The new machinery regulation provides for the introduction of an additional module G - conformity assessment based on unit verification. An explanation of the scope of obligations in the field of conformity assessment based on module G is specified by the legislator in Annex X of the Machinery Regulation 2023/1230/EC (Table 1). The Machinery Regulation also includes a division of machines to which one of the conformity assessment procedures applies. For the categories of machinery or related products set out in Part A, the EU-type examination procedure (module B) followed by internal production control (module C) and the procedures for full quality assurance (module H) and conformity assessment

based on unit verification (module G). For the categories of machinery or related products set out in Annex I, Part B, the following procedures apply internal production control (module A), EU-type examination (module B) followed by conformity to type (module C), and full quality assurance (module H) and conformity assessment based on unit verification - module G (Regulation..., 2023). In the case of the Machinery Directive 2006/42/EC, the categories of machinery to which the procedures described under module A, module B+C, and module H were applied were listed in Annex IV, the new regulation changed, the categories and division of machines were defined in Annex I (Table 1).

The EU legislator in the Machinery Regulation 2023/1230/EU also refers to the use of new technologies, such as artificial intelligence, the Internet of Things, and robotics in terms of security threats. The changes are intended to fill gaps in the security risk posed by new digital technologies (Regulation..., 2023).

#### **4.2. Machinery conformity assessment - Regulation 2023/1230/EU**

The conformity assessment of the product, including machinery, is the responsibility of the entity that places it on the market or puts it into service. In accordance with the Machinery Regulation 2023/1230/EU, the manufacturer carries out a conformity assessment under one of the four modules and declares under his sole responsibility that the machine meets the requirements of the Machinery Regulation. Important aspects also appear in the annexes to the regulation, which indicate, among others, the need to draw up technical documentation, issue an EU declaration of conformity, CE marking, the need for a third party to participate in product testing, and the manufacturer to have a quality assurance system. The characteristics of individual modules and the manufacturer's obligations under the Machinery Regulation 2023/1230/EU are listed in Table 2. The selection of the conformity assessment procedure depends on the category of machinery to which the machine is classified in accordance with Annex I.

The key element to meet the requirements of the legislator is to reduce the risk to the machine. In accordance with the requirements of the Machinery Regulation 2023/1230/EU, the manufacturer is to ensure that a risk assessment is carried out for a product falling within the scope of the Machinery Regulation. In the case of the regulation, there is also mention of a risk assessment, which should apply to future updates or changes to the software installed on the machine (Regulation..., 2023). The regulation refers to the basic parameters characterizing the risk, i.e., the probability and severity of the consequences. The number of parameters characterizing the risk may change, depending on the applied risk assessment method. The choice of the risk assessment method is left to the manufacturer of the machinery.



**Table 2.***Conformity assessment for machines - manufacturer's obligations*

No.	Conformity assessment procedure	Manufacturer's obligations	Machine risk assessment
1	Module A (internal production control)	<ul style="list-style-type: none"> <li>- the manufacturer prepares the technical documentation in accordance with Annex IV, Part A;</li> <li>- the manufacturer monitors and ensures that he manufactures the product in accordance with the provisions contained in the technical documentation;</li> <li>- issues an EU declaration of conformity;</li> <li>- affixes the CE marking to the machine.</li> </ul>	
2	Module B (EU type-examination)	<ul style="list-style-type: none"> <li>- the manufacturer prepares the technical documentation in accordance with Annex IV, Part A;</li> <li>- percent selects a notified body and prepares an application for EU-type examination (Annex VIII);</li> <li>- the manufacturer informs the notified body of any changes made to the machinery;</li> <li>- the manufacturer follows the procedure described under module C.</li> </ul>	
3	Module C (conformity to type based on internal production control)	<ul style="list-style-type: none"> <li>- the manufacturer declares his responsibility for the machinery in conformity with the type described in the EU-type examination certificate;</li> <li>- the manufacturer ensures and monitors that the manufactured machine complies with the type described in the EU-type examination certificate and the relevant requirements of the Machinery Regulation;</li> <li>- issues an EU declaration of conformity;</li> <li>- affixes the CE marking to the machine.</li> </ul>	
4	Module H (conformity based on full quality assurance)	<ul style="list-style-type: none"> <li>- the manufacturer prepares the technical documentation in accordance with Annex IV, Part A;</li> <li>- the manufacturer ensures and declares on his sole responsibility that the machinery complies with the requirements of the Regulation that apply to it;</li> <li>- the manufacturer has an approved quality system for the design, manufacture and final product inspection and testing of machinery;</li> <li>- the manufacturer selects a notified body to which he applies for assessment of his quality system for machinery;</li> <li>- the manufacturer keeps the notified body that approved the system informed of the intended modifications to the system;</li> <li>- the manufacturer provides the notified body with access to design, inspection, testing and storage locations;</li> <li>- issues an EU declaration of conformity;</li> <li>- affixes the CE marking to the machine.</li> </ul>	
5	Module G (conformity based on unit verification)	<ul style="list-style-type: none"> <li>- the manufacturer ensures and declares on his sole responsibility that the machinery complies with the essential health and safety requirements set out in Annex III;</li> <li>- the manufacturer draws up the technical documentation and makes it available to the notified body;</li> <li>- the manufacturer takes measures so that the manufacturing process and its monitoring ensure compliance of the manufactured machinery with the essential requirements that apply to it;</li> <li>- makes the machine available to a notified body that carries out or has carried out the examinations and tests; issues an EU declaration of conformity;</li> <li>- affixes the CE marking to the machine.</li> </ul>	

Source: Own study based on Regulation 2023/1230/EU and Decision No 768/2008/EC (Regulation..., 2023, Decision No 768/2008/EC).

### 4.3. Tools supporting the preparation of documentation, risk assessment

In the process of preparing documentation for machines, risk assessment, computer tools supporting this type of work may be useful. The manufacturer of the machine chooses the method he will follow. Computer software in its scope has modules that enable:

- a summary of data on basic information related to the machine - data on the design, manufacturer, type, and machine number,
- a general description of the machinery, its technical characteristics, intended use and inappropriate, foreseeable use of the machinery, mode of operation, and limitations of the machinery, including space constraints,
- list of harmonized standards and technical specifications,
- essential requirements for machinery,
- identification, list of hazards - including measurements of measurable factors,
- information on the technical documentation of the machine, the operating instructions for the machine,
- threat analysis and machine risk assessment - a method developed by computer software developers,
- preparation of declarations of conformity.

The use of tools in the form of computer software significantly facilitates the implementation of the obligations imposed on machine manufacturers, due to the compilation of the manufacturer's obligations in individual software modules (Małysa et al., 2023). The software includes a so-called checklist (list of essential requirements) that allows you to assess which points of the regulatory act apply to the machine in question.

## Summary

Ensuring safety in terms of design and operation is an important issue for the EU legislator, manufacturers, and users of machines. The expected level of safety during their operation will be possible thanks to the cooperation of entities having an impact on its construction, as well as the conditions in which they will be operated.

Within the scope of the essential requirements constituting the subject of this study, the Machinery Directive 2006/42/EC applies, which will be replaced by Regulation 2023/1230/EU, in which the legislator introduced additional requirements resulting from technological progress and also draws attention to new risks that should be taken into account machine manufacturers. The provisions will become fully applicable from January 27, 2027, however, machine manufacturers should adapt machines to the essential requirements during this transitional period, so that after that date they can introduce products that comply with its

requirements to the EU single market. An important element will also be access to harmonized standards and the emergence of standards that will cover issues not covered by the provisions of the Machinery Directive 2006/42/EC.

Manufacturers can support their work by using computer software supporting work related to the preparation of full documentation for the machine, instructions for the machine, risk assessment, etc. The use of computer software may facilitate the implementation of statutory obligations that rest on entities placing machines on the market or putting them into service.

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## References

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## SURVEY OF EMPLOYEES' AWARENESS REGARDING OCCUPATIONAL HEALTH AND SAFETY IN THE AUTOMOTIVE INDUSTRY

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**Purpose:** The aim of the research was to assess the awareness of middle-level employees in the field of health and safety at work and the rules related to work safety in the plant being the subject of the analysis.

**Design/methodology/approach:** For the purposes of this study, a four-stage methodology of own work was adopted. Adopting a four-stage approach allowed for the assessment of the awareness of middle-level employees regarding issues related to occupational health and safety in the automotive industry. To assess the awareness of middle-level employees regarding issues related to occupational health and safety, a criterion was adopted, according to which awareness was rated as low or high.

**Findings:** On the basis of the conducted research, it was found that middle-level employees have knowledge of the methods and tools used to improve work safety, and also see their significant impact on improving safety at the positions they are directly responsible for.

**Research limitation/implications:** The analysis carried out was limited to quantitative data obtained from a survey addressed to a specific group of respondents - middle-level employees.

**Practical implications:** The conducted research may constitute important information for management staff in assessing the awareness of middle-level employees in the field of occupational health and safety. They also allow for the identification of areas requiring further improvement aimed at achieving the goals set by the management staff and the occupational health and safety department.

**Social implications:** The article raises the issue of awareness of middle-level employees of the automotive industry in the field of occupational health and safety.

**Originality/value:** The conducted research made it possible to assess the awareness of middle-level employees in the field of occupational health and safety and to determine the directions of future research directions in an enterprise in the automotive industry in Poland.

**Keywords:** occupational health and safety (OSH), surveys, employee awareness, automotive industry.

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

## 1. Introduction

The formation of safe and hygienic working conditions is an important issue in terms of scientific work and company management. Every day, employees are injured at work, and suspicions of occupational diseases or near misses are registered. Therefore, an important element is shaping the awareness of all employees in the field of occupational health and safety. The key element is the involvement of employees in pro-safe activities and raising their awareness in this regard.

Employers, in accordance with applicable EU and national law, are obliged to cooperate with employees in the field of occupational health and safety. Awareness raising can take place through training, even in the form of short thematic lessons, providing information on workplace safety through visual messages (pictograms, the LOTO system, quantitative data on noise measurement or the number of registered accidents, etc.). The work refers to the process of assessing the awareness of direct superiors, and middle-level employees. Due to the fact that these people have contact with their subordinates every day, they know the employees that make up the group they manage best. In connection with the above, this group was the target group in terms of assessing awareness of general OSH issues and applicable rules related to ensuring safety at the workplace, as well as the requirements set by the employer.

The aim of the study was to assess the awareness of middle-level employees regarding issues related to occupational safety. The conducted research allowed for the assessment of employees' awareness in the field of occupational health and safety training, methods, and tools supporting the development of safe working conditions, accident rates, and communication in the workplace on occupational health and safety. The research has practical significance for the company and will help determine the direction of future research in this field.

## 2. Literature review

Awareness is a complex concept (Berkowska et al., 2014) and in the field of occupational health and safety, it refers to the set of information and beliefs of employees about how to perform work without an accident, as well as the company's strategy in the field of health and safety and training (Gajdzik, 2008). Employees' awareness is influenced, among other things,

by knowledge about adopted patterns of safe behavior, methods used to improve occupational safety, and employee involvement in pro-safety activities. However, a lack of safety awareness may cause negative actions that may translate into the occurrence of accidents and thus generate economic and social costs (Chomątowska, 2009). Therefore, building awareness based on cooperation between all employees becomes an important element (Gajdzik, 2009, 2013). The issue of employees' awareness of the occurrence of threats in the workplace, their involvement and influence on solutions to improve safety, behavioral patterns, and a comprehensive approach to health and safety issues is also a key element from the point of view of health and safety culture (Ejdys, 2010). Awareness and safety culture is important for all employees, but also for those who supervise employees, plan, organize, and monitor the performance of specific types of work (e.g., in various industries). In the literature, safety culture (safety climate) is defined as attitudes, behaviors, norms and values, personal responsibility, and a set of shared views and beliefs that employees have about safety in the workplace (Cooper et al., 1994; Glendon et al., 2000; Mohamed, 2003; Nowacki, 2019). It also refers to the extent to which employees consider safety to be a priority and its measurement is considered to be an early warning of a potential safety system failure (Cooper et al., 2004).

For the study, the assessment of awareness was related to middle-level staff managing employees and their attitudes, knowledge about the safety of subordinates, and, above all, their knowledge and involvement in activities aimed at limiting dangerous situations that may lead to negative effects on the life and health of employees. Employee awareness understood in this way can have a significant impact on shaping a culture regarding health and safety.

The issue of awareness and shaping of occupational health and safety culture is important in both scientific and practical terms. Scientific studies draw attention to the need to build employee awareness (Gajdzik, 2009, 2013) and shape an appropriate occupational health and safety culture (Bąk et al., 2016), its creation (Cierniak-Emerych et al., 2013), as well as the impact of national culture on organizational safety culture (Yorio et al., 2019). There is also talk about the use of solutions that have an impact on it, including the 5 minutes for safety method, aimed at reminding employees about the health and safety rules in force in the workplace (Woźny et al., 2018). Research on health and safety awareness and culture focuses on various sectors of the economy: metallurgy (Gajdzik, 2013; Wołowczyk, 2021) mining (Kapusta, 2017; Nędza et al., 2009), construction (Al-Bayati, 2021), medical (Brborowicz et al., 2022; Wagner et al., 2020), railway (Rydzewska, 2018), manufacturing (Ociecek et al., 2016; Shan et al., 2022), metal (Lin et al., 2017), construction (Mohamed, 2003) - which indicates the essence of the subject of research. The authors refer to the role of people who have an impact on occupational health and safety in the workplace, including occupational health and safety specialists (Sadłowska-Wrzesińska et al., 2017), supervisory employees (Kapusta, 2017), as well as employee education (Ociecek et al., 2016) or the conflicts that shape it (Antonsen, 2009). Due to the above, a research gap was identified in the field of examining employees'

awareness of occupational health and safety in the automotive industry, with particular emphasis on the aspect of group selection by top management.

Therefore, the study focused on assessing the awareness of middle-level staff and the use of their knowledge in the field of shaping safe behavior at work in the automotive industry in Poland. Employee awareness has a significant impact on the safety culture (Gajdzik, 2008), which is unique to each organization individually. The literature on the issue mentions two types of security culture (Mielczarek, 2000; Żurakowski, 2015), i.e.:

- low safety culture - lack of interest of superiors in safety issues, failure to comply with applicable regulations, low rank of health and safety issues in the company, failure to apply risk mitigation measures,
- high safety culture – personal responsibility for safety matters, commitment to OHS activities, free and open communication, OHS training and recognition of employees' needs, knowledge of the applied risk mitigation solutions and their application.

### 3. Methodology

The study of awareness of occupational health and safety in enterprises was carried out based on a survey questionnaire addressed to a specific group of respondents - middle-level employees of automotive industry enterprises. The respondents were selected by top management and included middle-level employees employed in the following departments: quality assurance (17 employees), technology (13 employees), maintenance (8 employees), production (23 employees), logistics, and warehouse (18 employees), administration (11 employees). The largest group were respondents with 16-20 years of work experience in the enterprise where the research was carried out (25 respondents), while the smallest group were respondents whose work experience was 31 years or more (4 respondents).

The questionnaire addressed issues related to occupational health and safety, the use of methods, Lean Manufacturing tools, and management systems (first stage - development of the questionnaire). The subject of analysis as part of the work was only the area related to work safety and the awareness of middle-level employees in this respect.

As part of the second stage of the work methodology, the employees to whom the survey was addressed were identified. Because the research covered two workplaces and work in a two-shift system, the survey was addressed to 90 middle-level employees.

In the third stage, the minimum number of respondents was determined. For this purpose, the PQStat statistical analysis tool was used. Assuming a significance level of 0.05 and an estimation error of 0.02, it was estimated that the necessary number of surveys should be 87. Employees' awareness of the questions asked was also determined, referring to low awareness (+), and high awareness (+++). Table 1 explains the importance of low and high awareness in



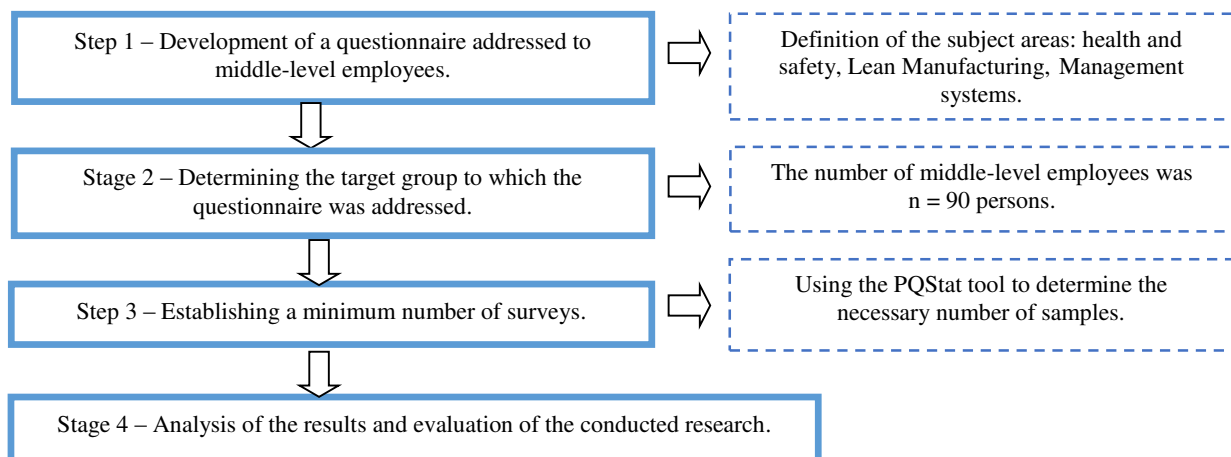
relation to the questions listed in Table 2. The assessment carried out was subjective based on the analysis of the results of each question individually (Table 2).

**Table 1.**  
*Characteristics of low and high employee awareness*

Low awareness	High awareness
Lack of awareness about occupational health and safety training that employees are subjected to, as well as their duration	Is aware of the occupational health and safety training that employees undergo and their duration
Lack of awareness about conversations regarding health and safety issues and their duration	Is aware of conversations regarding occupational health and safety issues and their duration
Lack of awareness of entities supervising work (OHS Service, Social Labor Inspectorate)	Knows the entities supervising work (OHS Service, Social Labor Inspectorate)
Lack of awareness of methods and tools supporting occupational health and safety	Is aware of methods and tools supporting occupational health and safety
Lack of awareness of registered accident events, places of injury, and protective preventive measures used	Is aware of recorded accident events, locations of injuries, and protective measures used

Source: Own elaboration.

In the fourth stage, the results obtained were analyzed (awareness rating low/high) and a proposal for improvement actions was presented in the areas requiring improvement. The step-by-step approach is graphically presented in Figure 1.



**Figure 1.** Methodology of own work.

Source: Own elaboration.

## 4. Researching employees' awareness of health and safety issues

### 4.1. Survey questionnaire and characteristics of research areas

In the developed research tool, which was a survey questionnaire addressed to  $n = 90$  middle-level employees, 40 survey questions were formulated. For the study, reference was made to the area of occupational health and safety. This area covered 12 questions, divided into research areas. As part of the research, the following areas were distinguished:

- training and their duration - the study consisted in determining the awareness of middle-level employees in the field of initial training before a new employee starts work and its duration. The initial training in the analysis in question included, in accordance with applicable regulations, OHS training, however, due to the scope of tasks, the employer provides additional training resulting from the specific profile of the automotive industry;
- communication and entities supervising working conditions - the questions referred to analyzes of work safety between top-level employees and middle-level employees; analyzes of middle-level employees with the employee teams they manage; knowledge of the number of people dealing with health and safety issues or the presence of a Social Labor Inspector at the plant, representing employees;
- management methods and tools used in the field of occupational health and safety - the question referred to the methods used, such as 5S, visual management (VM), standardization, Kaizen and suggestion system, and autonomous maintenance, the implementation of which may improve safety at the workplace, therefore middle-level employees must be aware of their practical use;
- accidents at work – as part of the research, it was assessed whether middle-level employees are involved in accidents, and above all, their awareness of registered accident events;
- post-accident prevention - within this area, reference was made to the knowledge of middle-level employees in the form of accident prevention.

Table 2 presents data regarding the group of respondents as well as information regarding the assessment of employee awareness based on the analysis of the obtained research results.

**Table 2.**

*Survey questions and data on the number of returned surveys along with an awareness assessment*

Question	N	Z	Awareness
Analyzed area: Training and their duration			
Please specify the scope of training to which employees are subject.	90	89	+++ (high awareness)
How many hours does it take to train a new employee?	90	89	+++ (high awareness)
Analyzed area: Communication and entities supervising working conditions			
How often do you discuss health and safety issues with top management in your company? (Select one answer)	90	89	+++ (high awareness)
How often is OHS discussed in your company in the team? (Select one answer)	90	89	+++ (high awareness)
How many occupational health and safety service employees are employed in your company? (Select one answer)	90	90	+++ (high awareness)
Does your company have a Social Labor Inspector? (Select one answer)	90	88	+ (low awareness)

Cont. table 2.

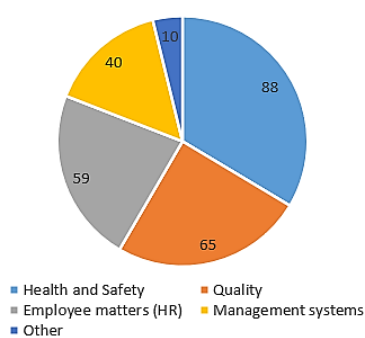
Analyzed area: Management methods and tools used to improve occupational health and safety			
Please specify the type of impact of the management methods and tools used in your company on the improvement of health and safety at work.	90	90	+++ (high awareness)
Please specify which of the tools and methods has the greatest impact on improving health and safety at your company.	90	89	+++ (high awareness)
Analyzed area: Accidents at work			
How often are serious accidents registered in your enterprise? (Select one answer)	90	88	+++ (high awareness)
How often are other accidents registered in your enterprise? (Select one answer)	90	89	+++ (high awareness)
Analyzed area: Accident prevention and monitoring			
What form of accident prevention is used in your company?	90	88	+++ (high awareness)

N – number of respondents, Z – number of answers.

Source: Own elaboration.

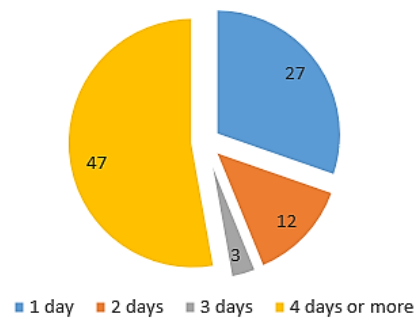
### 4.2. Analysis of survey results

As part of the analyzes on the awareness of middle-level employees in terms of knowledge of training, including training related to occupational health and safety. Middle-level employees most often indicated the type of training that is carried out in the production plant. Of the 90 respondents to whom the survey was addressed, 88 indicated OSH training, which is graphically presented in Fig. 2a. When specifying the duration of training, the vast majority indicated that training is in 4 or more days (47 respondents out of 89 responding to the question in the survey). These results indicate that middle-level employees are aware of the implementation of training (high awareness +++) and the time they spend on them (high awareness +++) (Fig. 2b) - including days for other training devoted to quality, employee matters or management systems used in the production plant.



**Figure 2a.** Awareness of employees in the field of training.

Source: Own elaboration.

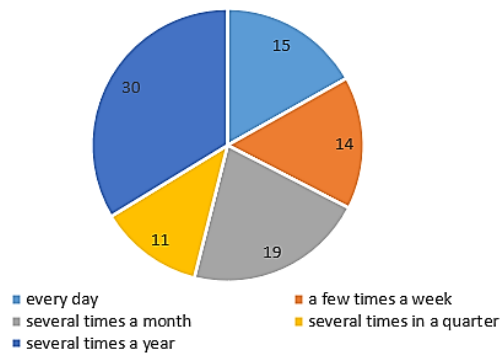


**Figure 2b.** Awareness of employees regarding the duration of training.

Source: Own elaboration.

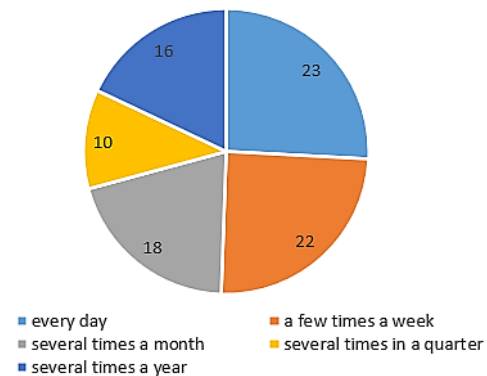
In the production plant where the survey was conducted, an important issue is communication regarding health and safety issues. Therefore, questions were formulated (Table 1) regarding conversations of middle-level employees with top management (Fig. 3a), the team they lead (Fig. 3b), as well as awareness of which entities (occupational health and

safety service (Fig. 3c), Social Labor Inspectorate (Fig. 3d) supervise working conditions inside the workplace.



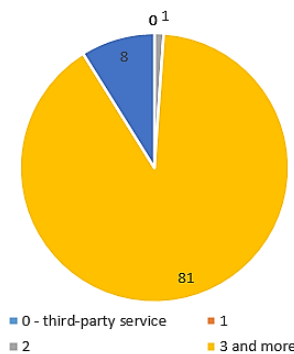
**Figure 3a.** Communication on health and safety issues with top management.

Source: Own elaboration.



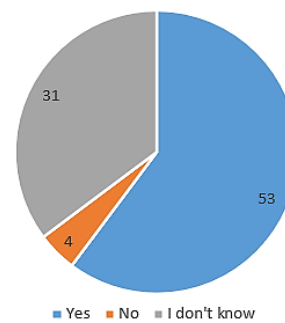
**Figure 3b.** Communication on health and safety issues for mid-level employees in the team.

Source: Own elaboration.



**Figure 3c.** Awareness of middle-level employees in the scope of operation of the OHS service.

Source: Own elaboration.



**Figure 3d.** Awareness of middle-level employees in the field of SIP operation.

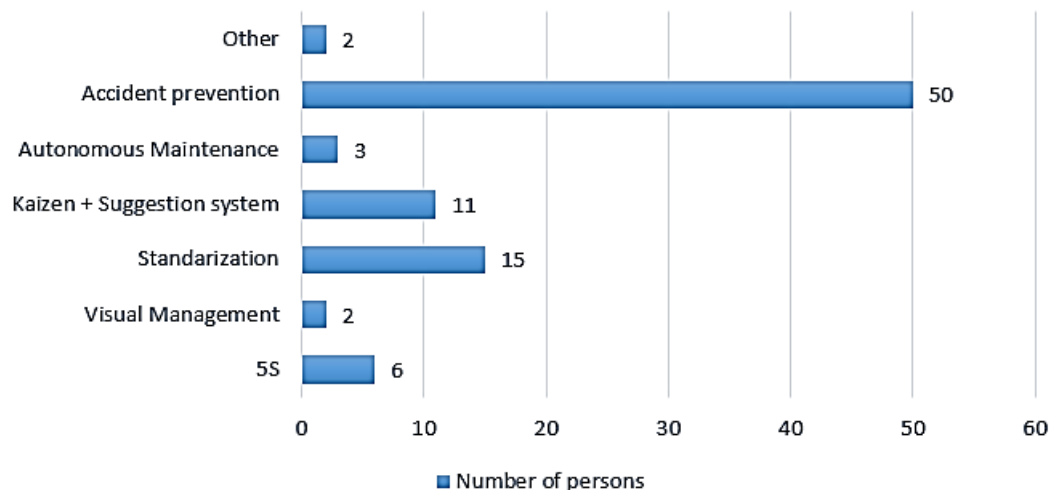
Source: Own elaboration.

Based on the conducted analyses, it is concluded that middle-level employees often communicate with top management on topics related to occupational health and safety. An important element is the fact that the highest values are recorded for: every day - 15 respondents, 14 respondents several times a week, and 19 respondents several times a month (Fig. 3a) - high awareness (+++). The number of respondents may also depend on the type of department in which they are employed and the number of accidents or near misses recorded. Communicating and exchanging information with top management may indicate involvement in activities aimed at shaping safe working conditions, which is also a positive element in shaping the occupational health and safety culture in the organization. Similar to communicating in a team-high awareness (+++).

In terms of entities supervising working conditions in the enterprise, the greatest awareness of employees is in the field of the OHS service and the OHS employees employed in its structures. In terms of this question, 81 respondents gave the correct answer – high awareness (+++). In the case of the Social Labor Inspectorate, which is also functioning, the awareness of

middle-level employees is already at a low level (+), only 53 respondents indicated the correct answer, while 31 respondents did not know this respect concerning the health and safety service operating in the company. This area should be improved, and the Social Labor Inspector should be informed about it.

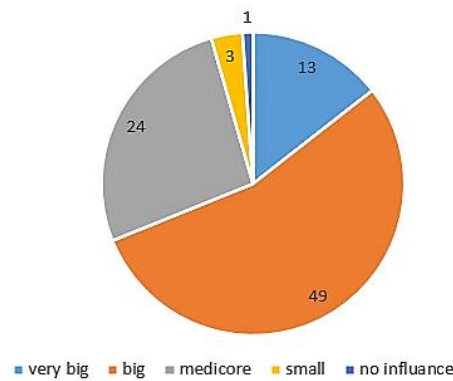
To improve occupational health and safety as well as the ergonomics of working conditions, selected tools of the Lean Manufacturing concept (Autonomous Maintenance, Kaizen + suggestion system, standardization, visual management, 5S method) and accident prevention measures were introduced. Based on the conducted surveys, it is stated that middle-level employees notice the actions taken as part of preventive care (Fig. 4) and most often choose actions that improve occupational safety provided for in accident prevention - 50 respondents indicated such an answer (high awareness +++). In the case of solutions provided for in the LM concept, the choice may depend on the department in which these solutions have been applied. Standardization of the workplace (15 respondents) and Kaizen and the suggestion system (11 respondents) were the most frequently chosen.



**Figure 4.** Methods and tools used to improve work safety.

Source: Own elaboration.

Concerning the applied solutions aimed at improving work safety, the respondents were asked about their subjective assessment of their impact on improving working conditions. Mid-level employees see the impact of selected methods and tools on improving security, assessing it as big (49 respondents), medium (24 respondents), and very big (13 respondents). Responses such as little or no impact were chosen by a total of 4 respondents (Fig. 5). The awareness of middle-level employees in the scope of the methods and tools used to improve safety at the workplace is an essential element in improving working conditions if they see the essence of their use and see a real impact on improving safety at workstations that are directly below them are subject to (awareness high +++).

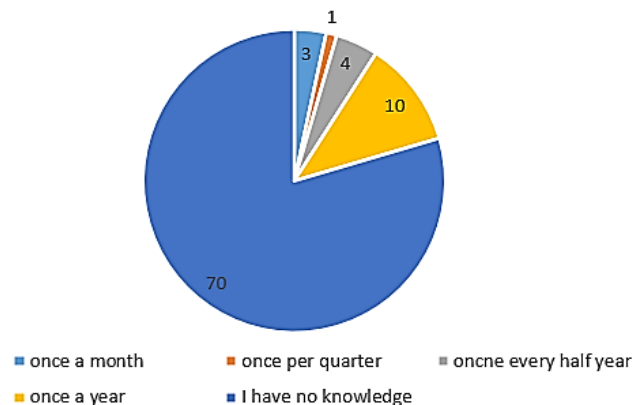


**Figure 5.** Assessment of employees' awareness of the impact of the methods and tools used on improving work safety.

Source: Own elaboration.

The issue of accidents at work is an important issue for every company. In connection with the above, the survey questions addressed to middle-level employees referred to the occurrence of such events. The questions were limited to accidents whose effects were assessed as severe or light (other accidents). The topic of fatal accidents in the survey questions was omitted due to the fact that such events were not registered in the statistics of the company where the research was conducted.

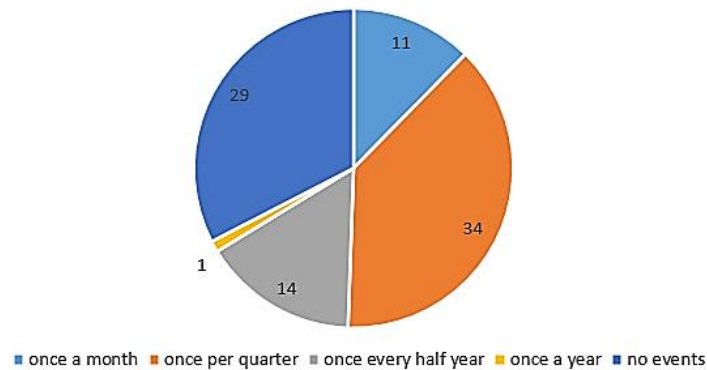
In the case of middle-level employees, 70 respondents indicated that serious accidents are not recorded in their departments (Fig. 6). In other departments, such events occur once a year (10 respondents), and then a downward trend in the occurrence of serious accidents is recorded in other departments. A limited number of serious accidents may prove the effectiveness of the implemented preventive measures. Thus, it can be concluded that middle-level employees have a high level of awareness (+++) of the occurrence and frequency of such events.



**Figure 6.** Evaluation of employees' awareness of the occurrence of serious accidents and their frequency.

Source: Own elaboration.

Other accidents (Fig. 7), which do not cause significant absenteeism, are also recorded in the company statistics. These events occur in department devices once a quarter (34 respondents) register the operation of this type of event, while 29 respondents do not register events other than in their own (+++ high awareness).

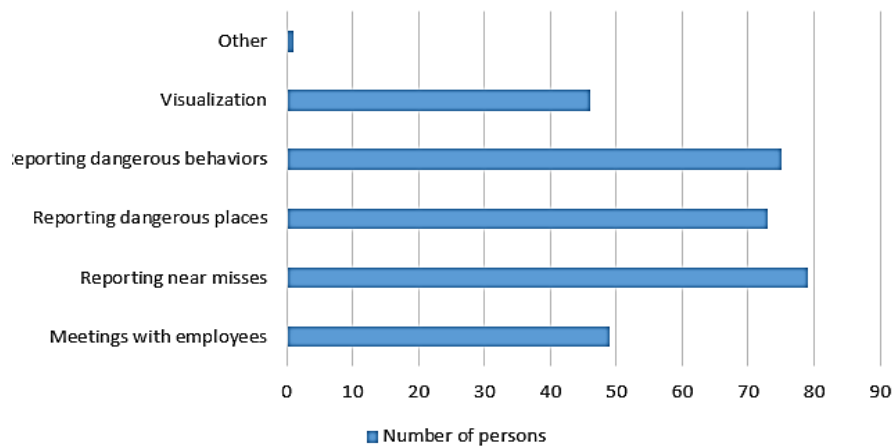


**Figure 7.** Evaluation of employees' awareness of the occurrence of other accidents and their frequency.

Source: Own elaboration.

The study of the occurrence of serious and other accidents made it possible to draw the attention of middle-level employees to the essence of the problem - the occurrence of accidents in the departments they manage. This information also made it possible to determine the departments where such events are registered, as well as the selection of actions to reduce their occurrence - a review of the methods and tools used.

Recording accidents at work in accident statistics requires the implementation of appropriate actions aimed at their elimination or reduction. Every company strives for a zero-accident policy and this is also the case in the company where the survey was conducted. As part of the conducted research, the following prevention activities were identified: meetings with employees, reporting near misses, reporting dangerous places, reporting dangerous behaviors, and visualization - of situations, and dangerous events. Depending on the department, middle-level employees indicate that the most frequently used prevention is reporting near misses (79 respondents), reporting dangerous behaviors (75 respondents), and reporting dangerous places (73 respondents) - Fig. 8. Under this question, employees could tick more than one answer, so it can be concluded that preventive measures may translate into improved occupational safety. Awareness (high awareness +++) in terms of the possibility of informing employees and communicating with them about dangerous events and dangerous situations may in the future translate into reducing accidents and improve working conditions. The exchange of information between employees and superiors is the most important element aimed at shaping a high culture of occupational safety. Each employee has an impact on safety, and good communication in this area translates not only into increased awareness of employees about existing threats but can also affect the occurrence of accidents at work.



**Figure 8.** Solutions used as part of accident prevention.

Source: Own elaboration.

## Summary

Shaping safety at work is an important element of the functioning of the enterprise, primarily the awareness and involvement of employees in activities aimed at improving occupational safety. The study presents the results of a survey addressed to middle-level employees, based on which employee awareness in selected areas related to occupational health and safety was assessed. Twelve survey questions were compiled in which respondents referred to issues related to occupational health and safety training, the methods and tools used in management, communication, and entities supervising working conditions, as well as the issues of accidents at work and accident prevention. The conducted research was directed to ninety respondents and was characterized by a high response rate of surveys and answers. The lowest number of responses (88 respondents) was recorded for the question on serious accidents. The registered number of respondents may result from the employee's lack of information on such events or the employee's omission of a survey question. However, it is believed that the number of 88 respondents providing the answer was satisfactory for the purposes of the research (methodological assumptions that the minimum number of people answering the question cannot be less than 87 respondents).

Based on the conducted analyzes of survey research, it is concluded that middle management is characterized by high awareness of health and safety issues (they engage in activities for health and safety), as evidenced by the obtained research results. Middle management is aware of:

- scope of health and safety training and time for their implementation,
- the scope of issues of registered accident events, taking into account the severity of the consequences,
- applied accident prevention, taking into account the methods/tools used in the company.



The area requiring improvement is the low awareness (+) of employees regarding the activities of the Social Labor Inspector, therefore improvement actions should be taken in this area. Based on the conducted analyses, it is concluded that the awareness of middle management is high and may have a significant impact on shaping safe attitudes and behaviors among the employees they manage. The awareness and knowledge of middle management in the field of occupational health and safety may translate into the level of safety culture in the workplace, which is also noted by other authors of works (Gajdzik, 2009). The obtained research results may also set directions for further improvement activities in the field of occupational health and safety undertaken by top management. Therefore, further research is planned to investigate the awareness of employees in the automotive industry. The research will be addressed to production workers and compared with the results presented in this study.

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## DIFFERENCES IN ORGANIZATIONAL COMMITMENT OF THE BABY BOOMERS AND THE GENERATIONS X, Y, Z

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**Purpose:** This paper attempts to answer the following questions: does the level of organisational commitment of employees' generations differ significantly as well as which generation has the highest and which the lowest level of organisational commitment? Its purpose is to identify the differences in the level of commitment between generations of employees and to recognise generations that are characterized by its lowest and highest level.

**Methodology:** The paper presents the results of a survey conducted among students and their family members representing diverse generations of employees. The sample consisted of 396 respondents of Baby Boomers and Generations X, Y, Z. The differences in the level of organizational commitment and its components between these generations were analyzed with the use of descriptive statistics, ANOVA analysis and nonparametric tests.

**Findings:** The levels of commitment differed significantly between the examined generations of employees. Generation Z was characterised by the lowest level, while Baby Boomers by the highest level of commitment. The findings also suggested that generation Y was more similar to generation Z than to generation X regarding organisational commitment.

**Research limitations/implications:** In future research, it would be particularly important to find out what activities are carried out to increase employee commitment in relation to the different generations of employees in organisations and whether they are in line with employees' needs and expectations. The purposive sampling method means that the results of the study are not representative and cannot be generalised, so a random sampling method should be used in the future.

**Practical implications:** By providing insight into generational differences in organisational commitment, the study can contribute to the formulation of effective age-related policies adapted to the specific characteristics of employees' generations in organisations.

**Value:** This study has provided empirical evidence on differences in the level of organisational commitment and its components between generations that were absent for four generations of employees.

**Keywords:** organizational commitment, Human Resource Management, generations of employees.

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

## 1. Introduction

For contemporary managers it is a difficult challenge to match human resource management methods with the needs of diverse generations of employees who today meet in organisations. Indeed, employees' approach to work, their requirements, and expectations depends on a number of socio-cultural and economic factors that determine the conditions of their growing up, education, and upbringing. Simultaneously, the situation of employees in the internal (organisational) and external labour market evolves. Gradually, the labour market becomes a market for the employee (Górniak et al., 2022). In the era of the knowledge-based economy, when human capital is gaining key importance, employers look for committed and creative employees who want to actively contribute to organisational achievements, as their commitment is one of the key factors influencing the success or failure of organisations (Wolniak, Grebski, 2018; Sungu, Weng, Xu, 2019). Moreover, changes in employees' careers have resulted in the temporary and flexible relationships between employees and the organisations what influences their loyalty and commitment into organizations. Contrary to common views, this issue does not only concern young employees, but also mature ones who over the years have become more mobile and are no longer as reluctant to change a job. These trends are strengthened by demographic changes. Today in many organisations generations of the Baby Boomers and the Generations X, Y, Z work together. On the one hand, the ageing of the population means that retaining older, experienced, and competent employees within an organisation becomes a necessity. On the other hand, it becomes all the more important to attract and retain young employees in the organisation, possibly by establishing their close ties with the organisation. In the face of growing labour shortages, the implementation of a policy of age diversity and the enhancement of organisational commitment of diverse generations of employees should become an inherent element of contemporary HRM. The rapid development of knowledge and technology accompanied by socioeconomic transformation in the last three decades means that today organizations have to cope with a strong diversification of age groups and considerable generational differences, manifested in the attitudes and behaviours. In this situation, recognising distinctive characteristics of generations and adjusting HRM policy to their specificity becomes an important condition for its success.

Despite a great deal of interest in both organisational commitment and distinctive features of different employees' generations, empirical studies on differences in organisational commitment between generations are still rare. Therefore, this paper attempts to answer the following questions: does the level of organisational commitment of particular employees' generations differ significantly as well as which generation has the highest and which the lowest level of organisational commitment? These aims will be reached by presenting a short literature review and the results of empirical study on organisational commitment of four generations of employees.

## 2. Theoretical framework and hypotheses development

### 2.1. Baby Boomers and Generations X, Y, Z of employees: their distinctive characteristics

Despite the fact that the notion “generation” is often understood just as a group “of people of more or less the same age” (Szymczak, 1979, p. 772), within the social science this term is interpreted more broadly. According to Wiktorowicz and Warwas (2016) a generation constitutes individuals who belong to the same culture group of similar age, attitudes, motivations, expectations, approach to life and values resulting from their shared historic and social situation. Consequently, generations of employees educated in different historical and sociocultural circumstances differ in their way of thinking, value system, expectations, and approach to work. Dynamic changes in the environment, especially the development of information technologies and the emergence of the digital economy, make the differences between them more apparent. There are four basic generations of employees currently active in the labour market, i.e. the generation of Baby Boomers, Generations X and Y, as well as Generation Z, which is just entering the labour market. These generations are distinguished primarily by age, although the periods falling within each generation are defined differently by researchers, because also their other characteristics are used as criteria of generational affiliation. The literature points to a number of specific characteristics of these generations.

The oldest generation still active in the labour market are the Baby Boomers, who are generally assumed to be born between 1965/70 and 1946 (e.g., Rosa, 2013; Muster, 2020). However, many of them have already retired. This generation matured during the period of significant socio-political changes, thus they adhere to such basic values as freedom and equal human rights, participation in collective actions, knowledge and education, prosperity, and responsibility (Rogozińska-Pawelczyk et al., 2019). They believe that a job success is a result of hard work and effort and it is measured by a position and salary. Due to their professional experience and approach to work, today they often become role models for others. In Poland, this generation of employees first worked at the time of socialism, then participated in the system transformation and they treat work as a duty (Rogozińska-Pawelczyk et al., 2019). They highly appreciate the value of work, its stability and job security. Their relationship with the organisation is mostly strong and long-term. They are loyal to their employer. They want to contribute to the success of their organization (Hysa, 2016). They prefer a traditional career model, which is determined by a sequence of promotions in the same organisation. They accept organizational hierarchy, procedures and job discipline (Becton et al., 2014). They prefer cooperation to competition and they are fulfilled in teamwork.

Generation X employees were born between 1965/71 and 1980. Their careers began during the period of the Polish economic transition, hence they highly value stability and job security in the organisation. Similarly to the Baby Boomers they also prefer a traditional model of career

and they change a job only when it is necessary. However, they are interested in innovations and new challenges. These employees are loyal to an employer, but their commitment is mainly based on continuance and normative commitment. They are characterized by high work ethics. Because they are not very self-confident in their value for the organisation, they willingly engage in various developmental activities and participate in trainings to increase their job competencies and value in the internal and external labour market. Generation X employees are conscientious, hard-working, and independent. They do not like hierarchy but accept the authority of supervisors. They need acceptance, support of their co-workers and a sense of belonging, therefore they also enjoy teamwork. This generation of employees is strongly motivated by position and status. They strive for promotions and career development, what often leads to their professional burnout and workaholism, being relatively common phenomena in this group of employees. Consequently, this generation has also started to look for a work-life balance more strongly than the previous one (i.e. Baby Boomers) but mostly at the end of their career.

Generation Y employees (also called Millennials) born between 1981 and 2000 are characterised by a greater distance to work and career than Generation Y. At work, these employees expect flexibility, autonomy, and a work-life balance. Generation Y is often described as demanding and overestimating their capabilities (Smolbik-Jęczmień, 2013). They are less loyal to an employer than Generation X. They do not feel strongly attached to an employer. They are characterised by a high degree of professional mobility, since they easily adapt to changes. Their career paths are often non-linear and diverse. They are aware of their value on the labour market; hence they prefer new career models such as a borderless career. They are good at new technologies, which they willingly use in both their professional and private life. They are continuously learning and this is their way of life and career development. They expect a well-paid job, fast promotion, openness in the work environment, opportunities for professional development, and for expression of their creativity (Smolbik-Jęczmień, 2013). They are concerned with a high standard of life thus well-paid work is their basis of livelihood. Their life attitude is characterised by a combination of apparent contradictions. On the one hand, the foundations of their intrinsic world are personal and affiliative values, while on the other, work is regarded as a condition for life success and as a source of personal satisfaction as well as a sense of fulfilment (Smolbik-Jęczmień, 2013).

The youngest Generation Z are employees born after 1999 at the turn of the 20th and 21st centuries (Rogozinska-Pawelczyk et al., 2019). These are individuals who are just entering the labour market. They are also often referred to in the literature as Generation C, which is derived from the words 'connected', 'communicating', 'computerised', 'community-orientated', since their lives are focused on technology and social networks (Kukla, Nowacka, 2019). This generation is often attributed negative traits such as laziness, demandingness, and individualism. These characteristics may make work with Generation Z difficult. They are the first generation to have grown up during a digital revolution, with widespread access



to the Internet and digital technology since childhood (Vengrouskie, Scarlata, Baker, 2023). These circumstances had a great influence on their life and work attitudes and behaviors, expectations, values, and abilities. They are therefore proficient in information technology, in practice often applying it intuitively what is highly valued by many employers. They are able to function simultaneously in the virtual world and the real world, what can also lead to blurred boundaries between their professional and private life (Rogozinska-Pawelczyk et al., 2019). They value freedom, independence, and empowerment, thus they prefer flexible work hours and forms of employment. They are ambitious and focused on achieving goals. Employees of this generation expect challenging and interesting work, as well as quick promotions because they want everything 'right now' without a great effort (Kukla, Nowacka, 2019). However, the opportunities for development and self-fulfillment, both professionally and privately have a great importance to them. They are characterised by high social awareness. They prefer new career models, as they are professionally mobile, willing to change not only an employer but even a profession, hence it is difficult to build their loyalty and attachment to an organisation.

The apparent differences between the generations of employees presented, resulting from the different socio-economic conditions in which they grew up and developed, mean that their expectations of organisations are diverse. To enhance their organisational commitment their work environment should be adjusted to their specific characteristics. This generational diversity in organisations makes its management an important area of contemporary HRM.

## **2.2. Organizational commitment: the framework of the concept**

As one of the key factors influencing employee performance, organizational commitment has been the subject of intense interest among management researchers for many decades. A study on organizational commitment began in the early 1960s. Its pioneer was Becker (1960), who first tried to provide its comprehensive conceptual framework. According to his approach organizational commitment of employees is based on their individual investments, which they make to remain in the organization and which they would lose if they leave it (Cohen, 2007). He also distinguished two kinds of commitment: calculative and attitudinal. His work was continued by Buchanan (1974) who defined organizational commitment as the emotional attachment of an employee to organizational goals and values as well as his role regarding these goals and values, thereby emphasizing significance of its emotional element.

In the later stage of the studies on organizational commitment Mowday, Steers and Porter (1979) also emphasized this emotional aspect of organizational commitment claiming that organizational commitment is the power of an employee's ties and his or her identification with the organization. However, they mainly referred to the social exchange theory as a framework of this construct. Later, the concept of organisational commitment evolved and it has come to be understood as a specific psychological state or mindset that characterizes the employee's relationship with an organization (Houfak Khoufak, Nouri, 2023). Since the 1980s a multidimensional approach to organizational commitment has become popular. Adopting this

perspective, O'Reilly and Chatman (1986) differentiated two dimensions of commitment, i.e. an instrumental exchange and psychological attachment. In their opinion, the exchange process results only in a superficial attachment of an employee to the organization but the deeper attachment arises from the employee's psychological attachment.

During this period Meyer and Allen (1984) began their study of this phenomenon. They defined organisational commitment as an employee's positive feelings of identification with the organisation and attachment to it. In their later study in the 1990s they proposed their three-component model and they developed its measurement instrument (Meyer, Allen, 1991). Despite many discussions, their concept is still one of the most popular and accepted approaches to organisational commitment. Consequently, their works were continued in numerous studies which analysed the essence of distinguished components of organizational commitment, as well as its various predictors and outcomes (e.g., Steijn, Leisink, 2006; Fu, Bolander, Jones, 2009; Cesinger et al., 2023).

The problem of organisational commitment also has awakened attention of Polish researchers for a long time. According to Spik and Klincewicz (2008), organisational commitment is employee's attachment to the organization and his/her identification with it. Juchnowicz (2010) following the approach proposed by Mowday et al. (1979) defined organisational commitment more broadly, claiming that it is an employee's identification with an organisation, its aims and values, a wish to be its member, and willingness to make an effort for the organization. Whereas Pec and Lewicka (2022) encapsulated organizational commitment as the employee's attachment and their dedication to the organisation. Similarly, organisational commitment is presented by Stefańska and Grabowski (2023), according to whom it is an employee's sense of bonding with the organisation. They also point to its relationship with job satisfaction. Dziopak-Strachm (2018) claimed that organisational commitment is not only identification with the organisation manifested in responsibility for its actions, but also a willingness to make autonomous decisions for the success of the organisation. In turn Kopertyńska and Kmiotek (2014) pointed out that organizational commitment represents a positive, work-related state of employee well-being and fulfilment that leads to behaviour that brings benefits to the organisation. To sum up, generally organisational commitment can be understood as the psychological links between an employee and an organisation that encourages him/her to remain an organizational member (Strange Noesgaard, Jørgensen, 2023).

One of the best known and most widely used models of organizational commitment is the one proposed by Allen and Meyer (1990). It has been also successfully validated in previous empirical research conducted in Poland (Bańka, Bazińska, Wołowska, 2002). This model encompasses three distinctive components of organizational commitment (Allen, Meyer, 1990, pp. 2-3):

- affective commitment which concerns employee's emotional and attitudinal attachment to the organization, which results in the desire to be its part,
- continuance commitment which is based on calculation reflecting subjective costs perceived by an employee related with leaving the organization,
- normative commitment showing the loyalty of an employee towards the organization based on his/her sense of obligation to stay in the organization.

It has been empirically proven that organisational commitment leads to a number of positive outcomes for both the employees and the organisations they work for. It is positively related to employee's performance, job satisfaction and career success (Sager, Johnston, 1989; Riketta, 2002). In empirical research, it has been found that organizational commitment is positively linked with organizational long-term orientation, innovation engagement, innovative behaviors and organizational learning which are important factors of organizational success (Meroño-Cerdán, 2023; Jafri, 2010; Rose et al., 2009).

Organizational commitment depends on many organizational factors, e.g. in empirical studies it was found that organizational culture, coworkers and perceived organizational support, organizational learning, HRM practices, procedural justice are its predictors (Khan, 2022; Soeling, Aulia, Indriati, 2021; Mon, Akkadechanunt, Chitpakdee, 2022; Meyer, Smith, 2000). Also job content and its characteristics significantly affect organizational commitment of employees. In the study carried out in a software solutions development firm in Denmark it was discovered that relational and cognitive job crafting encourage affective, normative, and continuous commitment of knowledge workers (Strange Noesgaard, Jørgensen, 2023). Moreover, numerous individual factors influence employees' commitment, e.g. employee competencies, self-efficacy, job satisfaction, sense of meaningful work, and sense of influence on organizational performance (Riyanto et al., 2023; Słocińska, 2014; Adamska-Chudzińska, 2016). Many researchers indicated a particular impact on demographic features such as age, job experience, gender, and educational level on employees' commitment (e.g. Cohen, 2007; Meyer, Smith, 2000; Meyer, Allen, 1984). In previous empirical research conducted among hospital and library employees Allen and Meyer (1993) found that affective and normative commitment increased with employee age, continuance commitment increased with organizational and positional tenure. Changes in values, expectations and work attitudes between Baby Boomers and Generations X, Y, Z also suggest that employees of these generations may differ significantly in the level of their organisational commitment. Moreover, specific characteristics of Generation Z such as a preference for flexible forms of employment, high job mobility and a desire for independence, make it reasonable to suppose that employees of this generation may be characterised by low level of organisational commitment. Otherwise, the oldest Baby Boomers are reluctant to change jobs because they value stability and job security in the same organisation, what can lead to strong relationships with the organisation and a high level of organisational commitment. Therefore, the following hypotheses were formulated:

- H1: There will be significant differences between generations of employees in the level of their organizational commitment.
- H2: Employees of Generation Z will report the lowest level of their organizational commitment.
- H3: Employees of Generation 'Baby Boomers' will report the highest level of their organizational commitment.

### **3. Empirical study**

#### **3.1. Research method**

To test the posted hypotheses, the survey was carried out from April to July 2023. Purposive sampling method was applied. To pick up generational differences the sample encompassed students (full and part-time working) of majors related with extensive use of information technology as representing generation Z and their family members constituting generations Y, X, and Baby Boomers. It was conducted among students of such majors as Digital Economy, Journalism and Social Communication, Urban Economy and Real Estate, Computer Science and Econometrics at the University of Economics in Katowice and Promotional and Crisis Communication at the University of Silesia in Katowice.

The final sample consisted of 396 respondents including 57.6% women (228 people) and 42.4% men (168 people). The structure of the sample with respect to the level of education of the respondents can be presented as follows: 28.8% of the participants had Master's degrees, 3.5% engineering degrees, 16.2% bachelor's degrees, 41.2% of the participants had secondary education (general or technical), 9.3% had vocational education and 1% of the participants had primary education. Their average age was 41.58 years (median 44.5 years) and the average seniority was 17.98 years (median 20 years). The great majority of respondents held executive positions (84.1%), and 15.9% held managerial positions. They were employed in organizations of such branches as 13.2% manufacturing, 11.9% wholesale and retail trade, 8.3% education, 7.1% public administration, 5.8% arts, entertainment and recreation, 5.3% healthcare, 5.1% accommodation and food service activities, 4.3% transport and storage, 4.3% information technology activities, 3.8% mining and quarrying, 3.8% legal and accounting activity, 3.0% financial and insurance activities, 2.3% construction, 2.0% administrative and support service activities, 1.5% telecommunication, 1.5% professional, scientific and technical activities, 1.3% publishing, and 15.5% of respondents were employed in other sectors. 47.2% of the respondents were employed in small organizations (1-49 employees), 19.9% in medium organizations (50-249 employees), and 32.9% were employed in big organizations (above 249 employees). The average period of existence of these organisations was 29.11 years.

Organizational commitment was measured with the Polish version of the Allen and Meyer's scale (1990) known as the Three-Component Organisational Commitment Questionnaire, which was validated by Bańka, Bazińska and Wołowska (2002). It consisted of eighteen items scored on a 7-grade Likert's scale (from 1 – strongly disagree to 7 – strongly agree) which refer to a different component of organisational commitment, i.e. affective, continuance commitment and normative commitment. Cronbach  $\alpha$  for a subscale of affective commitment was 0.87, for continuance commitment it was 0.89, and for normative commitment 0.89, and Cronbach  $\alpha$  for the whole scale of organizational commitment was 0.93, what indicated high reliability of the scale used.

Key demographic information about the respondents and organizations employing them was also applied, i.e. gender (coded: 1 – male, 2 – female), educational attainment (coded: 1 – primary education 2 – basic vocational education, 3 – secondary education (general or technical), 4 – engineering degree, 5 – bachelor's degree, 6 – Master's degree, age (a number of years), position (1 – executive position, 2 – managerial position), seniority (a number of years), branches where they were employed (letters), size (1– less than 10 employees, 2 – 10-49 employees, 3 – 50-249 employees, 4 – 250-499 employees, etc.), and period of existence of organizations (a number of years). This information was obtained with single items. Data was processed by means of SPSS 29.0.

In the first step, four generations of employees were distinguished, i.e., Generation Z (up to 23 years,), who were 22.5% of the sample, Generation Y (24 to 42 years), who were 24.7%, Generation X (43 to 55 years), who were 37.6% and the oldest Baby Boomers (56 years and over), who were 15.2% of the sample. In order to test the proposed hypotheses descriptive statistics, ANOVA analysis, nonparametric tests were conducted.

### **3.1. Results of the study**

The results obtained indicate that respondents generally rated their overall organisational commitment as average. Its mean rating was 3.73 points on the 7-point scale (median 3.61) (Table 1). The component of affective commitment was the highest rated by employees, i.e. mean score was 4.22 points (median 4.33). It was noticeably higher rated than the other two components of organizational commitment, i.e. continuance and normative commitment, which both received the mean rating of 3.49 points (median 3.33). Ratings of all components were also characterized by significant diversity (standard deviation overrun 1.4 point) (Table 1).

**Table 1.**  
*Descriptive statistics of organizational commitment*

Variables	Mean	Median	Std. Deviation	Range	Minim.	Max.
Affective commitment	4.22	4.33	1.41	6	1	7
Continuance commitment	3.49	3.33	1.50	6	1	7
Normative commitment	3.49	3.33	1.44	6	1	7
Organizational commitment (overall)	3.73	3.61	1.23	6	1	7

Source: own developed.

Next, the level of organisational commitment and its components of each generation were analysed (Table 2). Baby Boomers were characterized by the highest mean score of the overall organisational commitment (mean: 4.47 points). They also rated other components of organisational commitment the highest. In contrast, representatives of generation Z rated their organisational commitment (mean: 3.15 points) and its components the lowest (Table 2). The greatest differences between generations in the rating of the components examined was found for the continuance commitment.

**Table 2.**  
*Descriptive statistics of the level of organizational commitment for Generations examined*

Variables	Generation Z	Generation Y	Generation X	Baby Boomers
Organizational commitment (overall)	3.15	3.40	4.01	4.47
Affective commitment	3.79	4.06	4.42	4.64
Continuance commitment	2.54	2.99	3.95	4.57
Normative commitment	3.12	3.15	3.66	4.19

Source: own developed.

To check whether these differences are statistically significant one-way analysis of variance (ANOVA) was applied. But first normality of the distribution of overall organizational commitment was checked with the use of Kolmogorov-Smirnov with Lilliefors' amendment test (at  $p = 0.05$ ). Next Levene's test of homogeneity of variance was applied. Because variance was homogenous ANOVA analysis was carried out in order to check whether the differences in the levels of organizational commitment were significant. Results of ANOVA analysis revealed significant differences of the average organizational commitment levels between the generations examined (Table 3).

**Table 3.**  
*Results of ANOVA analysis: organizational commitment overall*

Organizational commitment	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	84.616	3	28.205	21.585	0.000
Within Groups	512.223	392	1.307		
Total	596.838	395			

Source: own developed.

Subsequently, to determine which generations differ significantly from each other regarding the level of organizational commitment, post hoc multiple comparison analysis was conducted using Scheffe's test. Significant differences between Generation Z and the Baby Boomers, Generation Z and Generation X, as well as between Generation Y and Generation X, Generation Y and Baby Boomers were found (at the significance level of 0.05). These results allowed to confirm the first formulated hypothesis (H1) (Table 4).

**Table 4.**

*The results of comparisons between the generations examined: organizational commitment (Scheffe's test)*

(I) gen	(J) gen	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Generation Z	Generation Y	-0.25	0.17	0.52	-0.72	0.22
	Generation X	<u>-0.86*</u>	0.15	0.00	-1.29	-0.43
	Baby Boomers	<u>-1.32*</u>	0.19	0.00	-1.85	-0.78
Generation Y	Generation Z	0.253	0.17	0.52	-0.22	0.73
	Generation X	<u>-0.60*</u>	0.15	0.00	-1.02	-0.19
	Baby Boomers	<u>-1.06*</u>	0.19	0.00	-1.59	-0.54
Generation X	Generation Z	<u>0.86*</u>	0.15	0.00	0.43	1.29
	Generation Y	<u>0.60*</u>	0.15	0.00	0.19	1.02
	Baby Boomers	-0.46	0.17	0.08	-0.95	0.03
Baby Boomers	Generation Z	<u>1.32*</u>	0.19	0.00	0.78	1.85
	Generation Y	<u>1.06*</u>	0.19	0.00	0.54	1.59
	Generation X	0.46	0.17	0.08	-0.03	0.95

Note. \*The mean difference is significant at the 0.05 level.

Source: own developed.

In the next step to get a deeper insight, differences between the level of components of commitment were also analysed. Firstly affective commitment was examined. Because the analysis showed that the distribution is not normal, in order to determine whether the differences occurring in the average level of affective commitment in the studied groups were statistically significant, the nonparametric Kruskal-Wallis test was applied. It showed that, at the 0.05 level of significance, belonging to a particular generation was a factor that significantly differentiated the level of affective commitment (Table 5).

**Table 5.**

*The significance of differences between the average levels of affective commitment in the generations examined: results of the Kruskal-Wallis test*

Null hypothesis	Test	Test statistic	Significance	Decision
Distribution of affective commitment is the same across generations of employees	Independent samples Kruskal-Wallis Test	17.916	<0.001	Reject the null hypothesis

Note. The significance level is 0.05; Asymptotic significances are displayed.

Source: own developed.

Then, a post-hoc test for nonparametric comparison to analyse the significance of differences in the level of affective commitment between particular generations was carried out (Table 6). The results suggest that there were statistically significant differences in the level of affective commitment between Generation Z and Generation X and between Generation Z and Baby Boomers (Table 6).

**Table 6.**

*The results of post-hoc nonparametric comparisons between the generations examined: affective commitment (pairwise comparison)*

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Generation Z - Generation Y	-22.757	16.749	-1.359	0.174	1.000
Generation Z - Generation X	-49.535	15.324	-3.233	0.001	0.007
Generation Z - Baby Boomers	-71.337	19.107	-3.734	<0.001	0.001
Generation Y - Generation X	-26.778	14.877	-1.800	0.072	0.431
Generation Y - Baby Boomers	-48.580	18.750	-2.591	0.010	0.057
Generation X - Baby Boomers	-21.802	17.489	-1.247	0.213	1.000

Note. Each row tests the null hypothesis that the Sample 1 and the Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05.

Source: own developed.

Since the distribution was not normal in relation to continuance and normative commitment, the Kruskal-Wallis tests were used too. An analysis of the significance of the differences in the mean levels of continuance commitment between generations was conducted, which showed that belonging to a particular generation significantly differentiated the level of continuance commitment of employees (Table 7).

**Table 7.**

*The significance of differences between the average levels of continuance commitment in the generations examined: results of the Kruskal-Wallis test*

Null hypothesis	Test	Test statistic	Significance	Decision
Distribution of continuance commitment is the same across generations of employees	Independent samples Kruskal-Wallis Test	90.647	<0.001	Reject the null hypothesis

Note. The significance level is 0.05; Asymptotic significances are displayed.

Source: own developed.

The results of the post hoc analysis obtained indicated that statistically significant differences exist between the generations surveyed (Table 8). Pairwise comparison showed that there were significant differences in the levels of continuance commitment between Generation Z and Generation X, between Generation Z and Baby Boomers, as well as between Generation Y and Generation X, and between Generation Y and Baby Boomers.



**Table 8.**

*The results of post-hoc comparisons between the generations examined: continuance commitment (pairwise comparison)*

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Generation Z - Generation Y	-36.600	16.749	-2.185	0.029	0.173
Generation Z - Generation X	<u>-111.128</u>	<u>15.324</u>	<u>-7.252</u>	<u>&lt;0.001</u>	<u>0.000</u>
Generation Z - Baby Boomers	<u>-151.058</u>	<u>19.108</u>	<u>-7.906</u>	<u>&lt;0.001</u>	<u>0.000</u>
Generation Y - Generation X	<u>-74.527</u>	<u>14.877</u>	<u>-5.009</u>	<u>&lt;0.001</u>	<u>0.000</u>
Generation Y - Baby Boomers	<u>-114.458</u>	<u>18.751</u>	<u>-6.104</u>	<u>&lt;0.001</u>	<u>0.000</u>
Generation X - Baby Boomers	-39.931	17.490	-2.283	0.022	0.135

Note. Each row tests the null hypothesis that the Sample 1 and the Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05.

Source: own developed.

Also with respect to normative commitment, the Kruskal-Wallis test showed that differences between particular generations were statistically significant, hence a post-hoc nonparametric analysis was also conducted (Table 9).

**Table 9.**

*The significance of differences between the average levels of normative commitment in the generations examined: results of the Kruskal-Wallis test*

Null hypothesis	Test	Test statistic	Significance	Decision
Distribution of normative commitment is the same across generations of employees	Independent samples Kruskal-Wallis Test	25.831	<0.001	Reject the null hypothesis

Note. The significance level is 0.05; Asymptotic significances are displayed.

Source: own developed.

Post-hoc nonparametric comparison revealed that similarly to continuance commitment there were also significant differences in the levels of normative commitment between Generation Z and Generation X, Generation Z and Baby Boomers, as well as between Generation Y and Generation X, and between Generation Y and Baby Boomers (Table 10).

**Table 10.**

*The results of post-hoc comparisons between the generations examined: normative commitment*

Sample 1-Sample 2	Test Statistic	Std. Error	Std. Test Statistic	Sig.	Adj. Sig.
Generation Z - Generation Y	-1.125	16.747	-0.067	0.946	1.000
Generation Z - Generation X	<u>-43.469</u>	<u>15.322</u>	<u>-2.837</u>	<u>0.005</u>	<u>0.027</u>
Generation Z - Baby Boomers	<u>-79.947</u>	<u>19.105</u>	<u>-4.185</u>	<u>&lt;0.001</u>	<u>0.000</u>
Generation Y - Generation X	<u>-42.344</u>	<u>14.875</u>	<u>-2.847</u>	<u>0.004</u>	<u>0.027</u>
Generation Y - Baby Boomers	<u>-78.822</u>	<u>18.748</u>	<u>-4.204</u>	<u>&lt;0.001</u>	<u>0.000</u>
Generation X - Baby Boomers	-36.479	17.487	-2.086	0.037	0.222

Note. Each row tests the null hypothesis that the Sample 1 and the Sample 2 distributions are the same. Asymptotic significances (2-sided tests) are displayed. The significance level is 0.05.

Source: own developed.

The conducted analyses proved that the lowest level of organizational commitment and its components characterized the Generation Z and the highest level of organizational commitment and its components characterized Baby Boomers. Because the presented analyses showed that these differences were statistically significant, hence there are no reasons to reject the second and third hypotheses (H2 and H3).

#### **4. Discussion and conclusions**

The results of the study revealed that there were no reasons to reject the posted hypotheses. Generally, the level of overall organisational commitment of the employees surveyed was rather average but differed significantly between the examined generations (H1). Generation Z was characterised by the lowest level of organisational commitment, while Baby Boomers were characterized by its highest level (H2 and H3). These findings are in line with a previous study indicating that employees' commitment is related to their age and seniority (Allen, Meyer, 1993). Furthermore, organizational commitment concerns the ties and loyalty of employees to the organization which develops over time, hence it is logical that younger employees of Generations Z and Y are less committed than the older generations X and Baby Boomers. In addition, changes in employees' career patterns and the conditions of the psychological contract between the employee and the organisation, which concerns especially younger generations, mean that young employees feel a weak bond with the organisation, do not feel internal obligation to stay with the organisation and are more likely to change jobs easily to one that better suits their preferences and needs. This statement is supported by the findings that differences between Generation Z and older Generations X and Baby Boomers were particularly considerable in their normative and continuance commitment. Regarding affective commitment despite significant differences in its levels, it should be noticed that it was the highest rated component of organisational commitment and its level was the most equal. These results suggest that regardless of the generation many of the examined employees stay in their organisations because they feel emotionally connected to them.

Obviously, the differences in work attitudes and behaviours between the generations increase as the 'age gap' between them grows. However, an interesting finding is that in case of ratings of overall organisational commitment, there were less differences between Generations Y and Z than between Generations Y and X. Similarly with respect to continuance and normative commitment significant differences were found between Generation Y and X but not between Generations Z and Y. These findings suggest that regarding organisational commitment Generation Y seems to be more similar to Generation Z than to Generation X.

Limitations of this study and directions for future studies should also be mentioned. First and foremost, it would be important to identify what employee commitment building activities are being undertaken for different generations of employees in organisations and whether they are aligned with their needs and expectations. Furthermore, an important question arises to what extent these activities are linked to employee career planning and development and whether they include generations of older employees, often overlooked in the Polish organisations. Therefore, on the one hand, further research should pay particular attention to organisational practices for later life work and active aging policy directed at Generation X and Baby Boomers. On the other hand, the reasons for the low level of organisational commitment of the youngest generations of employees should also be examined in depth.

Moreover, it should be noted that the purposive sampling method makes it impossible to generalise results, hence in future a random sampling method should be used. To capture the differences between the younger and older generations, the respondents representing the youngest generation were students in fields related to the use of the latest communication technologies. As a result, the differences between them and older generations may be more pronounced than for other members of Generation Z. In turn, because family members were also surveyed as representatives of older generations, their work attitudes may be influenced by socialisation processes in the family, what also limits representatives of the results obtained.

To sum up, the new challenges associated with the ageing of society, longer work life, labour market shortages lead to increasing age diversity in organisations, where today four generations of employees, i.e. Generations X, Y, Z, and Baby Boomers meet. These generations grew up in different socio-economic environments which shaped their specific competencies, weaknesses and strengths, values, work attitudes and behaviours. This diversity with the appropriate HRM policy can create many new opportunities for the organisation rather than threats. However, this requires the use of HRM methods and tools adapted to the needs of different generations of employees. In the face of these changes, organisations should encourage partnership and collaboration between different generations of employees and enhance their commitment regardless of age, allowing their mutual learning and the utilization of their specific strengths (Gajdzik, 2016). Given the rapid growth of knowledge and the fast obsolescence of employee competencies, it is particularly important to provide opportunities for professional development, which for many employees, especially Generation Z, is an important factor in increasing their organizational commitment. This area is closely linked to career planning, which in turn often does not encompass older generations of employees in organizations. As a result, many of them fear the premature end of their careers, while at the same time wishing to remain in the labour market for as long as possible and be useful for organizations.

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## PERCEPTION OF ORGANIC, FUNCTIONAL AND GENETICALLY MODIFIED FOODS – A STUDY AMONG CONSUMERS IN GDYNIA, POLAND

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**Purpose:** The main objective of the research was to identify the factors, including gender and generation, which affect the decision-making process of purchasing and consuming organic, functional, and GMO foods.

**Design/methodology/approach:** The research instrument was a survey questionnaire administered through the CAWI method using Google forms. The survey was conducted in spring 2023 among a group of 194 respondents in Gdynia, Sopot and Gdansk in the Pomeranian Voivodeship (Northern Poland). To select the respondents for the survey sample, the snowball sampling technique was used. They also acknowledged the inherent risk factors associated with conducting an interview using the CAWI method. The interview questionnaire consisted of thematic blocks including scales on: subjective self-assessment of health and diet, attitudes towards organic food, functional food, GMOs and health and health values of food.

**Findings:** The assessment of respondents' attitudes towards different types of food: organic, functional and GMO foods, as well as health and health values of food, showed mostly ambivalent attitudes of respondents in the subject studied.

**Research limitations/implications:** The research carried out has certain limitations. The identification of factors influencing the attitudes of consumers belonging to generations X, Y, Z towards organic, functional and GMO food, as well as the health and health values of food, was carried out using a snapshot sample of the inhabitants of Gdynia. The results of the survey are therefore not representative of the entire Polish population and should be interpreted with caution.

**Practical implications:** The results of this study can be used as a basis for discussion and consideration of the development of intelligent food systems using information and communication technologies (ICT). These systems will provide consumers (Generations X, Y, Z) with knowledge about the range and quality of organic, functional and GMO foods and help to meet the nutritional needs of societies.

**Social implications:** The research conducted is part of health risk management and health promotion in the Polish population.

**Originality/value:** The results of the pilot study indicate that respondents' knowledge of the nutritional value and safety of organic, functional and GMO products is very low. Changing respondents' attitudes from ambivalent to positive towards organic and functional foods will lead to an expansion of the range of foods consumed and minimise the risk of developing non-communicable diseases, including metabolic and cardiovascular diseases.

**Keywords:** attitudes to food, quality of food, quality of life, health, consumer behaviour of generations X, Y, Z.

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

## 1. Introduction

The complexity of consumer behaviour makes it challenging to determine, given the numerous internal and external factors that contribute to it. The study of such behaviour is a difficult process. The various determinants of consumer behaviour aid in market development, as new facilities and bespoke products and services are created to meet their needs (Bilska et al., 2012). Understanding consumer behaviour is crucial for creating and executing a successful course of action for any business in the market. This knowledge empowers businesses to shape consumer choices (Górska-Warsewicz, 2017).

The environment surrounding consumers is highly varied and complex, particularly in terms of the stimuli which impact them directly (Grębowiec, 2018). This environment is shaped by socio-cultural, personal, and psychological factors. Personal factors arise from individual attributes like age, gender, personality, preferences, needs, interests, hobbies, opinions, and financial status. Psychological factors include higher-order needs. These include the needs for self-actualisation, motivation, esteem, belongingness, recognition (Rybowska, 2018). A consumer's motivation to take action depends on his or her personality and motives, while the choice of a product and the final decision to purchase it depend on the consumer's attitude towards the object, which is the result of the consumer's evaluation of the product and beliefs (Jeżewska-Zychowicz, 2009).. Socio-cultural factors are: culture, subculture, status, education, family, friends, social groups, work. Culture sets the framework in shaping our social norms, values and perception of needs. It influences how consumers make decisions and their purchasing behaviour (Gawęcki et al., 2000; Bilska et al., 2012).

The consumer environment is greatly influenced by market conditions relating to factors such as demographic, social, economic, competition and technological advances. Demographic factors, such as population, number of people in the household, age and income level, can influence consumer demand for goods and services. The significance of these rules originates from prevailing social and cultural norms, which dictate gender and age-appropriate

behaviours. The violation of said norms is generally viewed negatively by the surrounding societal group (Gawęcki et al., 2000). Socioeconomic factors, including income, education, occupation, and family structure, have a significant impact on the frequency of purchases and the level of goods consumed. The development of new products and production approaches through technological advancements can alter supply and demand, generating market competition.

The food-related sector is an essential part of the market that is continually evolving due to social, cultural, and demographic changes. Consumer value systems and behaviour are transforming as a result of globalisation, changing lifestyles, frequent travel, and the fading of borders (Grębowiec, 2018; Zabrocki, 2014). Eating behavior encompasses various aspects such as food and dish selection, purchase organization, food storage, planning and preparation for consumption, meal composition, mealtime and location, customary dining partners, and food quality in its broadest interpretation (Goryńska-Goldmann, Ratajczak, 2010; Bigliardia, Galati, 2013).

Paying attention to health and environmental factors is increasingly significant in contemporary societies (Żakowska-Biomas, 2011; Didkowska et al., 2017). This factor deeply impacts consumer perception and food choices. The choice of food for consumption is predominantly concerned with its beneficial effects on human health, as evidenced by various studies (Błaszczak, Grześkiewicz, 2014; Bryła, 2018; Fabisiak, Grochowicz, 2018; Kołodziejczyk, Wojciechowski, 2020). It is also essential to choose products that are free of chemical contaminants and synthetic additives, according to Hermaniuk (2018) and Gadomska et al. (2014). For instance, environmentally conscious individuals might be more prone to purchase eco-friendly products (Wiśniewska, 2022).

The introduction of non-traditional foods has sparked controversy and scepticism among certain consumer groups (Barska, 2018). The fear and anxiety associated with new foods can prevent consumers from acquiring knowledge and experiencing these new products (Socha et al., 2009; Platta, 2019; Siddiqui et al., 2022). As a consequence, a reduced variety of products purchased reduces the demand for new foods in the market (Kozioł-Kozakowska, Piórecka, 2013).

Identifying trends in the consumption of organic, functional, and GMO foods constitutes a crucial matter for fulfilling the nutritional requirements of present and future generations. Although studies on the topic are available in literature, they mainly pertain to organic food. The articles cited contend that a disparity exists between the professed favourable attitudes and the actual purchasing behaviour of consumers towards organic produce (which they only buy in small volumes) (Buder et al., 2014; Caniëls et al., 2021; Paladino, Ng, 2013; Young et al., 2010). In the context of consumer willingness to purchase foods (including organic, functional and GM foods), elements such as convenience of purchase and use, degree of satisfaction of a perceived need, their quality, performance, sustainability and trust in the provider and its offer are also not without importance (Lewicka-Strzałecka, 2015). Given that consumers may differ

in their attitudes towards organic, functional and GM foods, which may be due to different awareness of the realisation of nutritional needs, lifestyle and socio-demographic variables, research in this area is warranted.

## 2. Research methodology

The main objective of the research was to identify the factors, including gender and generation, which affect the decision-making process of purchasing and consuming organic, functional, and GMO foods.

The empirical research was carried out using the survey method. The research instrument was a survey questionnaire. The survey was conducted in an indirect form using the CAWI method (Google forms). The survey was conducted in spring 2023 among a group of 194 respondents in Gdynia, Sopot and Gdańsk in the Pomeranian Voivodeship (Northern Poland). A snowball sampling technique was used to select the respondent for the survey sample. A total of 109 females (56.19%) and 85 males (43.81%), aged between 19 and 59, participated in the study. The study sample was primarily composed of individuals from Generation X, with 52.94% of men and 58.72% of women. Secondary education (40.37%) and higher education (38.53%) were the dominant educational levels among women, while men's education was distributed evenly. Participants provided informed and voluntary consent to take part in the study. The participants affirmed their knowledge of potential hazards in employing the CAWI method for interviews. The characteristics of the study sample are presented in Table 1.

**Table 1.**  
*Study sample characteristics*

Parameters	Percentage [%]	
	Male	Female
<b>Gender</b>	43.81	56.19
<b>Generation</b>		
Z	24.71	24.77
Y	22.35	16.51
X	52.94	58.72
<b>Education</b>		
Primary or vocational education	32.94	21.10
Secondary	34.12	40.37
Higher	32.94	38.53

Source: own elaboration based on survey results.

The interview questionnaire consisted of thematic blocks including scales on: subjective self-assessment of health and diet, attitudes towards organic food, functional food, GMOs and health and health values of food.

Respondents answering the questions: 1. "How would you rate your health?" could indicate 1 of 5 answers: very bad, bad, neither bad nor good, good, very good; 2. "How would you rate your diet?" could indicate 1 of 5 answers: definitely correct, rather correct, sometimes correct and sometimes incorrect, rather incorrect, incorrect.

The study used quasi-standardised interview questionnaires to assess respondents' attitudes towards organic, functional and GMO foods (Roininen, Tuorila, 1999). Each respondent stated his or her attitude towards the statements on scales according to a 5-point scale with boundary marks "strongly disagree" to "strongly agree", which were assigned a logical number of points reflecting increasing intensity of the attribute when the results were compiled (Ritchey et al., 2003). All possible answers are: strongly disagree - 1 point, rather disagree - 2 points, neither disagree nor agree - 3 points, rather agree - 4 points, strongly agree - 5 points. On the basis of the average value of the sum of points, 3 categories of attitudes towards organic food, functional food and GMO were determined to describe the surveyed group of respondents. 1/3 and 2/3 of the mean score values were used as a criterion for division: negative attitudes (<1/3 of the range), ambivalent attitudes (1/3 to 2/3 of the range) and positive attitudes (> 2/3 of the range).

Respondents' attitudes towards organic food were assessed by answering 6 statements: 1) I don't eat processed foods because I don't know what's in them; 2) I try to avoid products with additives; 3) I would like to eat only organic food; 4) Palatability additives are harmful; 5) Organic food is no better for health than conventional food; 6) I do not pay attention to the additives in the products I eat every day. In accordance with the methodology, reverse scoring was applied to 2 (out of 6) statements made: 5, 6.

Respondents' attitudes towards functional foods were assessed based on their responses to 8 statements: 1) I eat functional foods for health reasons; 2) It's great that modern technology is enabling the development of functional foods; 3) Functional foods are completely unnecessary; 4) Functional foods improve my well-being; 5) Functional foods are a total scandal; 6) Functional foods are useless; 7) Functional foods support a healthy lifestyle; 8) Healthy people should not eat functional foods. In line with the methodology, reverse scoring was applied to 4 (out of 8) statements made: 3, 5, 6, 8.

Respondents' attitudes towards GMO foods were assessed by answering 6 statements: 1) GM food production will be the answer to world hunger; 2) I don't trust modified foods because I don't know what the health effects of eating them might be; 3) I trust GM food because it is controlled at every stage of production; 4) Eating GM food is good for health; 5) I am afraid of GM food because I don't know what it contains; 6) Genetic modification makes it possible to increase the nutritional value of products, with beneficial effects on health. In accordance with the methodology, reverse scoring was applied to 2 (out of 6) statements made: 2, 5.

Respondents' attitudes towards the health and health values of food were assessed using the General Health Interest (GHI) scale (Roininen, Tuorila, 1999). The GHI scale consists of 8 statements: 1) I am very particular about the healthiness of food I eat; 2) I always follow a healthy and balanced diet; 3) It is important for me that my diet is low in fat; 4) It is important

for me that my daily diet contains a lot of vitamins and minerals; 5) I eat what I like and I do not worry much about the healthiness of food; 6) The healthiness of food makes no difference to me; 7) The healthiness of snacks makes no difference to me; 8) I do not avoid foods, even if they may raise my cholesterol. In line with the methodology, reverse scoring was applied to 4 (out of 8) statements made: 5, 6, 7 and 8.

The questionnaire included questions that addressed the sociodemographic characteristics of the respondent, including: gender, age and education level.

When formulating the final conclusions and discussing the results of the study, the factors of gender (male and female) and age (belonging to generations X, Y and Z) were taken into account as differentiating features among the group of respondents under study. Accordingly, the empirical data collected underwent statistical analysis, utilizing Statistica 13.3 (Tibco, Krakow, Poland). The results of this analysis were subsequently presented via the percentage distribution of individual assessments. The chi-square test with Yates correction was used to determine the influence of gender and age on health status, diet and respondents' attitudes towards organic food, functional food, GMOs and health and health values of food. For all analyses, significance was set at  $p \leq 0.05$ .

### 3. Results and discussion

#### 3.1. Subjective self-assessment of health and diet

The respondents' health status and diet were assessed by gender and age group of the respondents (generation Z, Y, X). Significant differences ( $p \leq 0.05$ ) were observed for both health ( $p < 0.01$ ) and diet ( $p < 0.01$ ) across age groups. In contrast, men and women did not differ significantly in their assessment of health status ( $p = 0.54$ ), but did differ significantly in their assessment of diet ( $p = 0.05$ ) (Table 2).

The highest proportions of men and women rating their health as very good and good were in the oldest age group (Generation X), 11.93 and 13.76% of men and 21.10 and 14.68% of women respectively (Table 2). Generation Y was dominated by those who rated their health as good (13.51% of men and 18.91% of women) and 'neither fair nor poor' (13.51% of men and 10.81% of women). In contrast, Generation Z respondents were most likely to rate their health as 'neither fair nor poor' (14.58% of men and 31.25% of women) (Table 2).

Significant differences were observed in respondents' subjective self-assessment of their diet, both between men and women ( $p = 0.05$ ) and within age groups ( $p < 0.01$ ) (Table 3).

**Table 2.**  
*Subjective self-perceived health status*

Health status	Gender	Percentage [%]		p
		Male	Female	
very good	X	11.93	21.10	<0.01* 0.54**
good		13.76	14.68	
neither bad nor good		4.59	11.02	
bad		5.50	2.75	
very bad		5.50	9.17	
very good	Y	10.81	5.41	
good		13.51	18.91	
neither bad nor good		13.51	10.81	
bad		8.11	8.11	
very bad		5.41	5.41	
very good	Z	8.33	4.17	
good		6.25	12.51	
neither bad nor good		14.58	31.25	
bad		6.25	6.25	
very bad		8.33	2.08	

Explanatory notes: \*Chi2 health status v generation; \*\*Chi2 health status v gender.

Source: own elaboration based on survey results.

**Table 3.**  
*Subjective self-perceived of diet*

Diet	Gender	Percentage [%]		p
		Male	Female	
Incorrect	X	6.42	9.17	<0.01* 0.05**
Rather incorrect		7.34	5.50	
Sometimes correct and sometimes incorrect		4.59	13.76	
Rather correct		14.68	11.01	
Definitely correct		8.26	19.27	
Incorrect	Y	5.41	5.41	
Rather incorrect		10.81	5.41	
Sometimes correct and sometimes incorrect		18.91	18.91	
Rather correct		10.81	10.81	
Definitely correct		5.41	8.11	
Incorrect	Z	8.33	4.17	
Rather incorrect		10.42	12.50	
Sometimes correct and sometimes incorrect		14.58	31.25	
Rather correct		8.33	4.17	
Definitely correct		2.08	4.17	

Explanatory notes: \*Chi2 health status v generation; \*\*Chi2 health status v gender.

Source: own elaboration based on survey results.

In Generation X, the highest percentage of respondents described their diet as "rather correct" and "definitely correct" (14.68 and 8.26%, respectively, and 11.01 and 19.27%, men and women, respectively). In generations Y and Z, the largest proportions of respondents, both men and women, described their diet as 'sometimes correct and sometimes incorrect' (18.91 and 14.58% and 18.91 and 31.25%, respectively) (Table 3).

### 3.2. Assessing attitudes to organic food

The modern consumer is conscious of what he or she buys. The quality and composition of a product are the most important factors influencing their decisions. Consumers are increasingly abandoning the consumption of traditional foods in favour of organic products (Kulyk, Dubicki, 2019).

Significant differences in attitudes towards organic food were observed both by gender and by age of the respondent group. It is noteworthy that only in Generation X there was a predominance of people with a positive attitude towards organic products (22.02% of men and 38.53% of women) and no people with a negative attitude. In generations Y and Z, most people had an ambivalent attitude. On the other hand, women of all ages did not express a negative attitude towards this food group (Table 4). Consumer interest in organic food is part of new trends in food market behaviour. EU legislation on organic food sets out the criteria for awarding quality labels and product certification, and provides the basis for shaping the economic benefits of organic food production (Kulyk, Dubicki, 2019).

**Table 4.**

*Attitudes to organic food*

Attitudes	Generation	Percentage [%]		<i>p</i>
		Male	Female	
positive	X	22.02	38.53	<b>&lt;0.01*</b> <b>0.04**</b>
ambivalent		19.27	20.18	
negative		0.00	0.00	
positive	Y	16.22	24.32	
ambivalent		32.43	24.32	
negative		2.71	0.00	
positive	Z	10.42	18.75	
ambivalent		31.25	37.50	
negative		2.08	0.00	

Explanatory notes: \*Chi2 attitudes to organic food v generation; \*\*Chi2 attitudes to organic food v gender.

Source: own elaboration based on survey results.

Significant generational differences were observed for most of the reported attitudes towards organic food (Table 5). Only the perception that the consumption of organic food has no more beneficial effects on human health than conventional food ( $p = 0.19$ ) and the attention paid by consumers to additives in the products they eat every day ( $p = 0.28$ ) did not differ (Table 5).



**Table 5.***Respondents' responses to organic products attitude scale statements*

Scale statements	Gender [% indications]			p
	X	Y	Z	
<b>I don't eat processed foods because I don't know what's in them</b>				
Strongly disagree	7.22	4.12	6.19	<b>0.02</b>
Rather disagree	8.77	3.09	7.73	
Neither disagree nor agree	10.82	2.58	1.04	
Rather agree	12.89	4.12	6.70	
Strongly agree	16.49	5.15	3.09	
<b>I try to avoid products with additives</b>				
Strongly disagree	4.12	3.09	5.15	<b>0.01</b>
Rather disagree	6.19	2.58	5.15	
Neither disagree nor agree	9.79	3.61	3.09	
Rather agree	23.20	9.28	7.22	
Strongly agree	12.89	0.52	4.12	
<b>I would like to eat only organic food</b>				
Strongly disagree	4.12	3.61	5.67	<b>0.02</b>
Rather disagree	3.61	1.04	3.61	
Neither disagree nor agree	10.82	5.15	5.67	
Rather agree	20.10	6.70	5.67	
Strongly agree	17.53	2.58	4.12	
<b>Palatability additives are harmful</b>				
Strongly disagree	1.55	1.55	3.61	<b>0.05</b>
Rather disagree	9.79	5.15	5.15	
Neither disagree nor agree	13.41	4.12	6.71	
Rather agree	16.49	6.70	5.15	
Strongly agree	14.95	1.55	4.12	
<b>Organic food is no better for your health than conventional food</b>				
Strongly disagree	14.43	2.06	4.64	0.19
Rather disagree	18.04	6.70	7.73	
Neither disagree nor agree	14.95	4.64	7.22	
Rather agree	4.64	3.09	4.64	
Strongly agree	4.12	2.58	0.52	
<b>I do not pay attention to the additives in the products I eat every day</b>				
Strongly disagree	12.88	3.61	7.22	0.28
Rather disagree	20.10	4.64	4.63	
Neither disagree nor agree	11.34	5.66	6.19	
Rather agree	8.25	3.61	6.19	
Strongly agree	3.61	1.55	0.52	

Explanatory notes: \*Chi2 attitudes to organic food v generation.

Source: own elaboration based on survey results.

Analysing the responses to the individual questions, it is clear that Generation X is not only characterised by a positive attitude, but also by nutritional knowledge. In the answers given by Generation X to the questions "I try to avoid products with additives", "Palatability additives are harmful" or "I would like to eat only organic food", the predominant responses were "I rather agree" and "I strongly agree", while no such variation between responses was observed in the other generations (Table 5). Studies by other authors confirm health consciousness, consumer knowledge, perceived or subjective norms, and perception of price influence consumers' attitudes toward buying organic foods. Availability is another factor that affected the purchase intentions of consumers. Age, education, and income are demographic factors that also impact consumers' buying behavior (Gundala, Singh, 2021; Hermaniuk, 2018).

### 3.3. Assessing attitudes to functional foods

The consumption of functional products can significantly reduce the incidence of many diseases, hence the dynamic development of this food sector (Makała, 2019). However, according to the literature, the majority of consumers have negative attitudes towards functional foods in terms of the nutritional enrichment of products, and positive attitudes towards these foods due to the elimination of substances harmful to human health from products (Gutkowska, Czarnecki, 2020).

The research papers showed that several factors, including socio-demographic, cognitive and attitudinal ones, seem to be serve as the basis for the acceptance of functional products (Topolska et al., 2021). Significant differences ( $p < 0.01$ ) were observed in attitudes to functional foods according to the generation of respondents. However, the groups did not differ significantly by gender ( $p = 0.09$ ). It is noteworthy that, in all groups, indifferent attitudes predominated among men (24.77% for X; 37.84% for Y and 27.08% for Z), whereas among women, with the exception of Generation X, positive attitudes towards functional foods predominated (24.32% for Y and 31.25% for Z) (Table 6).

**Table 6.**

*Attitudes to functional foods*

Attitudes	Gender	Percentage [%]		<i>p</i>
		Male	Female	
positive	X	15.60	23.85	<b>&lt;0.01*</b> 0.09**
ambivalent		24.77	28.44	
negative		0.92	6.42	
positive	Y	13.51	24.32	
ambivalent		37.84	21.62	
negative		0.00	2.71	
positive	Z	16.67	31.25	
ambivalent		27.08	22.92	
negative		0.00	2.08	

Explanatory notes: \*Chi2 attitudes to functional foods v generation; \*\*Chi2 attitudes to functional foods v gender.

Source: own elaboration based on survey results.

When assessing attitudes towards functional foods, generations X, Y and Z differed significantly in their responses to the statements: "Functional foods are completely unnecessary" ( $p = 0.02$ ), "Functional foods are a total scandal" ( $p < 0.01$ ), "Functional foods are useless" ( $p < 0.01$ ) and "Healthy people should not eat functional foods" ( $p = 0.03$ ) (Table 7).

**Table 7.***Respondents' responses to functional food attitude scale statements*

Scale statements	Gender [%indications]			
	X	Y	Z	p
<b>I eat functional foods for health reasons</b>				
Strongly disagree	8.25	3.61	4.64	0.95
Rather disagree	9.28	2.07	5.15	
Neither disagree nor agree	13.92	5.15	5.67	
Rather agree	13.40	4.12	5.67	
Strongly agree	11.34	4.12	3.61	
<b>It's great that modern technology is enabling the development of functional foods</b>				
Strongly disagree	7.73	2.06	2.06	0.97
Rather disagree	10.31	3.61	5.67	
Neither disagree nor agree	15.98	5.15	6.70	
Rather agree	15.98	5.67	6.19	
Strongly agree	6.19	2.58	4.12	
<b>Functional foods are completely unnecessary</b>				
Strongly disagree	6.70	1.03	4.12	0.02
Rather disagree	10.82	3.62	9.28	
Neither disagree nor agree	18.56	6.70	7.73	
Rather agree	12.37	6.70	1.55	
Strongly agree	7.73	1.03	2.06	
<b>Functional foods improve my well-being</b>				
Strongly disagree	5.15	1.55	2.58	0.29
Rather disagree	13.92	4.64	3.09	
Neither disagree nor agree	20.09	6.19	11.34	
Rather agree	10.82	6.19	4.12	
Strongly agree	6.19	0.52	3.61	
<b>Functional foods are a total scandal</b>				
Strongly disagree	6.19	2.06	8.25	<0.01
Rather disagree	14.94	2.06	6.70	
Neither disagree nor agree	18.04	9.28	7.22	
Rather agree	9.79	4.64	1.55	
Strongly agree	7.22	1.03	1.03	
<b>Functional foods are useless</b>				
Strongly disagree	7.22	1.55	9.78	<0.01
Rather disagree	11.86	3.09	3.61	
Neither disagree nor agree	19.58	9.28	8.25	
Rather agree	10.31	4.12	2.58	
Strongly agree	7.22	1.03	0.52	
<b>Functional foods support a healthy lifestyle</b>				
Strongly disagree	6.70	2.06	3.10	0.89
Rather disagree	9.79	2.58	3.10	
Neither disagree nor agree	15.98	6.70	8.76	
Rather agree	17.01	5.15	5.15	
Strongly agree	6.70	2.58	4.64	
<b>Healthy people should not eat functional foods</b>				
Strongly disagree	4.64	1.03	4.64	0.03
Rather disagree	11.34	2.06	6.70	
Neither disagree nor agree	20.62	7.73	9.79	
Rather agree	11.86	6.70	2.58	
Strongly agree	7.73	1.55	1.03	

Explanatory notes: \*Chi2 attitudes to functional foods v generation.

Source: own elaboration based on survey results.

All groups were dominated by responses reflecting ambivalent attitudes ('neither agree nor disagree') towards these types of products (Table 7). Gutkowska and Czarnecki (2020) showed that when choosing these functional foods, consumers pay attention to well-formulated marketing messages that take into account the health-promoting properties of the products, supported by legal regulations that increase consumer trust in food producers. Adequate knowledge and evidence-based communication seem to be the most promising ways to increase consumers' interest in these kinds of products (Topolska et al., 2021).

### 3.4. Assessing attitudes to GM foods

Respondents' attitudes to GMO food differed significantly between generations X, Y and Z ( $p < 0.01$ ), while no significant differences were observed according to respondents' gender ( $p = 0.09$ ). All groups were dominated by those with ambivalent attitudes (in Generation X: 24.77% of men and 36.70% of women; in Generation Y: 21.62% of men and 35.13% of women; in Generation Z: 29.16% of men and 50.00% of women) (Table 8).

**Table 8.**

*Attitudes to GMO food*

Attitudes	Generation	Percentage [%]		<i>p</i>
		Male	Female	
positive	X	3.67	5.50	<0.01* 0.09**
ambivalent		24.77	36.70	
negative		12.84	16.52	
positive	Y	18.92	5.41	
ambivalent		21.62	35.13	
negative		10.81	8.11	
positive	Z	10.42	4.17	
ambivalent		29.16	50.00	
negative		4.17	2.08	

Explanatory notes: \*Chi2 attitudes to GMO food v generation; \*\*Chi2 attitudes to GMO food v gender.

Source: own elaboration based on survey results.

Science is constantly evolving, leading to both positive and negative developments in public health and the environment. One result of scientific progress is the introduction of foods based on genetically modified organisms, the effects of which on human health are still poorly studied and inconclusive (Gutorova et al., 2018). It was shown that generations X, Y, Z differed significantly in their responses to the statements: "GM food production will be the answer to world hunger" ( $p = 0.03$ ), "Eating GM food is good for health" ( $p=0.01$ ), "I am afraid of GM food because I don't know what it contains" ( $p < 0.01$ ) (Table 9).

**Table 9.***Respondents' responses to GMO food attitude scale statements*

Scale statements	Gender [%indications]			p
	X	Y	Z	
<b>GM food production will be the answer to world hunger</b>				
Strongly disagree	17.53	3.61	2.58	<b>0.03</b>
Rather disagree	16.49	5.15	5.67	
Neither disagree nor agree	13.40	5.67	10.32	
Rather agree	3.09	1.55	4.12	
Strongly agree	5.67	3.09	2.06	
<b>I don't trust modified foods because I don't know what the health effects of eating them might be</b>				
Strongly disagree	5.15	4.12	3.61	0.17
Rather disagree	5.67	2.06	5.67	
Neither disagree nor agree	9.79	2.06	4.64	
Rather agree	16.49	6.19	6.19	
Strongly agree	19.08	4.64	4.64	
<b>I trust GM food because it is controlled at every stage of production</b>				
Strongly disagree	20.62	4.12	5.15	0.41
Rather disagree	15.46	6.19	8.77	
Neither disagree nor agree	11.34	4.12	6.19	
Rather agree	4.64	1.55	3.09	
Strongly agree	4.12	3.09	1.55	
<b>Eating GM food is good for health</b>				
Strongly disagree	20.10	4.64	4.12	<b>0.01</b>
Rather disagree	14.95	5.15	7.73	
Neither disagree nor agree	11.34	3.09	10.83	
Rather agree	5.67	2.58	1.55	
Strongly agree	4.12	3.61	0.52	
<b>I am afraid of GM food because I don't know what it contains</b>				
Strongly disagree	5.15	2.06	3.63	<b>&lt;0.01</b>
Rather disagree	1.03	3.09	5.15	
Neither disagree nor agree	9.79	4.12	5.67	
Rather agree	18.56	4.64	4.64	
Strongly agree	21.65	5.15	5.67	
<b>Genetic modification makes it possible to increase the nutritional value of products, with beneficial effects on health</b>				
Strongly disagree	19.59	5.15	3.09	0.12
Rather disagree	13.40	4.64	7.73	
Neither disagree nor agree	14.43	6.70	11.35	
Rather agree	4.12	1.03	1.55	
Strongly agree	4.64	1.55	1.03	

Explanatory notes: \*Chi2 attitudes attitudes to GMO food v generation.

Source: own elaboration based on survey results.

In recent years, many studies have been conducted on public perception of functional foods and genetically modified foods. The results of these studies show that consumers are not very confident about consuming these types of foods because they have little knowledge about them. In addition, they fear that controls on new foods are not carried out reliably or that they are cheated by producers (Klimczuk-Kochańska, 2017). According to the literature on the subject, consumers expressed the greatest concerns about GMO foods, which are produced by manipulating the genetic material of plants or animals. Consumers do not consider GMO foods as a safe type of food and have a very low level of knowledge about GMO products (Szyba, Iwaszczuk, 2019). Studies by other authors These findings indicate a need to clarify guideline

recommendations for health-related risks associated with foods derived from biotechnology (Pakseresht et al., 2021).

### 3.5. Assessing health attitudes and food health value

Significant differences were observed in the respondents' attitudes towards the health and health values of food by generations X, Y, Z ( $p = 0.01$ ), while the groups did not differ significantly by gender ( $p = 0.32$ ). Among Generation X, both positive (20.18% of men and 31.19% of women) and ambivalent (19.27% of men and 27.53% of women) attitudes towards health and the health value of food were found. Ambivalent attitudes predominated in generations Y and Z (in generation Y 43.24% of men and 37.84% of women; in Generation Z 29.17% of men and 35.42% of women) (Table 10).

**Table 10.**

*Attitudes towards health and the health value of food*

Attitudes	Generation	Percentage [%]		<i>p</i>
		Male	Female	
positive	X	20.18	31.19	<b>0.01*</b> 0.32**
ambivalent		19.27	27.53	
negative		1.83	0.00	
positive	Y	8.11	10.81	
ambivalent		43.24	37.84	
negative		0.00	0.00	
positive	Z	12.50	18.75	
ambivalent		29.17	35.42	
negative		2.08	2.08	

Explanatory notes: \*Chi2 attitudes towards health and the health value of food v generation; \*\*Chi2 attitudes towards health and the health value of food v gender.

Source: own elaboration based on survey results.

When assessing attitudes to General Health Interest scale statements, generations X, Y and Z differed significantly in the frequency of responses to the statements: "I am very particular about the healthiness of food I eat" ( $p = 0.02$ ), "I always follow a healthy and balanced diet" ( $p = 0.03$ ), "It is important for me that my diet is low in fat" ( $p < 0.01$ ) (Table 11).

**Table 11.**

*Respondents' responses to General Health Interest scale statements*

Scale statements	Gender [% indications]			<i>p</i>
	X	Y	Z	
<b>I am very particular about the healthiness of food I eat</b>				
Strongly disagree	3.09	2.06	1.55	<b>0.02</b>
Rather disagree	6.19	3.09	8.25	
Neither disagree nor agree	10.32	5.15	5.67	
Rather agree	16.49	4.12	6.19	
Strongly agree	20.10	4.64	3.09	

Cont. table 11.

<b>I always follow a healthy and balanced diet</b>				
Strongly disagree	6.19	1.03	2.06	<b>0.03</b>
Rather disagree	8.25	6.19	7.22	
Neither disagree nor agree	11.86	2.58	6.70	
Rather agree	15.96	7.73	5.67	
Strongly agree	13.92	1.55	3.09	
<b>It is important for me that my diet is low in fat</b>				
Strongly disagree	2.09	2.58	4.12	<b>&lt;0.01</b>
Rather disagree	5.68	4.12	9.77	
Neither disagree nor agree	17.53	6.17	4.64	
Rather agree	17.53	4.64	4.12	
Strongly agree	13.40	1.55	2.06	
<b>It is important for me that my daily diet contains a lot of vitamins and minerals</b>				
Strongly disagree	1.03	2.06	1.03	0.12
Rather disagree	8.78	3.09	6.70	
Neither disagree nor agree	8.25	4.12	5.15	
Rather agree	21.65	7.22	6.70	
Strongly agree	16.49	2.58	5.15	
<b>I eat what I like and I do not worry much about the healthiness of food</b>				
Strongly disagree	8.76	2.58	2.58	0.86
Rather disagree	14.43	4.63	6.19	
Neither disagree nor agree	14.95	3.61	6.19	
Rather agree	11.86	6.70	6.70	
Strongly agree	6.19	1.55	3.08	
<b>The healthiness of food makes no difference to me</b>				
Strongly disagree	12.89	2.08	3.09	0.62
Rather disagree	14.95	5.15	6.70	
Neither disagree nor agree	11.34	4.12	5.15	
Rather agree	11.86	4.12	5.67	
Strongly agree	5.15	3.61	4.12	
<b>The healthiness of snacks makes no difference to me</b>				
Strongly disagree	9.79	3.61	5.15	0.42
Rather disagree	15.46	3.09	3.61	
Neither disagree nor agree	12.37	5.15	6.70	
Rather agree	13.43	3.09	6.19	
Strongly agree	5.15	4.12	3.09	
<b>I do not avoid foods, even if they may raise my cholesterol</b>				
Strongly disagree	11.86	1.55	4.12	0.11
Rather disagree	17.01	3.09	5.15	
Neither disagree nor agree	12.38	6.70	6.70	
Rather agree	11.86	5.15	4.64	
Strongly agree	3.09	2.58	4.12	

Explanatory notes: \*Chi2 attitudes towards health and the health value of food v generation.

Source: own elaboration based on survey results.

#### 4. Conclusion and future perspectives

Perceptions of different types of food have been an issue for years and opinions are very divided, making it difficult to make food choices and maintain a healthy lifestyle. Food knowledge allows consumers to broaden their choices and provides opportunities to try

new foods. The assessment of respondents' attitudes towards different types of food: organic, functional and GMO foods, as well as health and health values of food, showed mostly ambivalent attitudes of respondents in the subject studied. No negative attitudes towards organic food were found among the group of women surveyed. The most frequently chosen response by the respondents to the statements in the scales presented in the study was "neither disagree nor agree". The second most frequent responses were: "rather disagree" and "rather agree". This indicates a high level of uncertainty among respondents about their answers.

The statements: "I try to avoid products with additives", "I would like to eat only organic food", "Palatability additives are harmful" were influential in shaping respondents' positive attitudes towards organic food. It was also shown that the statements "I eat functional foods for health reasons" and "Functional foods support a healthy lifestyle" influenced the occurrence of positive attitudes towards functional foods in the sample group of women and men. It was shown that the statement: "I don't trust modified foods because I don't know what the health effects of eating them might be" best described the attitudes of the male group surveyed towards GMO foods. Among women, the statement with the highest average score was: "GM food production will be the answer to world hunger". The statements: "I am very particular about the healthiness of food I eat" and "It is important for me that my daily diet contains a lot of vitamins and minerals" were influential in the emergence of positive attitudes towards health and the health values of food among the respondents.

The authors believe that research into consumer perceptions of different food types should continue, as the results of the pilot study indicate that respondents' knowledge of the nutritional value and safety of organic, functional and GMO products is very low. Changing respondents' attitudes from ambivalent to positive towards organic and functional foods will lead to an expansion of the range of foods consumed and minimise the risk of developing non-communicable diseases, including metabolic and cardiovascular diseases.

This study analyses the attitudes of consumers (Generation X, Y, Z) towards organic, functional and GMO foods and their concerns about the health and health values of food, and the results can be used as a basis for discussion and consideration of the development of intelligent food systems using information and communication technologies (ICT). These systems will provide consumers (Generations X, Y, Z) with knowledge about the range and quality of organic, functional and GMO foods and help to meet the nutritional needs of societies. In view of the challenges of the Sustainable Development Goals, it is useful and legitimate to carry out research to monitor the eating habits of different population groups in order to diagnose the need for hedonistic measures that are linked, among other things, to the issue of ensuring health and taking greater care of the mental and physical condition of current and future generations. The research conducted is part of health risk management and health promotion in the Polish population.



The research carried out has certain limitations. The identification of factors influencing the attitudes of consumers belonging to generations X, Y, Z towards organic, functional and GMO food, as well as the health and health values of food, was carried out using a snapshot sample of the inhabitants of Gdynia. The results of the survey are therefore not representative of the entire Polish population and should be interpreted with caution.

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## IMPLEMENTATION OF INVENTORY POLICY IN LOCAL GOVERNMENT UNITS

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**Purpose:** The aim of this article is to present the determinants of a properly conducted inventory process in local governments and to demonstrate the role of local Government Shared Service Centers (SSCs) in improving the quality of the inventory process.

**Design/methodology/approach:** The authors, based on a research tool - a case study, presented the results of inventory conducted in a rural municipality using a selected municipality in the Kuyavian-Pomeranian Voivodeship as an example. The inventory process was preceded by an analysis and development of appropriate internal documents, as well as employee training. After the inventory was completed, surveys were conducted among the employees involved in this process. The collected responses and the conducted literature studies, especially the analysis of post-control findings of national control organizations such as the Regional Audit Offices, allowed for drawing conclusions and achieving the set research goal.

**Research limitations/implications:** The conducted studies on the literature related to the subject and the available post-control findings in the area of public finances of local government units allow for drawing conclusions regarding the complexity of the inventory process. Despite the legally and substantively well-defined process of conducting inventory in the Accounting Act, public entities, and particularly the local government units examined in this article, still make many mistakes in this process. The inventory process is especially crucial for the accurate preparation of financial statements for entities, including local government units.

**Originality/value:** The research highlights the need to distinguish between the organizational and substantive aspects of the inventory process. While local government units can handle the substantive part (selecting proper methods and principles for individual assets), the organizational aspect poses challenges, especially in rural municipalities with complex structures and limited staff. The study reveals the close connection between the inventory process and internal documents like Municipal Office Regulations, employee records, and asset responsibilities. The findings identify problematic areas in the inventory process. The authors suggest that utilizing SSCs could enhance efficiency and security.

**Keywords:** inventory, Local Government Shared Services Centers, public finance, public management.

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

## 1. Introduction

The inventory policy is an exceptionally significant document in the process of creating accurate financial reports for local government units. Legal provisions, particularly Chapter 3 of the Accounting Act, govern the principles of inventory preparation, integrating them into the general accounting principles applicable to the respective entity (*Ustawa z dnia 29 września 1994 r. o rachunkowości*, 2023). However, the results of the Regional Audit Offices (Polish: Regionalna Izba Obrachunkowa – RIO) audit indicate numerous issues arising during the inventory process. The National RIO Council has pointed out that, I quote: *...errors occurred to varying degrees at each stage of the inventory process. The audit revealed numerous instances of non-compliance with applicable legal provisions and internal regulations, often conducted in an unreliable manner, involving actions or omissions, both on the part of unit managers and chief accountants. Irregularities included, among others: - failure to inventory all assets and liabilities, - conducting inventory in contravention of prevailing legal provisions and established procedures and instructions, - insufficient and unreliable inventory control, - failure to account for or incorrect accounting of the inventory* (Serwis Samorządowy PAP, 2016). As a result of the published report, the RIO called for the strengthening of managerial control in this area (Kęпка, 2016). Adamek-Hyska also perceives inventory as a component of managerial control and emphasizes that frequent errors in its improper planning and execution represent a significant violation of public finance discipline, affecting key individuals in public finance units, namely the manager of the public finance sector unit and its chief accountant (Adamek-Hyska, 2015). Maszczak also highlights commonly encountered errors in conducting inventory, which have a detrimental impact on the statutory purpose of its implementation, ultimately hindering the achievement of the intended outcome – the accurate preparation of the unit's financial report (Maszczak, 2017). The inventory process in local government units can be divided into stages, the scope and schedule of which are partly derived directly from the provisions of the Accounting Act (Polish: *Ustawa o Rachunkowości – UoR*). However, a crucial element of this process is its proper preparation. As indicated by Wachowicz, a key element of this process is the appropriate organizational preparedness of the unit, which encompasses the proper development of internal documentation and the training of employees (Wachowicz, 2017). Regional Audit Offices in Wrocław, in its 2016 report, pointed out the following categories of irregularities related to non-compliance with the provisions of the Accounting Act concerning inventory (Regionalna Izba Obrachunkowa we Wrocławiu, 2016):

1. Failure to conduct the inventory of individual assets and liabilities (resulting from the failure of the entity's manager, despite the statutory obligation to order its execution) or incomplete inventory of all assets and liabilities.

2. Conducting inventory activities in a manner inconsistent with legal regulations, including the use of inappropriate inventory methods, failure to meet inventory deadlines.
3. Lack of documentation or improper documentation of the results of the inventory.
4. Failure to reconcile the results of the inventory in the books for the year to which it pertained.
5. Failure to conduct a physical count of fixed assets owned by other entities.
6. Incorrect internal regulations of entities concerning inventory.

Therefore, we can group the identified inventory process irregularities into substantive ones related to methods, tool selection, or the lack of appropriate documentation, and those of an organizational nature, including the proper training of employees or the absence of assigned asset responsibility.

## 2. Literature review

The obligation, frequency, and scope of conducting inventory are defined in the provisions of the Accounting Act (Article 26 of the Accounting Act). Additionally, the Accounting Act imposes responsibility on the unit's manager for its execution, by requiring them to prepare the financial report of the unit in accordance with the provisions of the Accounting Act (*Ustawa z dnia 29 września 1994 r. o rachunkowości*, 2023). The legal framework for inventory matters in local government units is broader in scope. The Accounting Act itself highlights the responsibility of the unit's manager for conducting physical inventory, specifies the methods and deadlines for inventorying individual assets and liabilities of the unit, provides guidance on accounting for inventory differences in the accounting records, and outlines the documentation and reporting requirements for the inventory process (Motowilczuk, 2015). Violation of the provisions of the Accounting Act regarding inventory procedures is reflected in Article 18 of the Act on Liability for Violation of Public Finance Discipline (*Ustawa z dnia 17 grudnia 2004 r. o odpowiedzialności za naruszenie dyscypliny finansów publicznych*, 2023). Detailed guidelines regarding the nature of municipal real estate components have been specified in the regulation of the Minister of Development and Finance dated March 8, 2017 (*Obwieszczenie Ministra Rozwoju i Finansów z dnia 8 marca 2017 r. w sprawie ogłoszenia jednolitego tekstu rozporządzenia Ministra Finansów w sprawie szczególnych zasad rachunkowości oraz planów kont dla budżetu państwa, budżetów jednostek samorządu terytorialnego, jednostek budżetowych, samorządowych zakładów budżetowych, państwowych funduszy celowych oraz państwowych jednostek budżetowych mających siedzibę poza granicami Rzeczypospolitej Polskiej*, 2017). Kowalczyk (Kowalczyk, 2012) and Adamek-Hyska (Adamek-Hyska, 2015) interpret the statutory responsibility of the unit's manager for conducting inventory as follows:

- a) *The unit's manager is responsible for personally performing accounting duties when specific responsibilities have not been delegated to another individual.*
- b) *The unit's manager is not directly responsible for performing accounting duties when specific responsibilities have been assigned to another person with their consent in writing.*
- c) *The unit's manager is responsible for supervising the execution of duties by other individuals, even if specific responsibilities have been delegated to another person.*
- d) *The unit's manager cannot transfer the responsibility for conducting inventory using the physical count method to another person.*

Kaczurak-Kozak also points out that inventory is a key element in the course of the information process within a local government unit (Kaczurak-Kozak, 2011). The issues related to responsibility for violations of public finance discipline have been extensively discussed by Winarska and Kaczurak-Kozak, who have highlighted a significant element in defining it. Public finance discipline, in addition to complying directly with the legal provisions in this area, also involves strict adherence to rules set either within a group or self-imposed rules. Winarska and Kaczurak-Kozak point out that the fundamental legal act defining violations of public finance discipline, based on the negation of actions, is the Act of December 17, 2004, on Liability for Violation of Public Finance Discipline. The legislator, in emphasizing responsibility for breaches of public finance discipline, has highlighted its substantive and personal nature. In this context, the area of inventory also emerges as a potential risk of violating discipline, which is defined by the failure to conduct or account for inventory or by accounting for it in a manner inconsistent with the provisions of the Accounting Act (Winiarska and Kaczurak-Kozak, 2018). From a managerial control perspective, the proper planning and execution of the inventory process in a local government unit entail a significant risk of violating public finance discipline. The post-audit recommendations from the RIO and a review of the literature suggest that the organization and preparation of inventory are critical aspects of this process. Any errors or shortcomings in this phase can have an impact on the final and accurate outcome of the inventory, consequently affecting the accuracy of financial data in the published reports of local government units. In the context of risk management in local government units and the enhancement of their efficiency, special attention should be paid to specific organizational units known as Shared Service Centers (SSCs). Grzybowski et al. emphasize that, *The principle is that the head of the public finance sector unit is responsible for the entirety of the financial management. In the case of implementing shared services for organizational units within a local government unit, which are classified under the public finance sector, cultural institutions, or other local legal entities established to carry out public tasks (excluding enterprises, research institutes, banks, and commercial companies), this responsibility should be determined, taking into account the scope of duties assigned to the unit (or units) providing services within the framework of shared services. The legislator in Article 53(5) of the Public Finance Act explicitly states that the head of the servicing unit is responsible*



*for financial management, accounting, and reporting of the serviced unit in the scope of duties assigned by a resolution or agreement regarding shared services* (Grzybowski et al., n.d.). In the case of delegating responsibilities related to accounting and reporting for the serviced units, these tasks should be transferred in their entirety. Therefore, in this situation, a Shared Service Center (SSC) assumes responsibility, among other things, for conducting inventory in the serviced units. The organization and efficiency of local government Shared Service Centers have been extensively discussed in the literature (Gawłowski, Modrzyński, 2018; Modrzyński, 2018, 2020b, 2020a; Modrzyński, Gawłowski, Modrzyńska, 2018; Modrzyński, Gawłowski, 2019; Karaszewski, Modrzyński, Modrzyńska, 2021). The utilization of SSCs in the public sector aligns with global trends aimed at implementing organizational changes to enhance the efficiency of public administration and local government operations. Pollitt and Bouckaert, in presenting reforms in the public sector, defined their purpose as follows: *Deliberate changes to the structures and processes of public sector organizations with the objective of getting them (in some sense) to run better* (Pollitt, Bouckaert, 2011). When presenting global trends in public administration and local government management, one cannot overlook the contribution of Osborne, who, while defining the principles of New Public Management (NPM), emphasized the following key elements of management effectiveness:

- Development of Service Integration: Creating units (centers) that provide integrated, standardized services to other public entities.
- Promotion of e-Government: Implementing integrated electronic applications for delivering public services.
- Emphasis on Network Development: Encouraging collaboration networks within the public sector and with private and social partners (Osborne, 2009).

Indeed, New Public Management (NPM) has had a significant impact on the development of accounting and the creation of new forms and areas of responsibility within the field. NPM's emphasis on performance measurement, accountability, and efficiency has led to changes in public sector accounting practices. It has prompted the adoption of accrual accounting, the development of performance-based budgeting, and the establishment of more transparent and results-oriented financial reporting systems in the public sector. These changes aim to enhance the financial management and accountability of public organizations, aligning them more closely with private sector practices (Kurunmäki, 2009). The implementation of organizational changes based on efficiency indicators, as mentioned in NPM, initiated the development of public sector accounting, aimed at providing appropriately aggregated data (Watkins, Arrington, 2007). The administrative reforms focused on financial outcomes (Hood, 1991; Lodge, Page, Balla, 2015) have placed public sector organizations under simultaneous institutional pressure concerning social and financial responsibility, which, in a sense, acted as a catalyst for changes in the field of budgetary accounting (Clarke, Lapsley, 2004). In the context of public sector reform, there is a simultaneous increase in expectations placed

on financial and budgetary reporting, whose control functions align with the field of managerial control (Rahman et al., 2015).

The transfer of responsibility and the execution of inventory processes by a specialized unit, such as a Shared Service Center, appear to be the right direction for organizational changes in local governments. As indicated by previous research on shared services in local government entities, entrusting accounting services is a fundamental subject area of local government shared services.

The topic of inventory in local government units is widely discussed. The available literature focuses on substantive aspects of this process (Kołodziej, 2008), such as the selection of appropriate methods (Kąkol, 2018; Majewska, 2023; Kurylak, n.d.), documentation of the inventory process (Kołodziej, 2008; Maszczak, 2017; Król, 2023), and the correct accounting of inventory discrepancies (Kusio-Szalak, nd.). Despite the control findings presented by the RIO, which also address errors in the organization of the inventory process and its impact on the correctness of the inventory, there is still a lack of publications on this topic in the literature. A review of the subject literature allowed for the identification of **a research gap concerning the study of the inventory process in local government entities in the context of proper organization of this process.**

### 3. Research methodology

The topic of inventory has been extensively described and presented in the literature. However, the mentioned RIO (Serwis Samorządowy PAP, 2016) report points out numerous problems and errors in the organization and execution of this process. There can be many reasons for the occurrence of so many irregularities, and among them, it's important to consider the size and characteristics of a particular local government. Rural municipalities are units with complex subject matter structures but typically have limited organizational capacity. The execution of complex and comprehensive processes, such as inventory, is often problematic in such cases.

This article presents **the results of developing and implementing internal legal regulations in the field of inventory and accounting policy in a rural municipality in the Kuyavian-Pomeranian Voivodeship during the period from November 2021 to March 2022.**

The selected research method, **the case study**, allowed the authors to provide a comprehensive description of the phenomenon - the organization and process of inventory in the selected municipality. Based on the gathered information, this approach enabled them to conduct an in-depth analysis and assessment of problematic areas.

Based on the analysis of the literature, especially the post-audit results from the Regional Audit Offices, the following **research objectives were set**:

1. Identify the key risk areas in the inventory process within the examined municipality.
2. Analyze the key internal legal regulations of the municipality related to managerial control of the inventory process.
3. Develop guidelines for the proper organization of the inventory process for other rural municipalities based on the insights gained.

In the conducted research, the following research questions were posed: What elements of the organization of the inventory process are crucial for ensuring its correctness? Would the involvement of specialized units, such as local government shared service centers, have a positive impact on the inventory process?

The research results and conclusions drawn from the analyzed rural municipality were compared with the findings of the inventory process carried out in a large urban municipality by a specialized local government unit - the Shared Service Center.

Within the agreed scope of work, the following stages/areas were included:

- Examination and verification of the internal documentation of the rural municipality concerning the inventory of assets of the Municipal Office. The process of verifying documentation encompassed all management directives, instructions, and regulations specified by the Mayor of the Municipality regarding the principles of conducting inventory at the Municipal Office.
- Examination and verification of the procedures for appointing inventory committees at the Municipal Office and the method of conducting inventory activities.

During the process of verifying the internal documentation of the examined rural municipality, the recommendations and post-audit findings of the Regional Audit Offices (RIO) were also taken into account. These findings pointed to significant problem areas. A critical issue was the lack of an up-to-date and properly prepared accounting policy for the municipality. Additionally, in the context of inventory, it was noted that the Mayor of the Municipality had delegated the tasks and responsibilities related to conducting a complete inventory to the Inventory Committee and the inventory teams responsible for conducting physical counts. Alongside formal and substantive deficiencies such as incomplete physical counts, lack of the Municipality Office seal, or missing elements specified in document templates, there was also a lack of valuation of inventory items, absence of signatures from members of inventory teams and individuals responsible for the inventory. Furthermore, RIO highlighted the absence of protocols documenting the results of the conducted inventory, which should have been prepared by the inventory committee.

A more extensive examination of internal documentation, including job descriptions for individual employees, revealed that in many cases, there was no formal transfer of responsibility for entrusted property items to specific employees. Additionally, RIO's audit indicated a failure to maintain records of strict accountability documents related to inventory

sheets for the years 2018-2020. According to the provisions of the Accounting Act and the Act on Responsibility for Violation of Financial Discipline, RIO identified the Mayor of the Municipality as the responsible person for these irregularities, and in the financial aspect, the Municipal Treasurer.

The analysis of internal and external documentation, as well as the results of control audits, allowed for the proper development of procedures and the planning of their implementation in the examined rural municipality.

The development of new procedures primarily aimed at aligning them with current external regulations and ensuring the completeness of procedures in accordance with applicable legal provisions. As a result of the audit and examination of the municipality, significant formal-legal and organizational determinants were identified that had an impact on the proper conduct of the inventory process for the municipality's assets. These determinants include:

1. The organizational regulations of the Municipality Office did not assign the management of its assets to a separate organizational unit.
2. There was no formal assignment of material responsibility to individual municipal employees to whom the municipality's property was theoretically entrusted.
3. Staff turnover, which in practice made it difficult to accurately account for individuals responsible for the municipality's assets.
4. Involvement of newly hired employees in inventory teams who lacked sufficient knowledge about the municipality's assets being inventoried.
5. Lack of comprehensive knowledge about inventory among members of the Inventory Committee.

#### **4. Discussion**

The analysis of the internal legal documentation of the examined municipality indicated that the organization of the inventory process was preceded by the establishment of a permanent inventory committee and the issuance of the appropriate order regarding the conduct of the inventory in the municipality's office. The inventory of assets and liabilities included the following components: inventory of assets and liabilities verified by the physical count method, confirmation of balances, comparison of accounting records with relevant documents, and verification. In accordance with the regulations, the inventory was conducted by the physical count method for the following items:

1. Fixed assets, other than land and fixed assets with restricted access (including infrastructure, buildings, residential or non-residential premises, and property rights classified as immovable), as of November 30, 2021.

2. Fixed assets, other fixed assets, machinery, and equipment included in assets under construction, as of November 30, 2021.
3. Foreign fixed assets owned by other entities, as of November 30, 2021.
4. Strict accounting forms, deposits, checks, foreign promissory notes, bank and insurance guarantees provided as security for the performance of agreements, as of December 31, 2021.
5. Materials, unused current assets components that directly charge costs at the time of purchase (e.g., office supplies, promotional materials), as of December 31, 2021.

Excluded from the inventory by physical count method are assets that do not meet the criteria for fixed assets with an expected economic useful life of less than one year and low-value assets with a gross value of up to 350.00 PLN.

The inventory by balance confirmation method, as of December 31, 2021, covered the following components:

1. Cash held in bank accounts.
2. Loans, borrowings, and bonds.
3. Receivables (excluding public law receivables, doubtful or disputed receivables, receivables from employees, and receivables from individuals not maintaining accounting records).
4. Long-term financial assets - stocks and shares.
5. Own assets entrusted/lent to other entities.

The inventory by comparing accounting records with relevant documents and verifying their values, as of December 31, 2021, covered the following components of the municipality's assets:

1. Land.
2. Fixed assets to which access is significantly restricted (including buildings forming infrastructure, residential or non-residential buildings, and rights classified as real property).
3. Fixed assets under construction.
4. Intangible assets.
5. Long-term financial assets - stocks and shares.
6. Disputed and doubtful receivables, public law settlements, settlements with employees, and settlements with individuals not maintaining accounting records.
7. Other unmentioned assets and liabilities not subject to inventory by physical count or balance confirmation.

The substantive framework of the inventory process has been correctly defined in accordance with the provisions of the Accounting Act (*Ustawa z dnia 29 września 1994 r. o rachunkowości*, 2023). The Mayor of the Rural Municipality's order specified the scope and methods of inventory and established 3-person inventory teams, with the number corresponding to the organizational structure of the municipal office, including its organizational units

(e.g., departments). This legal arrangement was designed to ensure the proper conduct of the inventory process. In total, 33 employees were involved in verifying the assets of the municipal office, with 27 working within 9 inventory teams and 6 appointed to the permanent inventory committee.

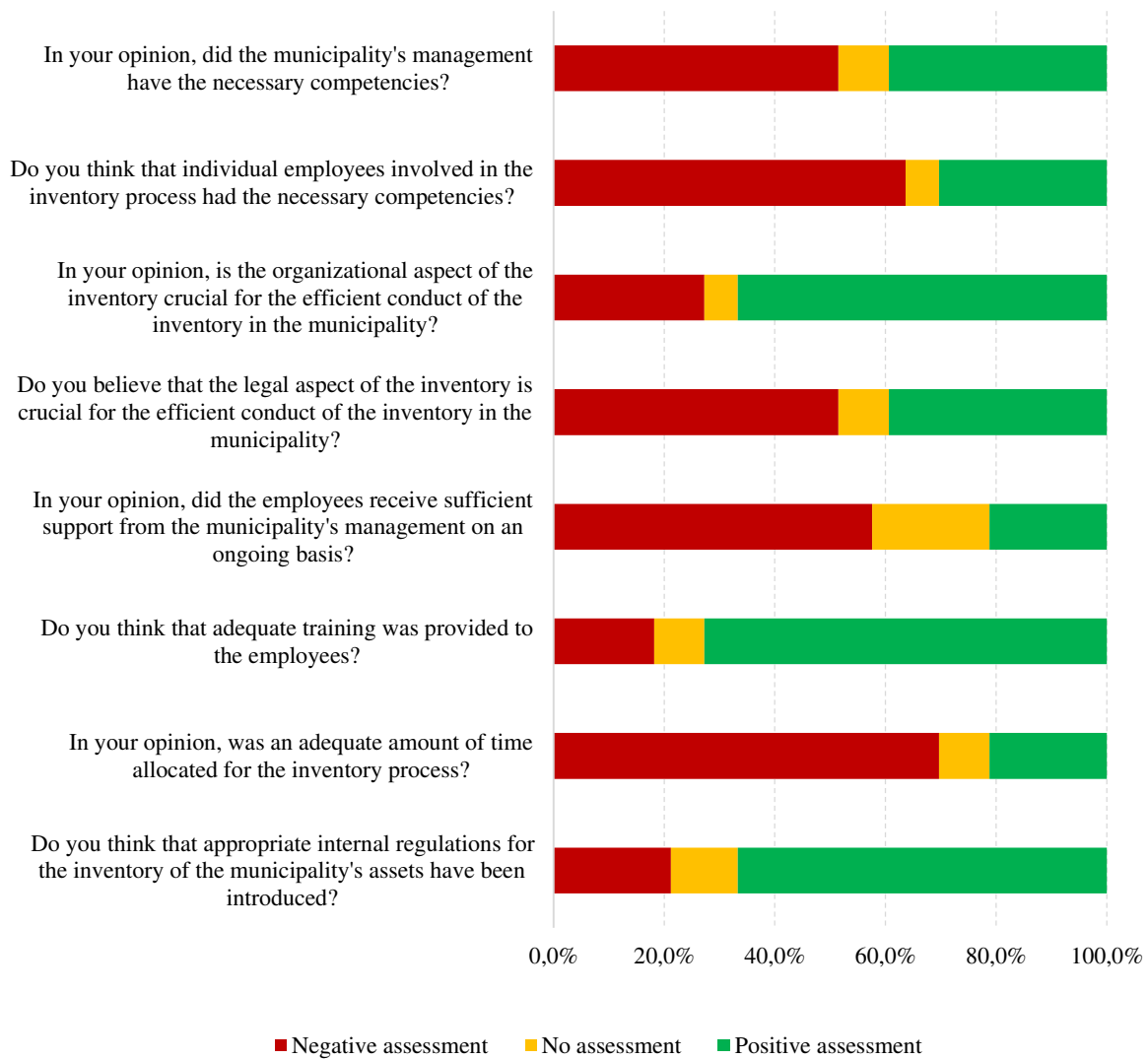
After developing and implementing internal procedures for the inventory process, training was provided to the selected employees responsible for carrying out the relevant tasks. Following the completion of the entire inventory process, a survey was conducted among this group of employees. The aim of the survey was to assess the effectiveness of the internal procedures implemented, the conducted training, and to identify potential problem areas. For this purpose, a questionnaire was prepared, consisting of six closed-ended questions and one open-ended question in which respondents were asked to indicate potential problematic areas. Table 1 presents the consolidated results of the survey for the closed-ended questions. Figure 1 displays the graphical results of the survey from Table 1, where positive ratings ("rather yes" and "definitely yes") and negative ratings ("rather no" and "definitely no") are grouped together. Figure 2 shows the collected and cataloged problematic areas as indicated by respondents in the open-ended question.

**Table 1.**

*Compilation of questions and responses regarding the organization of the inventory process in the examined municipality*

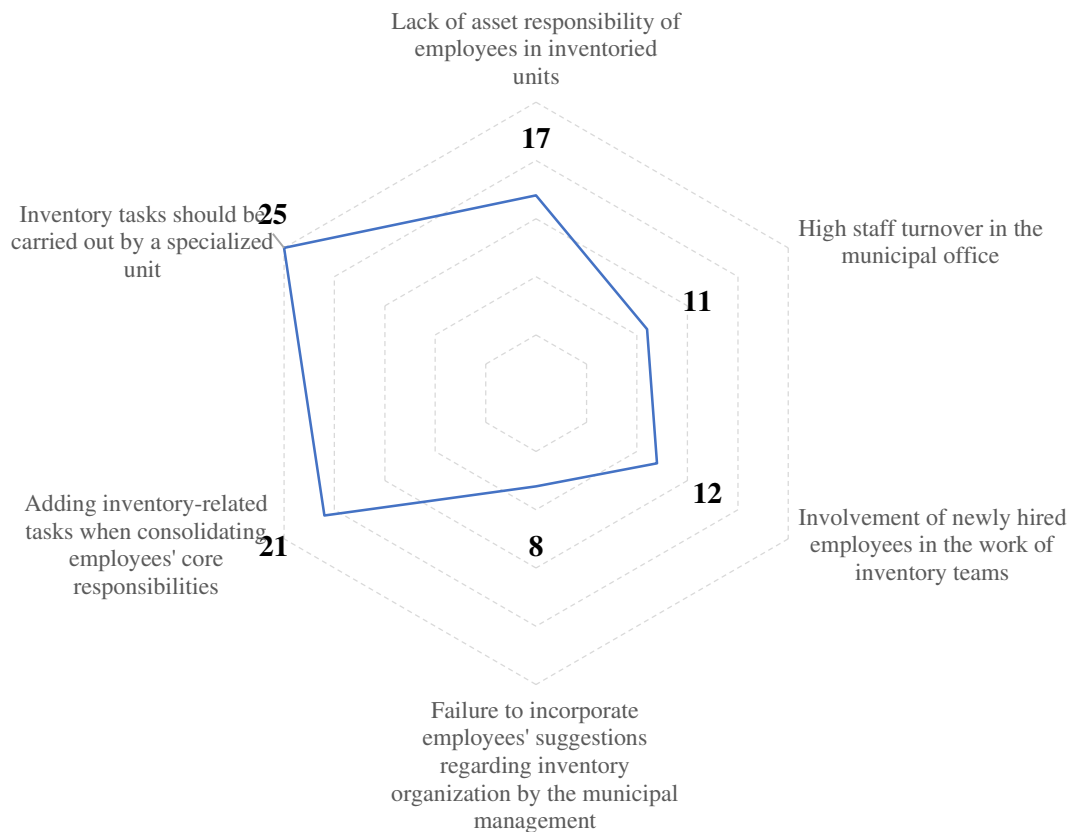
Itemization	definitely no	rather no	I don't have an opinion	rather yes	definitely yes	sum of responses
Do you think that appropriate internal regulations for the inventory of the municipality's assets have been introduced?	2	5	4	14	8	33
In your opinion, was an adequate amount of time allocated for the inventory process?	8	15	3	5	2	33
Do you think that adequate training was provided to the employees?	2	4	3	19	5	33
In your opinion, did the employees receive sufficient support from the municipality's management on an ongoing basis?	7	12	7	5	2	33
Do you believe that the legal aspect of the inventory is crucial for the efficient conduct of the inventory in the municipality?	5	12	3	11	2	33
In your opinion, is the organizational aspect of the inventory crucial for the efficient conduct of the inventory in the municipality?	4	5	2	16	6	33
Do you think that individual employees involved in the inventory process had the necessary competencies?	9	12	2	8	2	33
In your opinion, did the municipality's management have the necessary competencies?	3	14	3	10	3	33

Source: Own compilation based on conducted research.



**Figure 1.** Evaluation of catalogued problematic areas in the inventory process.

Source: Own compilation based on conducted research.



**Figure 2.** Presentation of catalogued problematic areas by the number of mentions by respondents.

Source: Own compilation based on conducted research.

The respondents highlighted two particularly problematic areas: the insufficiently short duration of the inventory process (69.7% negative ratings) and the competencies of employees involved in these tasks (63.6% negative ratings). To interpret the above responses, it's worth noting the respondents' comments in the open-ended question, where they mentioned the inclusion of newly hired or relatively inexperienced employees in the inventory work (12 mentions) and the high staff turnover (11 mentions). Experienced employees with not only substantial expertise but also a deep understanding of the office's layout and organizational changes, which can significantly hinder the proper identification of assets, should participate in inventory committees. Furthermore, the conclusions drawn from the implementation of inventory procedures in the examined municipality indicate that the substantive and legal aspects of inventory were carried out correctly, and employees in this area did not raise significant concerns (over half of the respondents had no objections here). According to the respondents, the proper organization of the inventory process itself in the municipality is a key element, as indicated by 66.7% of responses. When comparing this result with the problems identified by those performing inventory activities, especially those involved in physical inventory, such as newly hired individuals and the mention of high staff turnover, it is possible to point to a significant connection between these elements.



In the examined municipality, a separate organizational unit or independent position responsible for asset matters was not established within the organizational structure. Based on the internal document analysis and personnel documentation, it was also found that partial asset responsibilities were not assigned to other employees, especially to the heads of individual departments - the primary organizational units of the municipality. As a result, problematic areas emerged, as indicated by respondents (17 mentions).

In the examined municipality, a separate organizational unit was established within its organizational structure, carrying out statutory tasks assigned to local government shared service centers. This unit provides full accounting and payroll services to the municipality's educational institutions as part of its core tasks. Based on the experiences of the inventory committees and other employees involved in the inventory process, it is suggested that these tasks should be carried out by a specialized unit in the future, such as the Shared Services Centers (25 mentions, which represents 75.8% of respondents).

## 5. Research implications

The presented research results allow for practical conclusions for individuals managing public finance sector units and local government entities responsible, among other things, for conducting inventory in the organization. Grzybowski et al. (Grzybowski et al., n.d.) and Modrzyński et al. (Modrzyński, Gawłowski, Modrzyńska, 2018) point to an increasingly common practice of creating Shared Service Centers within local government structures and incorporating accounting responsibilities into the scope of shared services. The reports prepared for the Association of Polish Counties (Polish: Związek Powiatów Polskich) and the Union of Polish Metropolises (Polish: Unia Metropolii Polskich) clearly indicate that the subject matter of shared services is very similar and largely involves tasks related to accounting and payroll services (Modrzyński, Gawłowski, 2018; Modrzyński, Gawłowski, Modrzyńska, 2019). The Chief Accountants of Shared Services Centers (SSCs) confirm the validity of including inventory activities in shared services. Commonly identified errors included issues like the lack of or improper maintenance of inventory books. SSCs allows for the application of economies of scale, where a designated team of employees can be responsible for all asset management activities in the serviced units, including standardized inventory bookkeeping, while another team of employees conducts inventory in accordance with the law and an approved schedule as part of the shared service. The municipal (city) council, in the resolution establishing the shared service, determines the subject matter and the scope of the shared service, and the SSC manager, acting under the appropriate authorization of the mayor/president, carries out inventory duties as defined by the Accounting Act<sup>1</sup>.

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<sup>1</sup> Developed based on an expert interview with the Chief Accountants of the Shared Services Centers in Katowice and Krakow.

## 6. Conclusions

The applicable legal regulations, including the Accounting Act, explicitly define the methods and deadlines for conducting inventory activities, but the correctness of its implementation requires a broader legal and organizational context. In this regard, direct reference should be made to the public finance regulations or the Act on Responsibility for Violation of Financial Discipline, which place significant emphasis on accountability and risk assessment at every level of the public sector entities, including local governments. The inventory process involves the confrontation of accounting documentation with the actual state of affairs, thus bridging the gap between accounting and administrative areas. There is a growing recognition of the effectiveness of managing and coordinating the efforts of various units involved in complex processes such as inventory. As Carnegie et al. suggest, cooperation and responsibility at different levels within an organization are key factors for success in this regard (Carnegie, Napier, 2023). A correctly conducted inventory represents a significant step in the process of preparing financial statements for various entities, including local government units. A review of the available literature in the examined area, especially an analysis of the results of audits conducted by the Regional Audit Offices (RIO), indicates the need to focus on improving inventory procedures. Research findings and the increasingly common practice in larger local governments that utilize comprehensive support from shared service centers suggest that the organization of the inventory process, as well as the experience and expertise of the staff responsible for these activities, are crucial elements for its proper execution.

The analysis of the case study - the implementation of internal inventory documentation and training of employees involved in this process - suggests that these are crucial actions to ensure the correctness of the inventory process. From a scientific perspective, it seems justified to conduct further research in this area. Two research directions can be identified in this area. First, similar studies can be conducted in other municipalities, allowing for a comparison of the collected results. Second, conducting research to assess the effectiveness of organizing the inventory process in municipalities where this process was carried out with the support and utilization of shared service centers. The presented publication contributes to this discussion, which should be continued.

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## Author Contributions

Conceptualization, P.M. and G.V.; Methodology, P.M. and G.V.; Project administration, P.M.; Supervision, G.V.; Writing—original draft, Writing—review & editing, P.M. and G.V. All authors have read and agreed to the published version of the manuscript.

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The graphs presented in this publication were developed by the authors based on the collected results of their own research. Detailed information about the source of the publication is attached to each graph.

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## Conflicts of Interest

The authors declare no conflict of interest.

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## IMPACT OF HYDROGEN CELLS ON ECONOMIC EFFICIENCY AND THE ENVIRONMENT ACCORDING TO RENEWABLE ENERGY STANDARDS

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**Purpose:** The research goal of the work is to determine the levels of profitability of hydrogen cells and their impact on the environment. The authors of the article answer the question under what boundary conditions there is an economic justification for the use of hydrogen cells in various branches of the economy while respecting environmental regulations and standardizing energy production by the principles of a sustainable economy.

**Design/methodology/approach:** The research was carried out using economic measurement model methods. These methods allowed the authors to calculate the market value of the investment with the assumed boundary criteria and to determine the economic effectiveness of the analyzed research problem. Additionally, the authors analyzed the problems of the widespread use of hydrogen in terms of its storage in technical, technological and economic terms.

**Findings:** Research has shown that it is possible to obtain up to 7% by weight. hydrogen relative to the mass of the metal. Carbon nanofibers may become the material of the future for making hydrogen tanks. The use of fuel cells brings many benefits: simple structure and operation, neutral impact on the environment, and low noise level. Moreover, hydrogen fuel cell technology allows for efficient operation for a long time and the possibility of high momentary overloads, which allows for considerable scalability and wide application with economic justification.

**Practical implications:** The presented models have shown that the project of their implementation is fully economically justified and will allow investors to make a rational investment decision.

**Originality/value:** The original contribution of this work is the implication of the data on real research models. This data allowed the authors to make calculations and indicate directions of improvement for the construction of innovative hydrogen cell solutions as part of the standardization of regulations on renewable energy sources in various sectors of the economy.

**Keywords:** Hydrogen, hydrogen storage, fuel cells.

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

## 1. Introduction

With the development of civilization and its accompanying technologies, the demand for energy increases. For decades, humanity has not thought about the size of deposits of natural raw materials from which energy is mainly obtained. Over the last few years, attention has been drawn to the possible problem of depletion of fossil fuel deposits. Government institutions and companies from the fuel and energy sector have started looking for a new energy source. This is not the only problem that exists. As deposits are depleted, the price of raw materials gradually increases, which translates into an increase in the price of final products. There may be concerns about a situation in which the population will not be able to use energy due to a lack of access to natural resources or for financial reasons. One of the most likely solutions is the introduction of hydrogen cell technology, which would replace current energy sources. This is due to its universality the occurrence of hydrogen in nature, which serves as fuel in hydrogen cells. This technology can be used in all segments that require power. Hydrogen cells are most widely used in the drive system of vehicles. The size of available cell types allows the technology to be tailored to the required application in such a way as to ensure the highest possible system efficiency. The first step to introducing hydrogen cell technology will be to find solutions for many technological and economic reasons.

The work aims to present the power supply possibilities offered by hydrogen cell technology and the ecological and economic feasibility of its implementation and use.

The article presents the reasons for searching for new energy sources and describes in detail the properties of hydrogen, methods of its acquisition and possibilities of its storage and transport. The research part determined the impact of the use of hydrogen in various applications on the environment and the economic benefits resulting from the use of the new power source.

## 2. Review of the Research Problem

### 2.1. The essence of the research problem

Hydrogen is already widely called the "fuel of the future" and may be one of the alternatives to replacing fossil fuels. Hydrogen is an important industrial raw material, mainly used in the petrochemical and refining industries, and is also used in the synthesis of many products important for the economy and for the production of methanol, ammonia, urea, hydrochloric acid, ethers, and higher alcohols (Folentarska et al., 2016). Hydrogen is not a primary energy source but can be used, like electricity, as an exchange method to obtain energy where it is required. As a renewable and emission-free energy source, hydrogen can find many portable

and stationary applications. As an energy carrier, hydrogen can increase energy diversification and security by reducing our dependence on hydrocarbon-based fuels. Hydrogen is different from other energy sources. Together with electricity, they complement each other and one can be transformed into the other. Together with energy electricity are complementary and one can be transformed into the other (Bioenergy International, 2020). It can be perceived as an energy source whose quality does not depend on the method in which it is produced or the source from which it comes. Hydrogen molecules produced during water electrolysis are identical to those produced from plant biomass, paper, coal gasification or natural gas. It is the basic chemical substrate in the production of gasoline, fuel oil, lubricants, fertilizers, plastics, paints, detergents and pharmaceutical products. Moreover, it is an excellent metal refining agent and an important preservative.

Hydrogen has the best energy-to-mass ratio, which is the justification for using it as a fuel in space vehicles. An important factor for assessing fuel quality is the fuel energy density, which provides information about the packing density of hydrogen atoms in the fuel. As the number of carbon atoms contained in a fuel molecule increases, the energy density decreases and, conversely, as the number of hydrogen atoms increases, the energy density increases. Based on these relationships, the superiority of hydrogen as a fuel over currently used fuels can be demonstrated. For example, a 500 dm<sup>3</sup> tank containing 408 kg of diesel oil will contain the same amount of energy as a tank containing 8000 dm<sup>3</sup> of hydrogen at a pressure of 25 MPa (Collins, 2020). This means 16 times greater tank capacity with a hydrogen content of 150 kg. In the case of liquid hydrogen, the same amount of diesel oil will be equal to a hydrogen tank with a capacity of 2100 dm<sup>3</sup>, which in this case gives 4.2 times greater capacity (Ouyang et al., 2018).

Hydrogen can be obtained from many sources because it occurs almost everywhere, from biological tissues and DNA to crude oil, gasoline, paper and water. Moreover, it can be produced in nuclear, solar, wind, hydroelectric power plants, thermal power plants or from plants (Li et al., 2019). What remains is to develop cost-competitive, efficient and fast methods of production, transport and storage. Currently, hydrogen is produced in the world from natural raw materials in the following percentages: natural gas - 48%, crude oil - 30%, coal - 18%, and water electrolysis - 4% (Niekurzak, 2021). Hydrogen is obtained through steam reforming of methane, gudron gasification, coal gasification and water electrolysis. The selected form of hydrogen storage must be appropriately matched to its applications. Table 1 shows an example of storing the amount of hydrogen (depending on its state) and methane, methanol and ethanol.

**Table 1.***Energy value and density for various types of hydrogen, methane and biofuel*

Form of storage	Energy value		Density
	kJ/kg	MJ/dm <sup>3</sup>	kg/dm <sup>3</sup>
Hydrogen (gas approx. 0.1 MPa)	120 000	0.001	0.00009
Hydrogen (gas approx. 20 MPa)	120 000	1.9	0.015
Hydrogen (gas approx. 30 MPa)	120 000	2.7	0.022
Hydrogen (liquid)	120 000	8.7	0.072
Methane (gas approx. 0.1 MPa)	56 000	0.0374	0.0007
Methanol	21 000	17	0.0008
Ethanol	28 000	22	0.0008

Source: own based (Sørensen and Spazzafumo, 2018).

Many commercially available technologies are used to store hydrogen. The most popular method is the use of high-pressure tanks available in various sizes and used in various pressure ranges. One such solution is large underground storage facilities, where hydrogen can be stored underground in caves, aquifers and spaces left after oil and gas extraction. In most cases, hydrogen is stored in pressure vessels. Currently, the best solution is ultra-light composite materials that can withstand pressures above 20 bar (Rogala, 2022). Additionally, hydrogen can be stored in liquid form in tanks. The technology of producing hydrogen in liquid form requires large energy inputs. The compressed hydrogen must be cooled to a very low temperature (20.28 K, -423.17 °F/-252.87 °C) (Sánchez, 2021). The main advantage of storing hydrogen in liquid form instead of gas is that it takes up much less space. When hydrogen is converted into a liquid state, it can be stored in special thermal high-pressure tanks. Hydrogen can also be stored as metal hydrides at moderate temperatures and pressures, which favours this technology over storing hydrogen as compressed or liquid gas. Therefore, storage in the form of metal hydrides is a good solution in vehicle construction. Research is still ongoing to find more efficient methods of storing hydrogen. One of the modern methods is to store hydrogen in carbon nanotubes (Sørensen, Spazzafumo, 2018). Carbon nanotubes are unique structures with amazing electrical and mechanical properties. One possibility is to create a super-strong composite material made from carbon nanotubes and polymers, which could be used in all kinds of new engineering structures (He et al., 2015). This would enable the construction of a tank that would withstand very high temperatures the pressure of stored hydrogen, used as fuel in fuel cells, the creation of super-bulletproof vests and indestructible clothing, and the construction of much more durable spacecraft.

## 2.2. Energy and climate strategies and hydrogen energy

Hydrogen is one of the pillars of the EU Green Deal, paving the way to a climate-neutral economy by 2050 by eliminating fossil fuels from transport, but also from industries that are difficult to decarbonize, such as the steel and chemical industries (Hauenstein et al., 2020). In July 2020, a document titled "Building a hydrogen economy for a climate-neutral Europe", is a working version of the EU strategy. The European Commission announced that it will take action to ensure that hydrogen constitutes 12-14% of the Community's energy mix by 2050.

Currently, the main source of hydrogen in the world is a process called "natural gas steam reforming" (Graetz et al., 2017). However, the accompanying carbon dioxide emissions are slightly lower than in the case of an internal combustion engine. Therefore, hydrogen obtained this way is commonly called "grey". A slightly less environmentally harmful method, because it uses CO<sub>2</sub> sequestration technology (capture and storage), is methane pyrolysis. Natural gas (hence the name: ("blue" hydrogen) is heated to high temperatures to separate hydrogen from carbon, which becomes solid and can be further used as a raw material. However, the real alternative to "grey" hydrogen is "green" hydrogen, obtained from surplus electricity from renewable sources and subjected to the electrolysis of water, i.e. decomposition into hydrogen and oxygen (Wang et al., 2019). Connecting wind turbines/solar panels to electrolyzers that split water into primary components would allow energy to be stored when there is excess production from renewable energy sources.

The European Commission is focusing on the development of "green" hydrogen, which is still rare while allowing low-emission "blue" hydrogen (the emissions associated with it are eliminated using carbon capture and storage technology) and completely rejecting "grey" hydrogen. The authors of the EU hydrogen strategy made an optimistic assumption that approximately half of the current hydrogen production from fossil fuels can be converted into low-emission ("blue" hydrogen) (Meyer, 2021). The European Greens claim that these estimates are inflated due to the dictates of the gas lobby. In their opinion, this lobby influences the climate commissioner and vice-president of the European Commission, Franz Timmermans. The International Association of Oil and Gas Producers (IOGP) warns that the EU hydrogen strategy will be doomed to failure if it focuses solely on the production of hydrogen from renewable energy sources, ignoring other low-emission sources, such as nuclear and methane pyrolysis.

One of the conditions for the success of the hydrogen revolution is to reduce the price of gas to 1-2 euros per kilogram (1 kg of hydrogen allows you to travel approximately 100 km) (Niekurzak et al., 2022). Brussels wants to achieve this goal by increasing the density of the electrolyzer network throughout the Community and increasing the installed capacity to at least 40 GW over the next decade. The amount of investment in electrolyzers is expected to amount to EUR 13-15 billion over the next 10 years (Jaworski et al., 2019). Additionally, EUR 50-150 billion is needed to invest in wind and solar energy for hydrogen production. In turn, the EU will spend EUR 120-130 billion on hydrogen transport, storage and refuelling stations (Mikulik, Niekurzak, 2023). The existing natural gas and LNG infrastructure will be reviewed to expand its application spectrum to include hydrogen to optimize costs. The total volume of investments in building adequate hydrogen production capacity by 2050 may amount to nearly EUR 0.5 trillion (Takach et al., 2022).

It is estimated that by 2050, renewable energy sources could constitute a significant part of the European energy mix, in which the share of hydrogen could increase to 20%, in particular in terms of its use in transport and industry (Hydrogen Strategy...). According to sources from

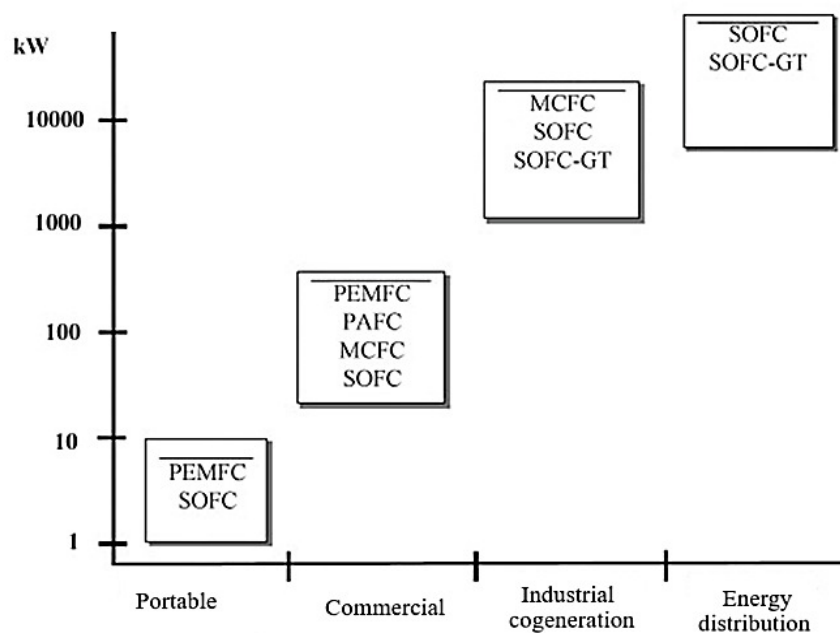
the bodies of the European Parliament (Directorate-General for Communication) (Hydrogen Strategy...), the European Parliament currently expects, in addition to "encouragement to stimulate demand and the creation of a European hydrogen market and the rapid implementation of hydrogen infrastructure", also a certification system for all imports hydrogen, as well as "assessing the possibility of changing the purpose of existing gas pipelines for the transport and underground storage of hydrogen". In recent years, the role of hydrogen in energy policy has been increasing (Nguyen et al., 2020) and (Starobrat, 2020) and (Ministerstwo Klimatu i Środowiska, 2019). As in Poland, we are responsible for the production of approximately one megaton of hydrogen per year, which constitutes 14% of hydrogen demand in Europe.

### **2.3. General characteristics of fuel cells**

A fuel cell uses the chemical energy of hydrogen or other fuels to produce electricity cleanly and efficiently. If the fuel is hydrogen, the only reaction products are electricity, water and heat (Romański, 2007). Fuel cells are unique in the variety of their potential applications, they can use a wide range of fuels and raw materials, and supply energy to systems as large as a municipal power plant and as small as a laptop. Hydrogen fuel cells can be used in a wide range of applications, providing power for applications in many sectors, including transport, industrial buildings, commercial buildings, residential buildings and long-term grid energy storage in reversible systems (Hemme, Van Berk, 2018). Hydrogen cells have several advantages over conventional fossil fuel technologies currently used in many power plants and vehicles. Fuel cells can operate at higher efficiency than internal combustion engines and convert energy chemicals in the fuel directly into electricity with an efficiency exceeding 60% (Castilla-Martinez et al., 2020). Fuel cells have lower or zero emissions compared to internal combustion engines. Hydrogen fuel cells only emit water, which addresses critical climate challenges because there are no carbon dioxide emissions. No air pollution causes smog and health problems at the place of operation. Cells are used to build batteries for portable devices, low- and medium-power generators, and stationary power plants. They are also widely used in transport, both in passenger cars and in public transport (Boateng, Chen, 2020). They are also expected to be used in heavy, air and sea transport. Which car drive will be the most effective and at the same time the cheapest? Battery or fuel cell using hydrogen? We can be sure of one thing - the drive of the future will be a vehicle with the most... lower emissions. The need to reduce dependence on fossil fuels and reduce CO<sub>2</sub> emissions has become an impulse to search for new energy sources and develop electromobility (use of electric vehicles, i.e. EV) (Wijayanta et al., 2019).

In fuel cells, the chemical energy of the fuel is directly converted into electrical energy. This type of conversion is an important advantage of cells because the efficiency of converting one form of energy into another is not subject to the limitations resulting from the theory of heat engines. Therefore, it is possible to achieve efficiency exceeding the efficiency of heat

conversion into mechanical energy at the currently controlled temperatures of heat supply to the circuit in which the heat engine (steam or gas turbine) operates. In the energy industry, fuel cells are considered to be used in small and medium-power units, including as distributed sources of heat and electricity (Wan et al., 2019). There are many criteria for classifying fuel cells. The basic division includes links for the direct use of a given fuel and the indirect use of its conversion (reforming) (Surygała, 2008). A typical representative of the first group is a cell powered by hydrogen and oxygen. The cell to which methane or biogas is supplied and oxidizer belongs to the second type of cell. An important division criterion here is the cell operating temperature (Niekurzak, Kubińska-Jabcoń, 2021). The application possibilities of hydrogen cells are very wide and promising. Depending on the type of application, the type of cell that will be best suited to perform the desired function changes (Han et al., 2008). The powers required by the market in which the cell will be used affect both its type and the costs of the entire installation. Therefore, this determines the purpose of different types of cells for different sectors. This division is presented in (Figure 1).



PEMFC – proton cell with replaceable polymer membrane.

SOFC – solid oxide cel.

MCFC – ogniwo ze stopionymi węglanami.

PAFC – ogniwo z kwasem fosforowym jako elektrolit.

SOFC-GT – solid oxide cell with gas turbine.

**Figure 1.** Market sectors for fuel cells.

Source: own.

The basic idea of using hydrogen cells is to use them to power passenger cars, buses and trucks, ships, trains and planes. In addition, they are used as stationary energy generators, integrated home systems to power portable devices or hydrogen highways.

### 3. Materials and Methods

#### 3.1. Efficiency of hydrogen cells

The thermal efficiency of an energy conversion device is defined as the ratio of the amount of useful energy produced to the change in chemical energy contained in the fuel, called thermal energy. Useful energy is obtained during the reaction of fuel and oxygen, it is also called non-volume work. This relationship is given by the formula:

$$\eta = \frac{\text{useful work}}{\Delta H} \quad (1)$$

where:

$\Delta H$  - the total caloric value of the reaction (including combustion reaction),

$\eta$  - thermal efficiency of the device.

Typically, chemical energy from fuel is first converted into heat, which is then converted into mechanical energy, which in turn can be converted into electrical energy. A heat engine is used to convert thermal energy into mechanical energy (Brückner, et al., 2014). In a fuel cell, chemical energy is directly converted into electrical energy.

$$\Delta G = \Delta H - T\Delta S \quad (2)$$

where:

$\Delta G$  – the maximum amount of work that can be obtained during a chemical change,

$\Delta H$  - the total caloric value of the reaction (including combustion reaction).

It follows that the theoretical efficiency of the reaction (assuming its ideal conditions) is determined by the relationship:

$$\eta = \frac{\Delta G}{\Delta H} = \frac{\Delta H - T\Delta S}{\Delta H} \quad (3)$$

In the case of chemical reactions, as in thermodynamic processes, the maximum work of an isothermal-isobaric reaction can be considered, which is determined by the relationship:

$$L'_{\max} = G_1 - G_2 = nFE \quad (4)$$

where:

$L'_{\max}$  – maximum work of the isothermal-isobaric reaction,

$G_1 - G_2$  – free enthalpy change,

$n$  – number of electrons transferred during the reaction,

$F$  – Faraday's constant (determines the number of units of electric charge - coulombs - per 1 mol of reaction),

$E$  – is the electromotive force of the cell.



The most commonly used fuel cell efficiency is based on the change in the free enthalpy of the reaction that occurs in the cell:



resulting from:

$$\Delta G_r^\circ = \underline{G}_{\text{H}_2\text{O}(\ell)}^\circ - \underline{G}_{\text{H}_2}^\circ - \frac{1}{2} \underline{G}_{\text{O}_2}^\circ \quad (6)$$

in which water is created in the form of liquid. Under standard conditions of 298 K and a pressure of 0.1 MPa, the chemical energy for the hydrogen/oxygen reaction is 285.8 kJ/mol, while the achieved free work energy for useful energy is 237.1 kJ/mol (Fellay et al., 2008). Based on this, it follows that the thermal efficiency for an ideal cell operating in a reversible process on pure hydrogen and smouldering under normal conditions would be:

$$\eta_{\text{ideal}} = \frac{237,1}{285,8} = 0,83 \quad (7)$$

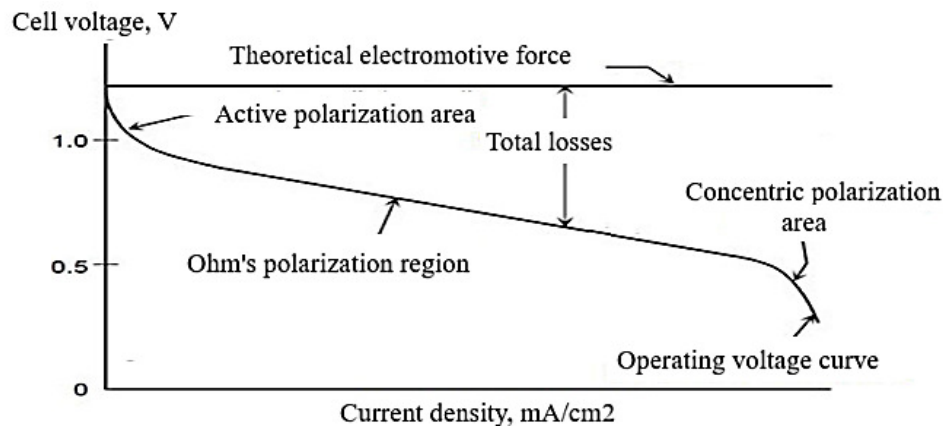
The efficiency of currently existing fuel cells is defined as the ratio of voltages in real and ideal states. For a fuel cell using the reversible conversion of hydrogen and oxygen at a pressure of 0.1 MPa, the ideal voltage at a temperature of 298 K is 1.229 V. The thermodynamic efficiency of a fuel cell operating at voltage  $V_{\text{real}}$ , based on the higher calorific value of hydrogen, is described by the relationship:

$$\eta = 0,83 \times \frac{V_{\text{real}}}{V_{\text{ideal}}} = 0,83 \times \frac{V_{\text{real}}}{1,229} = 0,675 \times V_{\text{real}} \quad (8)$$

The efficiency of a fuel cell is determined by the voltage, which in turn corresponds to the current density. The cell can operate at different current density values, which are expressed as  $\frac{\text{mA}}{\text{cm}^2}$ . As the current density decreases, the cell voltage and its efficiency increase. However, to maintain the same power of the cell while reducing the density, its active surface must be increased (Wang et al., 2020) and (Yildirim, Farha, 2018). This means an increase in investment capital along with an increase in efficiency and a decrease in operating costs.

### 3.2. Losses occurring in the fuel cell

Fuel cell performance is lower than its ideal potential. This is caused by irreversible losses, which are presented in (Figure 2). These losses are often referred to as polarization, overpotential and overvoltage.



**Figure 2.** Ideal and actual fuel cell voltage.

Source: own.

The sources of losses are:

- activation polarity,
- ohm polarization,
- concentration polarization.

Activation losses result from the activation energy of electrochemical reactions at the electrodes. It depends on the speed at which these reactions occur. The following factors contribute to the activation polarization: the process of reactant absorption, electron transfer and the type of electrode Surface (Xiao et al., 2020). Ohmic losses are caused by the resistance to the flow of ions in the electrolyte and electrodes. They are proportional to the current density and depend on the selected material, slope geometry and temperature. Concentration polarization is caused by the slow occurrence of electrochemical reactions resulting from the conditions of diffusion of reactants through the electrolyte. It is strongly influenced by current density, reactant activity and electrode structure.

### 3.3. Properties of fuel cells

Table 2 presents the reactions occurring in fuel cells depending on their type.

**Table 2.**

*Electrochemical reactions in fuel cells*

Cell type	Anodic reactions	Cathodic reactions
PEMFC	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$	$\frac{1}{2} \text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}$
AFC	$\text{H}_2 + 2\text{OH}^- \rightarrow 2\text{H}_2\text{O} + 2\text{e}^-$	$\frac{1}{2} \text{O}_2 + \text{H}_2\text{O} + 2\text{e}^- \rightarrow 2\text{OH}^-$
PAFC	$\text{H}_2 \rightarrow 2\text{H}^+ + 2\text{e}^-$	$\frac{1}{2} \text{O}_2 + 2\text{H}^+ + 2\text{e}^- \rightarrow \text{H}_2\text{O}$
MCFC	$\text{H}_2 + \text{CO}_3^{2-} \rightarrow \text{H}_2\text{O} + \text{CO}_2 + 2\text{e}^-$	$\frac{1}{2} \text{O}_2 + \text{CO}_2 + 2\text{e}^- \rightarrow \text{CO}_3^{2-}$
SOFC	$\text{H}_2 + \text{O}^{2-} \rightarrow \text{H}_2\text{O} + 2\text{e}^-$	$\frac{1}{2} \text{O}_2 + 2\text{e}^- \rightarrow \text{O}^{2-}$
	$\text{CO} + \text{O}^{2-} \rightarrow \text{CO}_2 + 2\text{e}^-$	
	$\text{CH}_4 + 4\text{O}^{2-} \rightarrow 2\text{H}_2\text{O} + \text{CO}_2 + 8\text{e}^-$	

Source: own based (Sørensen, Spazzafumo, 2018).

A summary of the operating conditions of individual fuel cells is presented in Table 3.

**Table 3.**  
*Basic operating conditions of fuel cells*

Conditions work	Cell type				
	PEMFC	AFC	PAFC	MCFC	SOFC
Electrolyte	perfluoro sulfonic acid (ion exchange membrane)	KOH solution in the matrix	concentrated H <sub>3</sub> PO <sub>4</sub> in the matrix	molten Li and K carbonates	ceramic ZrO <sub>2</sub> yttrium stabilized
Working temperature	353 K	338-493 K	478 K	923 K	873-1273 K
Load carrier	H <sup>+</sup>	OH <sup>-</sup>	H <sup>+</sup>	CO <sub>3</sub> <sup>2-</sup>	O <sup>2-</sup>
Catalyst	Pt	Pt	Pt	Ni	perovskite
Possible fuels	H <sub>2</sub> , CH <sub>3</sub> OH	H <sub>2</sub>	H <sub>2</sub>	H <sub>2</sub> , CO, hydrocarbons	H <sub>2</sub> , CO, hydrocarbons
Reformer	external	external	external	internal	internal
The role of gases:					
CO	poison > 50 ppm	poison	poison > 0,5%	fuel	fuel
CH <sub>4</sub>	thinner	poison	thinner	fuel	fuel
CO <sub>2</sub> i H <sub>2</sub> O	thinner	poison	thinner	thinner	thinner
H <sub>2</sub> S i COS	poison	poison	poison > 50 ppm	poison > 0,5 ppm	poison > 1,0 ppm

Source: own based (Sørensen, Spazzafumo, 2018).

Due to the low-temperature operation of PEMFC, AFC, and PAFC cells and the use of highly active platinum catalysts, the use of pure hydrogen and oxygen raw materials is required to obtain satisfactory efficiency. In the case of high-temperature MCFC and SOFC cells, due to the high operating temperature, platinum catalysts are not required, which allows the use of H<sub>2</sub>, CH<sub>4</sub> (methane), CO and heavier hydrocarbons as fuel. However, they are sensitive to the presence of sulfur compounds H<sub>2</sub>S and COS in the fuel. Table 4 shows the operational advantages of fuel cells (Lhuillier et al., 2020).

**Tabela 4.**  
*Usable advantages of fuel cells*

Fuel Type	Electrical efficiency, %	Power density, MW/cm <sup>2</sup>	Power range, kW	Application	Advantageous features	Unfavorable features
PEMFC	40-50	300-1000	0.001-1000	- transport, - electricity generation, - power supplies	- low operating temperature, - fast start, - no corrosion	- expensive catalytic converter, - high sensitivity to poisons
AFC	50	150-400	1-100	- space research, - army	- fast start, - high efficiency	- expensive catalytic converter, - sensitivity to poisons
PAFC	40	150-300	50-1000	- transport, - electricity production	- cogeneration efficiency up to 85%, - resistance to poisons present in H <sub>2</sub>	- necessary catalyst Pt, - low-efficiency electric, - large mass and volume
MCFC	45-55	100-300	100-100000	- electricity production, - heat production	- high efficiency, - fuel flexibility, - catalyst flexibility	- high corrosiveness, - high failure rate, - expensive materials
SOFC	50-60	250-350	100-100000	- electricity production, - heat production	- high efficiency, - fuel flexibility, - catalyst flexibility	- expensive high-temperature materials, - difficulties with seals

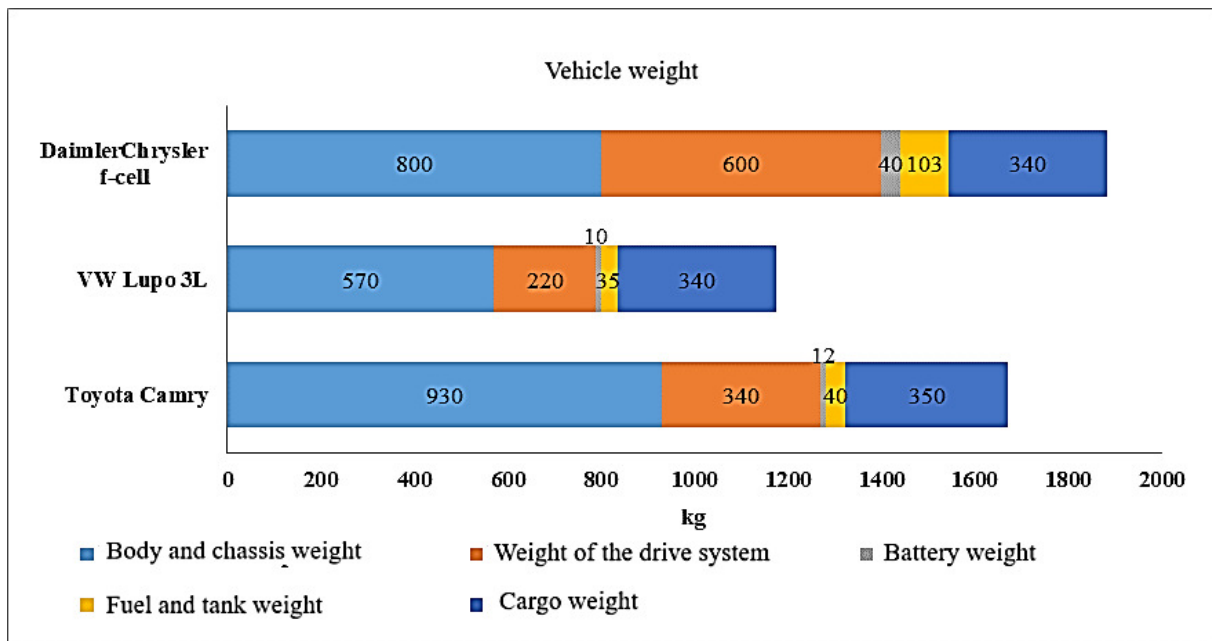
Source: own based (Sørensen, Spazzafumo, 2018).

Despite great efforts put into the development of fuel cell technology, as a source of clean energy production, this technology is only in the initial stage of development. For this technology to enter everyday life, there must be an improvement in the strength and reliability of materials, a reduction in the size and weight of devices, an improvement in water and heat management and a reduction in the costs of energy obtained (Assfour et al., 2010). Engines using fuel cells should demonstrate reliability and durability at the level of currently produced internal combustion engines, i.e. approximately 5000 hours (300,000 km) of operation, and the operating temperature should be 313-353 K (Dorociak, Tomecki, 2019). As for stationary systems, their reliability should exceed 40,000 hours, and the operating temperature is in the range of 238-313 K.

## **4. Results and discussion**

### **4.1. The impact of hydrogen cell technology on the environment**

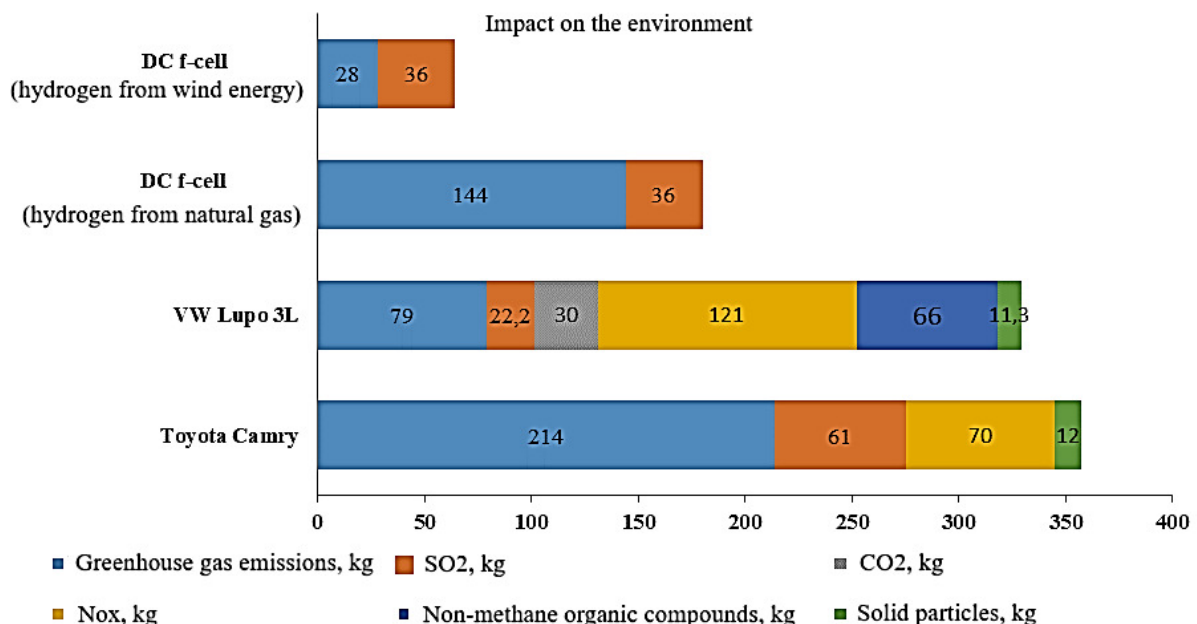
A very big challenge for any new technology that is to be widely commercially used is to demonstrate its benefits. They must be significant enough to outweigh the disadvantages associated with newer technology, e.g. higher costs than currently used technologies. In the case of hydrogen cells, the arguments in favour of them are the benefits of a direct, positive impact on the environment and the quality of people's lives. "Environmental" factors include such aspects as air, water, soil and fauna and flora pollution, noise level, and impact on the landscape. All these factors must be considered on both a global and local scale, including the impact on the climate through greenhouse gas emissions or substances that deplete the ozone layer. Additionally, there are factors determining the impact of technology on human life, its safety and the level of satisfaction needs. As part of the research, three vehicles were compared and their utility values were compared depending on the drive used. The comparison participants included a Toyota Camry powered by a gasoline engine, a VW Lupo 3L equipped with a diesel engine and a Daimler Chrysler "f-cell" powered by hydrogen cells. These vehicles differed significantly in their construction, as shown in (Figure 3), which shows the masses of individual vehicle elements. It is worth noting that Daimler Chrysler and VW Lupo were vehicles of similar size, while Toyota is the largest of them. It can be observed that the cell vehicle, despite its much smaller size, was larger than the Toyota. The biggest impact on weight was the body, chassis and the entire drive system, which is almost twice the weight. The weight of the vehicle adversely affects both its performance, which is weaker than that of traditional vehicles and its range, which is extremely important for the vehicle's usability. The latest designs provide a range allowing normal use of the vehicle.



**Figure 3.** List of vehicle masses with various types of drive.

Source: own-based (Surygała, 2008).

The main aspect in favour of hydrogen cells is their beneficial impact on the environment. Combustion vehicles emit greenhouse gases during operation, while the cells produce heat and water. It can therefore be concluded that hydrogen cells are a "clean" technology, however, assuming that only the operation of the cell itself is taken into account. Greenhouse gas emissions may occur at the hydrogen production stage, which depends on the production method used. Figure 4 shows the emissions of individual compounds.



**Figure 4.** Summary of the environmental impact of vehicles with different types of drive.

Source: own-based (Surygała, 2008).

The emissions level of Chrysler's Daimler vehicle was divided according to the hydrogen production process. You can see that there is a huge difference between obtaining hydrogen from electrolysis using wind energy and the process based on natural gas. However, despite the production of greenhouse gases during the production process, their level is much lower than in a combustion vehicle. In the case of a diesel engine, fewer greenhouse gases are produced than in the case of a Daimler Chrysler vehicle, but in addition to them, several other harmful compounds are also produced. As a result, the ecological advantage of cells over combustion engines is huge.

Another summary of the level of carbon dioxide emissions is presented in (Figure 5) taking into account the latest production technology and EU standards. The data was divided according to the type of vehicle and the fuel used. Pollutants generated during hydrogen production were also taken into account. Analyzing the data of combustion vehicles, it can be seen that over the next ten years, there will be a significant improvement in the environmental friendliness of gasoline-powered vehicles, but their emission level is still much higher (more than twice as compared to vehicles with hydrogen cells, for which hydrogen is obtained from natural gas). Considering the data of hybrid and "plug-in" hybrid vehicles, it is clear that this type of drive is "cleaner" than that used in traditional vehicles. Comparing gasoline-powered vehicles, the difference is approximately 40%, to the advantage of hybrid vehicles. However, it should be emphasized that hybrid vehicles are considered a transitional solution due to the need to continue using fossil fuels. It is worth paying attention to the huge difference in CO<sub>2</sub> production when biofuels (e.g. cellulosic ethanol) are used. Then, when comparing such a hybrid vehicle with a traditional gasoline-powered vehicle, the difference is as much as 84%, to the advantage of the hybrid. The solution that seems to be the most future-proof is vehicles powered by hydrogen cells. Even if hydrogen is obtained from natural gas (after taking into account the carbon dioxide produced during production), its advantage over a traditional vehicle (both gasoline and natural gas) is significant. When compared, their difference is 51% in favour of a hydrogen cell vehicle. Analyzing further data, it is clear that by choosing a more ecological production process, the difference in the level of pollutant emissions becomes huge. In the best case, hydrogen is obtained by electrolysis using energy wind it is as much as 90%.

With the commercialization and spread of hydrogen cell technology, the level of environmental pollution may decrease to a greater extent, because the formation of harmful compounds can only occur at the stage of hydrogen production. When the cell operates in a vehicle or another application, no pollutants are emitted, unlike currently used vehicles and energy sources. For this reason, the increasing number of vehicles will not increase environmental pollution, but on the contrary. In locations with high traffic intensity, there will be a significant decrease in emissions of harmful compounds, which in turn will improve the quality of life, e.g. in large urban agglomerations. Table 5 shows the percentage difference in carbon dioxide emissions for different types of vehicles and fueling methods. The percentages refer to the level of pollutant emissions expected from traditional petrol-powered vehicles

achieved according to new emission standards. Negative values express the percentage reduction in emissions compared to a traditional vehicle.

**Table 5.**

*Summary of percentage differences in carbon dioxide emissions depending on the type of drive*

	Fuel	g CO <sub>2</sub> /km	Difference in emission level, %
<b>Vehicle power types</b>	Petrol	338	+32,03
<b>Traditional vehicles</b>	Petrol	256	100,00
	Natural gas	200	-21,88
<b>Hybrid vehicles</b>	Petrol	156	-39,06
	Diesel	138	-46,09
	Corn ethanol - E85	119	-53,52
	Cellulosic ethanol - E85	41	-83,98
<b>Hybrid vehicles plug-in type</b>	Petrol	150	-41,41
	Cellulosic ethanol - E85	94	-63,28
<b>Powered vehicles hydrogen cells</b>	H <sub>2</sub> from natural gas	125	-51,17
	H <sub>2</sub> from coal	69	-73,05
	H <sub>2</sub> from biomass	34	-86,72
	H <sub>2</sub> from water electrolysis using wind energy	25	-90,23

Source: own based (Sørensen, Spazzafumo, 2018).

## 4.2. Hydrogen production costs

The production costs of hydrogen obtained from natural gas through steam reforming are known by knowing the input fuel costs. At low pressure (in the pipeline) it is approximately USD 1.0/kg. When filling flasks under pressure, the price is 30% higher, and when liquefying it is more than twice as high. On the other hand, assuming lower transmission volumes, transport costs are lower and by abandoning central hydrogen production, pipeline gas has the highest costs (\$5/kg), and based on liquefied gas they are lower (\$3.7/kg), depending on assumptions regarding transport distances and technology. It was estimated that obtaining hydrogen from biomass generates a cost of USD 2.5/kg and electricity in the electrolysis process - approximately USD 5/kg. For small electrolyzers, the cost of hydrogen has been estimated at USD 8-12/kg, while for larger units using wind energy, the cost decreases to USD 2/kg. In the case of coal gasification, costs exceed USD 12/kg (Tarasov et al., 2021).

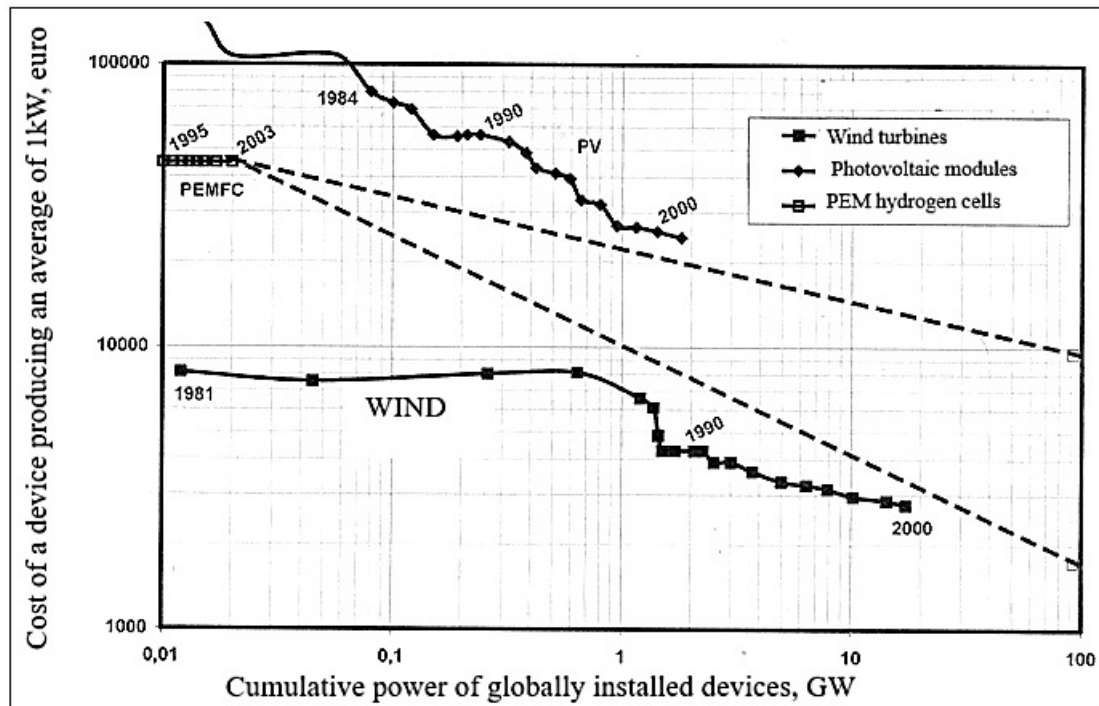
In the case of converting excess electricity into hydrogen through a hydrogen cell in a reverse process, but "paid for" by this energy production, and when the costs of the reverse hydrogen cell are similar to that operating in the "one-way", then the cost of hydrogen obtained based on electrolysis in a hydrogen cell may be as low as the cost of the energy used. The energy used for such hydrogen production may be off-peak power or excess power from renewable energy sources such as wind or solar that cannot be used to meet demand at the time of generation.

### 4.3. Costs of a hydrogen cell

Types of hydrogen cells such as those using molten carbonates or solid oxides are not expected to be in commercial use within the next decade. Initial costs for possible commercialization are estimated at USD 3,200/kW and are expected to drop to USD 1,300/kW in 2050. The problem is the availability of lanthanum (La), used in high-temperature ceramics. Due to previous success, AFC cells are still cheaper than PEM cells, however, both types of cells are still far from meeting all the requirements for large-scale commercial use. The chances of a rapid decline in projected costs for PEM cells do not appear to be equivalent for AFC cells. This fact is explained by the lack of interest in the development of this technology in the future. The costs of a small package of AFC cells are USD 1,750/kW, with the possibility of reducing them to USD 155/kW for large-scale mass production. The costs for a small package of PEM cells are around 2,000 USD/kW, but it is possible to reduce them to USD 20/kW during mass production for the automotive industry (50 kW packages). In 2025, the expected costs are expected to be €30/kW, assuming production of 250,000 units of hydrogen cells per year. The costs of ancillary equipment (gas circulation system, pipes, electronics and electrolyte recirculation system in the case of AFC, and humidifier system in the case of PEM) for PEM cells are estimated to be three times higher than for AFC cells and although they are much lower compared to the cost of the cell, if the price of cells drops, the costs of additional devices may become very significant.

Estimates of profits resulting from the introduction of PEM cells into mass production are determined based on future costs as a function of both the production volume and two parameters: improvement of power density (increase from 2 to 5 kW/m<sup>2</sup>) and development speed (taken as the slope of the assumed logarithmic curve cognition (logarithmic learning curve) and are in the range of 15-392 US/kW. The lower cost assumes the appearance of 5 million vehicles powered by hydrogen cells by 2025, with an average power of 110 kW, while the higher one assumes 50,000. vehicles reaching 3 kW/m<sup>2</sup>. Vehicles powered by PEM cells are currently designed for a lifespan of approx. 5,000. hours, where, for comparison, stationary generators are designed with a minimum life of 40,000 hours. Current "semi-commercial" vehicles powered by PEM cells do not achieve this level of service life. The estimated cost-effective price for stationary cells by 2025 is \$1,200/kW for 5 kW home systems and \$700/kW for much larger 250 kW installations (Tarasov et al., 2021). Hydrogen cell units currently being introduced in small series and on a small scale, both in vehicles and in stationary generators used in buildings, may provide a better basis for predicting the possibilities of reducing costs in the future. This could be significant when compared to the learning curves of other energy sector technologies (including wind, photovoltaic energy and battery development). Figure 5 presents the results of the analysis of cognitive curves for wind and photovoltaic technologies.





**Figure 5.** Learning curves for the costs of wind turbines and photovoltaic modules as a possible direction of development of PEM fuel cells.

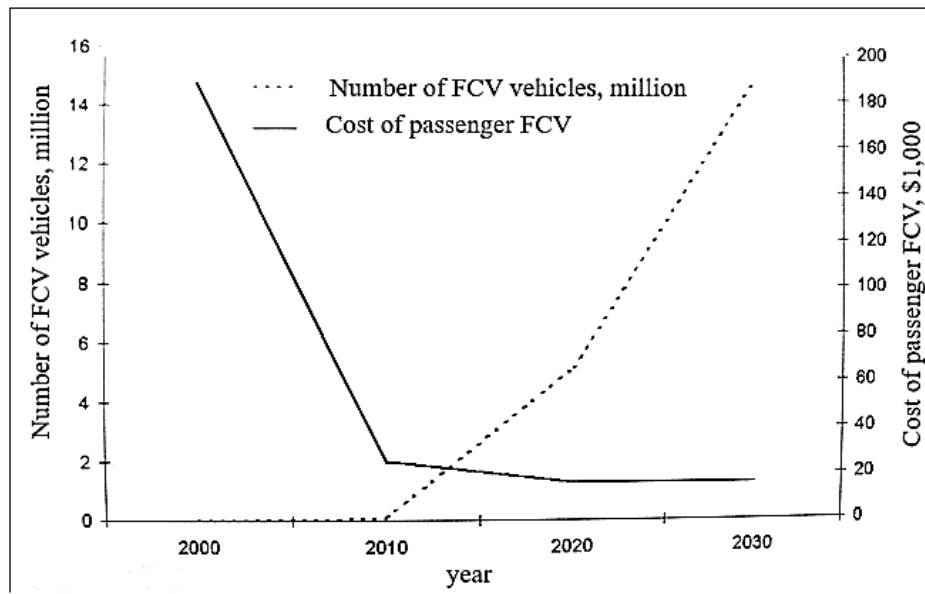
Source: own-based (Surygała, 2008).

Economists often describe such data as straight-line logarithmic behaviour, describing it as cost 'Y' as a function of cumulative output 'X':

$$\log Y(X) = -r \times \log x + \text{constant} \quad (9)$$

Tilt '-r' is sometimes called "progress indicator" (*progress ratio*)  $PR = 2^{-r}$  or as a "cognition index" (*learning rate*)  $LP = 1 - PR$ .

The nature of new technologies does not allow precise determination of initial prices. The reduction in the costs of PEM cells in the future is shown in (Figure 6) in the form of two curves corresponding to 10-20% of the cognitive curves corresponding to photovoltaic modules and wind turbines. However, even for the lower of the curves, the profitability point will not be exceeded if the cumulative energy production does not exceed 500 GW (Tarasov et al., 2021). However, oil market issues could make a hydrogen cell vehicle competitive at a higher price than the break-even point shown in (Figure 6).



**Figure 6.** Change in the number and price of FCV vehicles after entering the Japanese market.

Source: own-based (Surygała, 2008).

#### 4.4. Hydrogen storage costs

The costs of hydrogen storage include the costs of using devices and operating costs, including the energy required for compression or condensation. The additional costs of recovering hydrogen from the liquid form are approximately USD 5/kg for small units and approximately USD 1/kg for large units. The additional costs of storing compressed hydrogen in tanks are approximately USD 0.4/kg for short storage times and increase as the storage time increases. Large-scale underground hydrogen storage in caverns, abandoned natural gas wells, aquifers or salt caves have significantly lower costs (total costs of \$5-20/kg, making them cheaper by an order of magnitude than storing liquid hydrogen and two orders of sizes below the cost of storing compressed hydrogen), making them a natural choice for central hydrogen storage. Total storage costs for metal hydrides have been estimated at the level of USD 2000-80,000/kg. Storage cycle costs are estimated at USD 0.4-25/kg. This type of storage may be considered for automotive applications, however, the weight will be an issue here except for non-chemical or carbon-based types of storage (Hennig, 2010). Unfortunately, even the best designs have cost several times higher than the costs of storage in pressurized tanks.

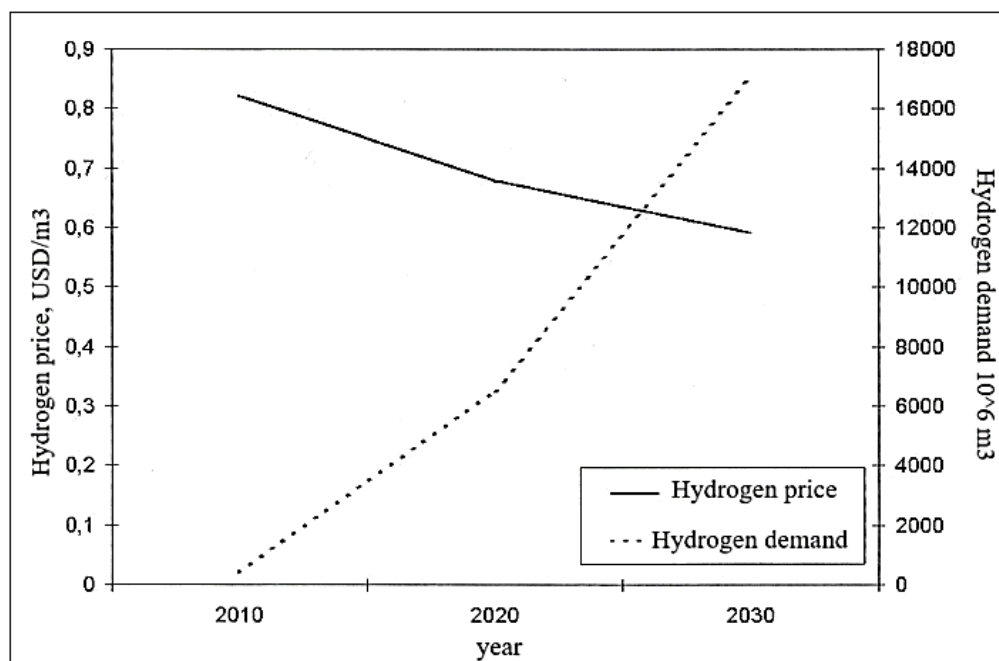
#### 4.5. Infrastructure costs

The costs of hydrogen transmission depend on both the diameter of the pipeline and the hydrogen flow rate. By increasing the pressure in the pipeline, the cost can be reduced by more than the additional costs of the compressors. The cost of road transport of liquid hydrogen is estimated to be lower, assuming transport costs for diesel vehicles. However, the additional costs resulting from the need to liquefy hydrogen make this solution unprofitable except in cases of transport over very long distances, e.g. intercontinental using ships. Converting vehicle gas stations into compressed hydrogen refuelling stations may increase the cost of hydrogen by

USD 0.1/kg, but alternatively, hydrogen production can take place at a gas station using any of the available methods (Hennig, 2010). The cost of the required modernization of a gas station so that it can be used for hydrogen refuelling is lower than the annual cost of maintaining a traditional gas station. Using hydrogen production inside a building to power a vehicle parked in a parking lot can double the prices of hydrogen production and refuelling.

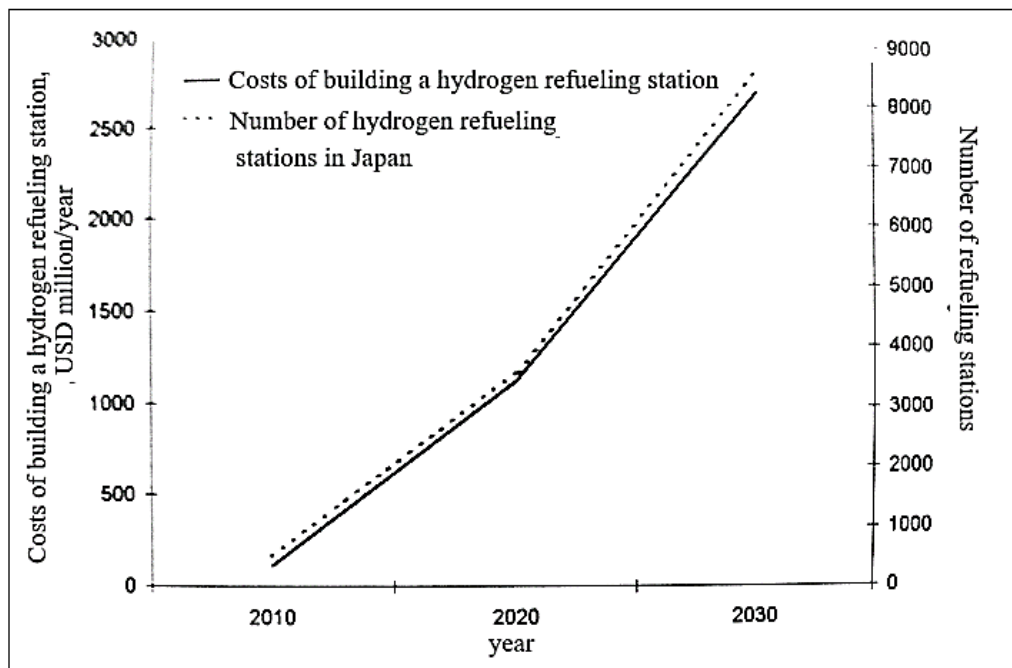
#### 4.6. System costs

The costs of a hydrogen cell system are part of the costs of the vehicle and systems installed in buildings and in a broader sense the total cost of the hydrogen economy with production, different types of use and infrastructure such as storage and transmission, distribution and filling points. Research on the PEM hydrogen cell in a car is not only focused on the cell itself but also the costs of the entire car as a system. The total cost of the cell, hydrogen storage, vehicle controllability and traction, battery pack (in the case of a hybrid vehicle) and vehicle energy management are taken into account. All these factors are examined to obtain the total costs incurred by the manufacturer during model development and to subsequently determine the appropriate price level. Studies have shown that the cost of a hydrogen cell will likely fall to \$40/kW in 2025 (one of several possibilities) and a corresponding increase in the number of FCVs passenger cars, trucks, buses, etc.) to 15 million in 2030. An increase in demand for vehicles powered by hydrogen cells can be expected as their price decreases. In 2025, the expected price of an FCV vehicle is estimated at approx. PLN 26,000 USD, which is close to the price of current combustion vehicles. Figure 7 shows the demand for hydrogen according to the Japanese scenario along with its costs. And (Figure 8) the number of hydrogen refuelling stations needed and the annual construction costs.



**Figure 8.** Change in demand and prices of hydrogen according to the Japanese scenario.

Source: own-based (Hennig, 2010) and (Sørensen, Spazzafumo, 2018).



**Figure 9.** Costs and required number of hydrogen refuelling stations in Japan.

Source: own-based (Hennig, 2010) and (Sørensen and Spazzafumo, 2018).

The scenario assumes a slight population decline in Japan, modest GDP growth and unchanged energy demand. According to the scenario, the production of vehicles with 106 hydrogen cells will increase from 50,000 to in 2010 to 3.1 million in 2030. Such sales in 2030 will allow for sales revenues of USD 59 × USD 109 (assuming that the price of the vehicle includes production costs and a 15% margin) (Hennig, 2010). By 2030, hydrogen-related activities are expected to account for 1% of Japan's total GDP.

## 5. Summary and Conclusion

Hydrogen cell technology faces many challenges. The very desire to replace conventional ways of powering vehicles or obtaining energy in the global sense in the future is a huge challenge for the entire fuel cell technology. Currently, fuel cells have many problems to solve before they can demonstrate the economic viability of introducing them to society on a global scale. These problems include: include too high costs, the level of reliability and the integration of systems included in cell technology. The level of reliability must be at least at the level of reliability of technologies used for traditional energy production, and the costs must also be comparable. Integrated systems must be able to attract the public's interest in making changes and switching to the new technology.

Cost reduction is essential for fuel cell technology to be successful. Society will not be willing to use new technology when the costs they would have to incur are higher than the costs currently incurred when using current technologies. Although there is a chance that they will

be willing to pay slightly more, I think that the degree of "how much more" will depend on the person's awareness of ecological responsibility. For example, until the cost per kW of energy falls, people will continue to use vehicles with traditional internal combustion engines. The main factor limiting the widespread introduction of fuel cells to society is the cost of the fuel fire and the installation costs of the entire system. Both of these costs must be reduced to the level of current energy generation methods. In addition to presenting the use of cells, it is also important to present the level of reliability of fuel cells. It is important to demonstrate that they can provide adequate reliability and quality supplied energy and the possibility of their operation for a long period. Additional factors that would encourage society to switch to the new technology would be subsidy systems for the purchase of fuel cell systems and systems providing benefits from the use of new, pro-ecological technology.

Based on the analysis performed in this work, the following conclusions can be drawn:

1. Due to the increase in energy demand and the prospect of exhaustion of fossil fuel resources, there is a need to develop a new energy source. Rising fuel prices will lead to a reduction in their availability to society, and at some point, they will cease to be a profitable source of energy.
2. The increase in energy consumption and the number of vehicles causes a global increase in pollution and requires the spread of "clean" energy sources. The analysis carried out on the example of the automotive industry showed the possibility of a significant reduction in pollutant emissions as a result of replacing conventional methods of powering vehicles with hydrogen cells.
3. The possibility of obtaining hydrogen from various sources allows us to become independent from fossil fuels. Moreover, hydrogen as a fuel is safer than conventional fuels due to its physical and chemical properties.
4. The multitude of developed types of hydrogen cells allows for their optimal adaptation to applications and working conditions. Thanks to this, it is possible to expand the range of available applications and adapt to the user's convenience.
5. Despite the promising parameters of hydrogen cells, it is currently not possible to use them in commercial applications. To successfully implement them, there must be a reduction in the costs of technology, fuel, use, improvement of operating parameters and an increase in the availability of devices and vehicles, as well as the related infrastructure.
6. It is necessary to introduce government programs encouraging society to use hydrogen cell technology. A useful tool in this case would be tax relief or financing of part of the costs addressed to private individuals and companies willing to use fuel cell technology.

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## QUALITY ASSESSMENT OF ZINC COATINGS APPLIED BY SELECTED METHODS

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**Purpose:** This article presents the problem of corrosion phenomena occurring on steel products, which contributes significantly to the shortening of safe service life. One method of corrosion protection is the application of metal coatings. The most commonly used zinc coatings are described, along with two methods of their application: the galvanizing bath method and the lamellar method.

**Design/methodology/approach:** Coatings were made on the S195 steel specimens in different process variations. Weight, hardness and thickness, as well as surface defects, were used as criteria for assessing the quality of the coatings.

**Findings:** It was found that the process in the galvanizing bath can produce untight coatings with defects. On the other hand, the coatings applied by the lamellar method, were characterized by better aesthetics, lower weight and thickness compared to galvanic coatings, higher hardness compared to galvanic coatings, and uniformly covered the material without discontinuities in the structure that could impair durability.

**Originality/value:** The research clearly indicated the directions of application of the analyzed galvanic and lamellar coatings. The application of coatings is justified in the use of products exposed to corrosive agents. In terms of decorative qualities, more favourable results were obtained on the specimens with lamellar coatings, as these coatings had a silvery colour and an aesthetically pleasing sheen compared to the galvanic coatings. Due to the characteristics of the coatings, galvanic coatings can be used on parts that are operated in harsh environments, while lamellar coatings can be recommended for products that are required to have a low weight change and certain aesthetics

**Keywords:** galvanizing, galvanic coatings, lamellar coatings, coatings quality.

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

## 1. Introduction

The phenomenon of corrosion is the destruction of material as a result of chemical or electrochemical processes in the environment. As losses recorded in industry due to corrosion processes are a real problem, much attention is being paid to protecting materials from corrosion. There is a particular need to protect metals, as the ease with which corrosion can occur on their surface is due to their properties, primarily their good affinity for oxygen (Amin, Ibrahim, 2011; Rezaee, Attar, Ramezanzadeh, 2013). There are many types of corrosion, but due to the nature of the damaged surface, two types in particular stand out: local corrosion and general corrosion. With local corrosion, corrosion foci can be observed with the unaided eye and their distribution is random and does not cover the entire surface of the metal. General corrosion is characterised by corrosion foci distributed uniformly or randomly across the surface, and the corrosion products formed do not have a protective function against further corrosion of the material (Gao, Zhang, Li., Jiang, Zhang, 2018; Le Bozec, Thierry, Rohwerder, Persson, Luckeneder, Luxem 2013; Zhmurkin 2009).

The measures taken to protect against corrosion can be of two types (Surowska 2002):

- measures to reduce the occurrence of corrosion at an early stage, e.g. through appropriate selection of materials or proper planning of the technological process,
- protective coating operations that will separate the product from the damaging effects of corrosive agents.

The primary function of protective coatings is corrosion protection, but developments in coating deposition technology have also made it possible for coatings to perform decorative and technical functions, owing to parameters such as hardness or abrasion resistance.

There are two types of coatings: metallic and non-metallic ones (Gao, Zhang, Li., Jiang, Zhang, 2018; Revie, Uhlig 2008). Metal coatings are produced using pure metal, its properties can vary depending on the type of metal and the application method. Zinc coatings are applied to steel products because, owing to the lower electrochemical potential compared to steel, the corrosive effect only occurs on the surface of the coating. It becomes the anode and forms a barrier on the surface of the product. The zinc coating is therefore an anodic coating. There are also cathodic coatings, in which case the coating is the cathode and the protected product the anode. The coating should be applied evenly over the product, otherwise corrosion foci appear in untight areas causing material deterioration. Non-metallic coatings are produced using ceramics, plastics, enamels and paints. They are aesthetic and have insulating properties in addition to their anti-corrosive properties (Katayama, Kuroda 2013; Prosek, Nazarov, Bexell, Thierry, Serak 2008).

Zinc is a popular material used for protective coatings applied to metals. In industry, galvanisation and lamellar (flake) galvanisation are most commonly used (Lostak, Maljusch, Klink, 2014). The choice of coating depends on the operating conditions, economic aspects and the final properties of the coating (Hulser, Donner, Bauer, Hahn, 2016).

The galvanic method produces a thin coating of zinc in the process of electrolysis. The cathode is the coated product, the anode is the zinc plate. Using an external current source, the zinc ions separate from the anode and dissolve in the electrolyte (aqueous solution). The positively charged ions then move to the cathode, combining with electrons on the outside of the material. They thus form centres of crystallisation, resulting in the formation of a coating (Spathis, Poulios, 1995). In addition to zinc ions  $Zn^{2+}$ , there are other additives in the solution to maintain a constant current density. In weakly acidic baths these are  $Cl^-$  ions, in alkaline baths  $NH_4^+$  ions, and in both cases also agents that give sheen, colour or other special properties to the coating (Elvins, Spittle, Worsley, 2005). The quality of the galvanic coating is influenced by how the surface is prepared. The substrate should be cleaned of all contaminants such as rust, oils, grease, fat, and oxide layers. Any residue reduces the durability of the coating and impairs adhesion, which may result in the need for frequent renewal of the coating. Before the substrate is cleaned, mechanical treatment (grinding, polishing) is applied to further improve the dimensional tolerances of the product (Gao, Zhang, Li., Jiang, Zhang, 2018; Diler, Rouvellou, Rioual, Lescop, 2014). The substrate is then degreased, rinsed and etched. The most common application is chemical degreasing, which involves immersing the product in hot baths of a suitable chemical composition (Surowska, 2002). Rinsing is an operation that separates the various stages of galvanic coating to prevent the transfer of contaminants or substances between successive surface preparation processes. The products are rinsed in hot (80-90°C) or cold water. It is recommended to rinse the products after each degreasing process first in hot water to wash off the bath components, followed by a rinse in cold water (Surowska, 2002). To remove corrosion products from the surface of the product, etching is used and the product is immersed in a bath of aqueous acid solution, in the case of steel, a 10-20% solution of sulphuric acid  $H_2SO_4$ . The bath gradually heats up from ambient temperature to a maximum of 70°C. The uniformity of the etching is ensured by adding inhibitors to the solution (Surowska, 2002). The next step, after surface treatment and preparation, is electrolysis in a suitably prepared bath. It should be able to form a coating with the specified parameters in the shortest possible time, have good opacity and ensure a high dissolution efficiency of the anode when the current density is high. The appropriate pH of the solution is obtained by adding  $H_2SO_4$ .

A distinction is made between acidic and weakly acidic, neutral, alkaline, and alkaline-cyanide baths. Acidic (sulphate and fluoroborate) or weakly acidic (chloride and ammonium chloride) baths are used for the galvanisation of iron and steel products with simple shapes of sheet, wire or strip (Surowska, 2002, Revie, Uhlig 2008). The advantages of acid baths are the high rate of coating deposition and the low cost of chemical components compared to other

types of bath, but the surface opacity can be poor. Disadvantages of coatings applied in acid baths can include low penetration, formation of dendrites, brittleness, and de-bonding (Surowska, 2002). In contrast, the opacity of the product in a weak acid bath is very good. The coatings have a mirror-like sheen, due to the shine-enhancing additives contained in the bath. Weak acid baths are also used for products with complex shapes, resilient and hardened components. Disadvantages of coatings deposited in weakly acidic baths include peeling and discolouration. Zinc coatings can be finished using chromate conversion with  $\text{Cr}^{3+}$  and  $\text{Co}^{2+}$  ions, which increases corrosion resistance and decorative effects (Szłapa, Jędrzejczyk, Skotnicki, Hajduga, Węgrzynkiewicz, 2014; Schaefer, Mischczyk, 2013).

Galvanic coatings are used in the machinery industry, automotive industry, for coating resilient components, machine parts operating in high humidity, and for decorative purposes. They are checked by measuring the thickness of the layer, hardness, and assessing its uniformity. These are the characteristics on which the durability of the coating and the quality of the corrosion protection of the product depend (Thierry, Prosek, Le Bozec, Diler, 2011; Qian, Li, Jungwirth, Seely, Fang, Shi, 2015).

The lamellar method, otherwise known as the flake method, is a non-electrolytic method of producing anti-corrosion coatings on a metal substrate (Fuarez, Gheno, White, 1993). The coating process involves immersing components or spraying a zinc-aluminium solution onto them. The resulting layer is cured by annealing in a furnace and then cooled by air flow (Giudice, Benftez, Linares, 1997).

As with galvanic coatings, the application of lamellar coatings is preceded by pre-treatment. Particularly important is the removal of impurities, which can be done by alkaline degreasing, shot-blasting or phosphating (21). Degreasing takes place in a hot alkaline bath with a pH of 11-14. The components of the bath produce a solution with very low surface tension, which avoids recontamination with oils. Objects are immersed in a solution of sodium hydroxide, crystalline sodium triphosphate, sodium hexaphosphate and water (in a ratio of: 4-1-0.5-supplementation to 100%) at 85-90°C, which improves the saponification of impurities. After a bath lasting about 10 minutes, the objects are rinsed first in hot and then in cold water. After degreasing, the surface is subjected to shot-blasting or phosphating, and these operations improve the surface adhesion properties. Shot-blasting is used on products with simple, flat surfaces and uncomplicated shapes. Stainless steel shot is commonly used, with a hardness of 450 HV and a particle size of 0.2-0.5 mm (Giudice, Benftez, Linares, 1997, Li, Du, Fan, Zhao, Ma, Wu, 2019).

Phosphating can be used instead of shot-blasting. The phosphating bath is applied by spray or immersion, on complex-shaped components with surfaces that are difficult to access (Hochmannová, 2002).

The proper, anticorrosive coating is applied to the prepared surface. In the lamellar method, these are zinc flakes with aluminium added in a 95:5 ratio. The coating can be applied by hot-dip galvanising with spinning, hot-dip galvanising or spraying. The spinning method uses

a special basket, into which the parts to be coated are placed, immersed in a previously prepared solution. During immersion, the basket rotates, eliminating the formation of air bubbles. The basket then rises and spinning begins, allowing the excess solution to be deposited on the walls of the basket. The immersion method is similar, however, the basket is not subjected to spinning after the immersion process and the removal of excess solution takes place in the furnace during drying (Hulser, Donner, Bauer, Hahn, 2016; Hochmannová, 2002). Spray application, on the other hand, is carried out using a pneumatic or electrostatic gun. In order to accelerate the deposition of the coating, the solution is heated to 20°C and the object to approximately 27-30°C. Compared to immersion, spraying enables a more uniform coating to be achieved, even on parts with complex shapes.

Regardless of how the coating is deposited, the object is then dried in a furnace at 180-320°C to cure the applied pigment. After the coating has cured, the objects are dried with an air stream until the object temperature reaches approx. 25°C (Muller, 2001).

In order to prolong the service life of lamellar coatings, sealing coatings (e.g. water-based lacquers) are additionally used to form an additional corrosion protection barrier. After the sealing coating has been applied, the component dries again.

Lamellar coatings have a number of advantages: resistance to elevated temperatures and to mechanical influences. They are environmentally friendly due to the absence of harmful substances in the coating application process. The replacement of zinc dust with flakes and the absence of acids makes it possible to eliminate hydrogen embrittlement, increase adhesion and reduce oxygen permeability. Lamellar coatings are used in the auto-motive, aerospace and energy industries, due to their ability to coat customised and mass-produced products with complex shapes with durable coatings in different colours (Hulser, Donner, Bauer, Hahn, 2016; Hochmannová, 2002; Muller, 200; Jędrzejczyk, Szłapa, Skotnicki, 2015).

The thickness of the coating determines its anticorrosive properties. Testing the thickness of the coating is the first step in determining the correctness of the workmanship, and its determination helps to decide the need for further quality tests. If the value obtained is not appropriate, e.g. does not meet the specified standards, then further analysis is discontinued, as it is assumed that the coating will not fulfil its primary, protective function.

The thickness of the coating can be measured by destructive or non-destructive methods by determining the local thickness, measured at a selected location, or the average thickness, which is the averaged result of several measurements taken at different locations on the product (Rodzyńkiewicz-Rudzińska, 1985). Due to their less labour-intensive nature, microscopic, weighing, drop or stream methods are most commonly used.

If the thickness of the coating meets the requirements, hardness is measured in the next step. In the case of protective coatings, it has to do with the structure, which can vary due to the possibility of using different baths, ingredients, and temperatures. Hardness is measured on the Brinell, Vickers or Knopp scale, using an indenter of appropriate shape (Łabędź, 2017).

The next step in assessing the quality of the coating is a visual evaluation of the characteristics of the external appearance, e.g. determining the colour, type of defects, degree of sheen, smoothness, etc. This assessment is carried out with the unaided eye or using microscopes (Łabędź, 2017).

## 2. Materials and Methods

S195 steel plate with the chemical composition given in Table 1, was used in the experimental study, from which 15 x 100 mm specimens were made (Wyrzgoł, 2022).

**Table 1.**  
*Chemical composition of S195 steel (Wyrzgoł, 2022)*

Ingredient	C	Mn	Si	S	P
Content, %	0.2	1.4	-	0.045	0.045

For galvanic coating, a stand consisting of a galvanic bath and a power supply unit with the following parameters was used: supply voltage 400 V  $\pm$ 10%, frequency 50-60 Hz, short-circuit voltage according to standard (UNE-EN 60204-1:2019), input current max. 9.6 A, number of phases – 3. The function of the anode during the coating application was performed by non-degradable graphite. A zinc sulphate bath from Technologie Galwaniczne Sp. z o.o. was used for galvanising (Wyrzgoł, 2022).

The application of the zinc coating using the lamellar (flake) method was carried out using YATO spray gun YT-82553. A pigment consisting of ZINTEK 400 zinc-aluminium flakes from Atotech was applied with a 2.6 mm diameter nozzle. After coating, the specimens were dried for curing in an FCF 22HP chamber furnace with the following parameters: operating temperature 1.220°C, temperature control range 20-1.300°C, supply voltage 400 V/2N, rated current 12 A, and rated power 4.8 kW (Wyrzgoł, 2022).

All specimens were weighed on an analytical balance before coating, then etched in concentrated H<sub>2</sub>SO<sub>4</sub> and later rinsed in distilled water.

Coatings were applied to the prepared specimens using two methods: galvanization in an acid zinc bath and lamellar method.

The bath galvanising process was carried out in the variants given in Table 2.



**Table 2.**  
*Parameters of galvanizing in the galvanic bath*

Specimen number	Intensity, A	Time, s
1	2	300
2	2	600
3	2	900
4	4	300
5	4	600
6	4	900
7	6	300
8	6	600
9	6	900

On the other hand, flake coating was carried out using a spray gun, in the case of which method the specimens were coated with pigment. All specimens in both coating method variants were then furnace dried to cure according to the scheme given in Table 3.

**Table 3.**  
*Variants for drying zinc-coated specimens*

Specimen number	Temperature, °C	Time, s
1	210	900
2	210	1500
3	210	2100
4	230	900
5	230	1500
6	230	2100
7	250	900
8	250	1500
9	250	2100

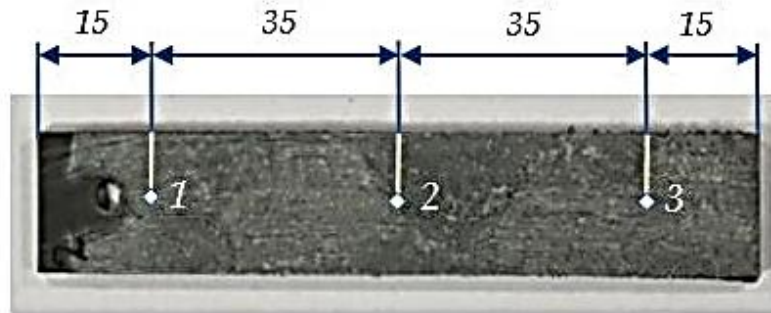
The applied coatings were assessed for macrostructure, thickness and hardness.

Macrostructure testing of the coatings was carried out using an Olympus SZX9 stereoscopic microscope, enabling images to be obtained at 5-30x magnification. Macroscopic images were taken at 12.5x magnification. Markers of the observed coating structures of 19 px for galvanic coatings and 8 px for lamellar coatings were determined.

The thickness of the zinc coating was measured using a TESTAN DT-25 probe thickness gauge from ALFA-TECH with the following parameters: measuring range 0-1500  $\mu\text{m}$ , measuring accuracy  $\pm(2\%+1)$   $\mu\text{m}$ , minimum radius of curvature 1.5 mm, minimum diameter of the measuring area 6 mm, minimum substrate thickness 0.5 mm, and operating temperature from 0-60°C.

The hardness of the coatings was measured using an Elcometer 3095 hardness tester from SciTeeX, designed for rapid Brinell hardness assessment using the indenter push method, with a pressure of 500g.

The thickness and hardness of the coating was tested at three points, shown in Figure 1.



**Figure 1.** Coating thickness and hardness measurement locations.

In the hardness tests, the indentation length was determined by gently lowering the indenter onto the test coating over a period of 30 seconds. After raising the indenter, the length of the resulting indentation was read using a microscope after 35 s. Hardness  $x$  was determined from the relationship:

$$x = 100/l \quad (1)$$

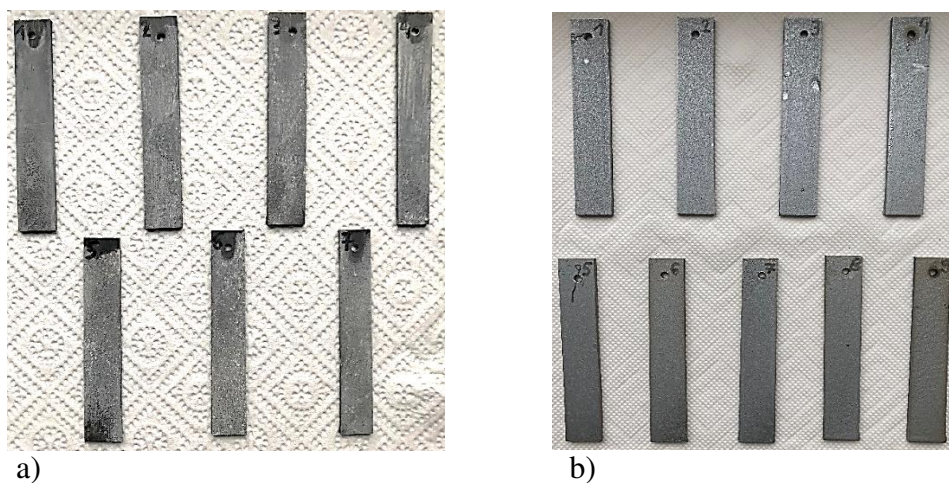
where:

$x$  – hardness,

HB;  $l$  – indentation length, mm.

### 3. Results

The specimens were weighed before the experiment, and after coating and drying (Figure 2), they were reweighed. The results of the specimen mass measurements are given in Table 4 and 5.



**Figure 2.** Specimens after zinc coating by: a) galvanic method, b) lamellar method.

**Table 4.***Results of weighing the specimens before and after the application of galvanic coating*

Specimen number	Weight before, g	Weight after, g	Weight gain, g
1	40.48	40.73	0.25
2	41.14	41.56	0.42
3	41.50	41.74	0.24
4	35.36	35.58	0.22
5	40.92	41.25	0.33
6	38.29	38.67	0.38
7	34.77	34.99	0.22
8	41.12	*	-
9	38.62	*	-

\* during the application of coating 7, it was observed that the electrolytic deposition of zinc was not proceeding properly, keeping the specimen in the bath did not result in an improvement of the coating condition. The performance of coatings over a longer period of time (Nos. 8 and 9) was abandoned.

**Table 5.***Results of weighing the specimens before and after application of the lamellar coating*

Specimen number	Weight before, g	Weight after, g	Weight gain, g
1	40.95	41.08	0.13
2	40.86	41.04	0.18
3	41.21	41.42	0.21
4	41.55	41.76	0.21
5	41.30	41.38	0.08
6	41.16	41.23	0.07
7	41.22	41.32	0.10
8	40.72	40.91	0.19
9	40.86	41.03	0.17

The results of the coating thickness measurements are shown in Tables 6 and 7.

**Table 6.***Results of thickness measurements of galvanic coatings*

Specimen number	Measurement 1 $\mu\text{m}$	Measurement 2, $\mu\text{m}$	Measurement 3 $\mu\text{m}$	Mean value $\mu\text{m}$	Variation
1	24.0	22.2	18.8	21.67	6.97
2	25.5	26.2	26.7	26.13	0.36
3	29.3	33.4	25.8	29.50	14.47
4	20.2	17.5	29.7	22.47	41.06
5	34.7	35.0	26.5	32.07	23.26
6	38.4	35.0	26.5	33.30	37.57
7	24.4	22.7	17.8	21.63	11.74
8	-	-	-	-	
9	-	-	-	-	

**Table 7.**  
*Results of lamellar coating thickness measurements*

Specimen number	Measurement 1 $\mu\text{m}$	Measurement 2 $\mu\text{m}$	Measurement 3 $\mu\text{m}$	Mean value $\mu\text{m}$	Variation
1	13.3	14.4	15.7	14.47	1.44
2	17.4	17.0	15.9	16.77	0.60
3	17.5	17.4	15.7	16.87	1.02
4	17.2	16.8	16.4	16.80	0.16
5	13.9	13.6	13.0	13.50	0.21
6	12.7	12.6	12.5	12.60	0.01
7	12.4	12.3	12.1	12.27	0.02
8	11.9	12.1	12.2	12.07	0.02
9	14.7	14.0	15.6	14.77	0.64

The results of the hardness test for coatings applied in the galvanic bath are given in Table 8 and those applied by the lamellar method in Table 9.

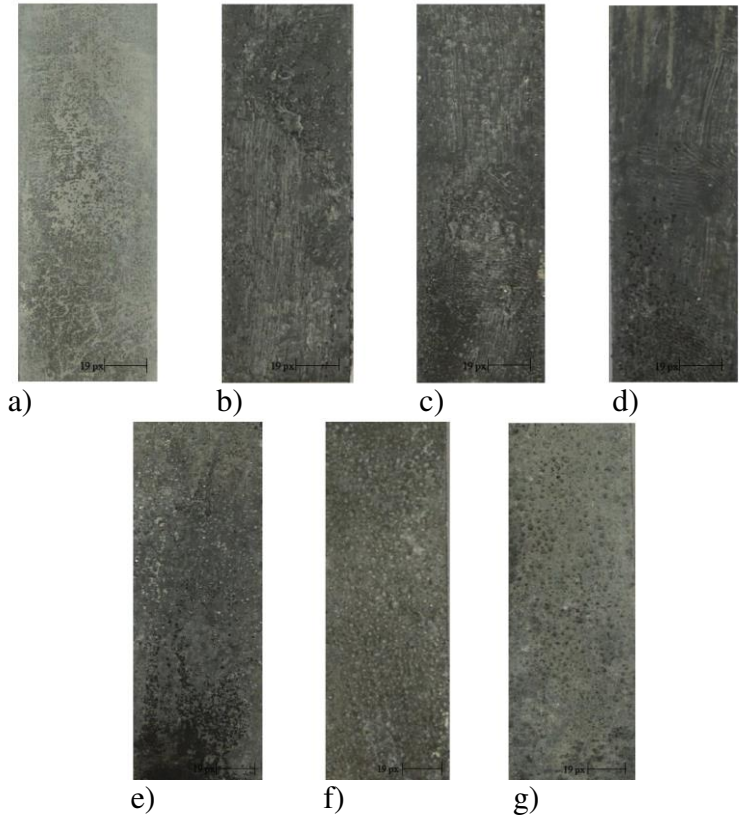
**Table 8.**  
*Hardness of galvanic coatings*

Specimen number	Measurement 1 HB	Measurement 2 HB	Measurement 3 HB	Mean value HB
1	52	50	56	52.7
2	40	42	48	43.3
3	53	50	48	50.3
4	55	58	52	55.0
5	47	43	43	44.3
6	43	55	50	49.3
7	58	66	63	62.3
8	-	-	-	-
9	-	-	-	-

**Table 9.**  
*Hardness of lamellar coatings*

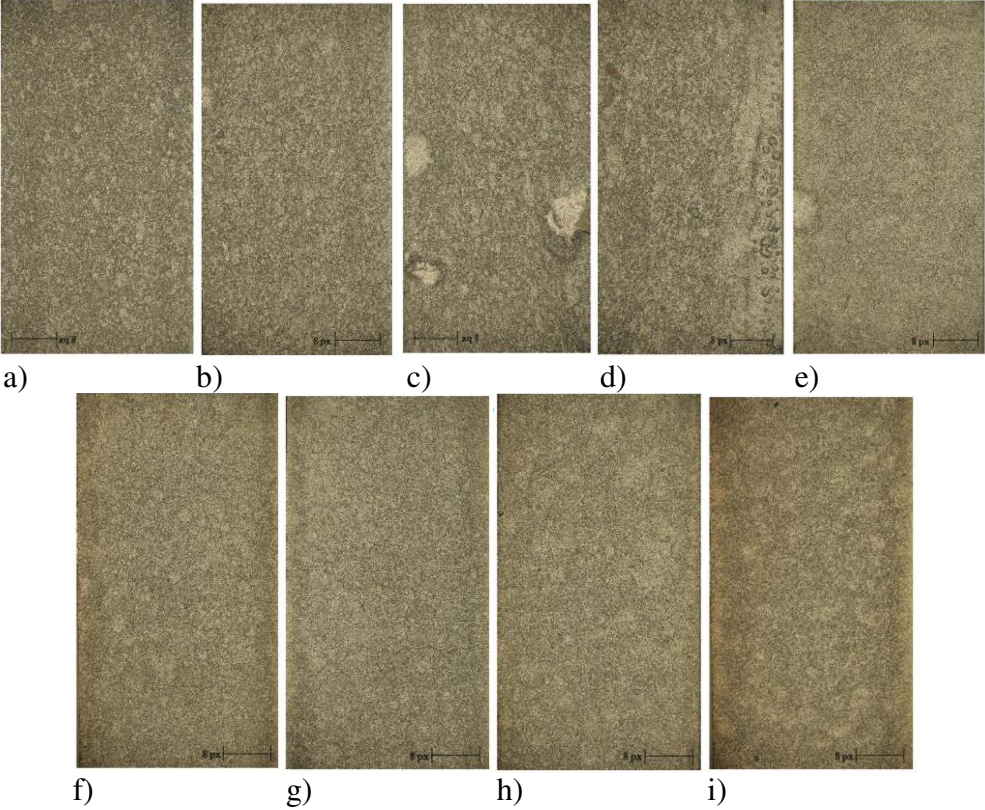
Specimen number	Measurement 1 HB	Measurement 2 HB	Measurement 3 HB	Mean value HB
1	83	77	71	77.0
2	77	83	77	79.0
3	83	91	100	91.3
4	100	111	100	103.7
5	111	111	91	104.3
6	100	125	111	112.0
7	91	91	100	94.0
8	100	83	91	91.3
9	67	77	83	75.7

The results of the macroscopic examination of the coatings are shown in Figures 3 and 4.



a) variant 1, b) variant 2, c) variant 3, d) variant 4, e) variant 5, f) variant 6, g) variant 7.

**Figure 3.** Macrostructure of galvanic coatings on specimens.



a) variant 1, b) variant 2, c) variant 3, d) variant 4, e) variant 5, f) variant 6, g) variant 7, h) variant 8, i) variant 9.

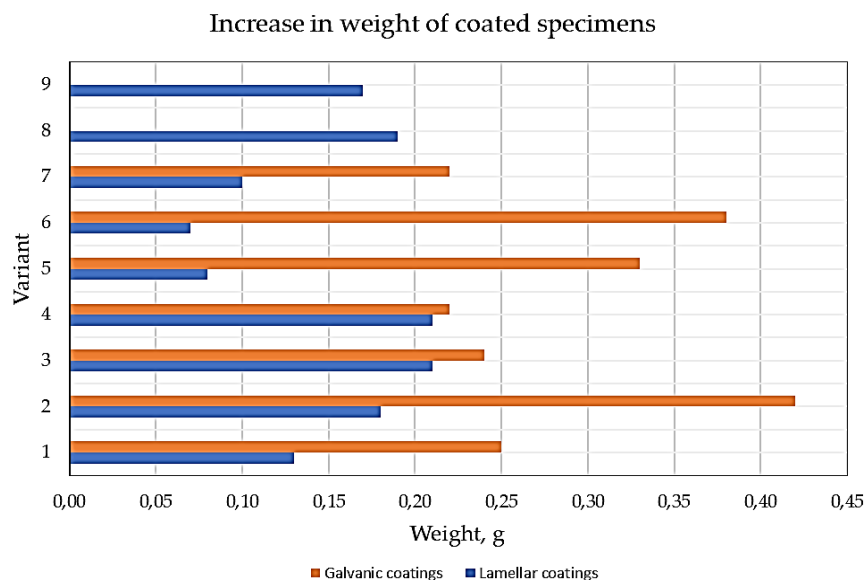
**Figure 4.** Macrostructure of lamellar coatings on specimens.

## 4. Discussion

In the experiment carried out, the application of the coating by the galvanic method in variants 8 and 9 proved to be unjustified. Observing the specimen during bath No. 7, it was observed that the electrolytic deposition at 6A for 300 s did not proceed properly. Separations in the form of zinc dendrites appeared on the surface of the coating, indicating an abnormal process and thus a lack of tight coating of the specimen surface. Therefore, extending the process to 600 and 900 s made no sense. The lamellar coating process was not affected with such difficulties.

Galvanic coatings were heavier than lamellar coatings (Figure 5). Their weight ranged between 0.22 and 0.42 g, while that of lamellar coatings ranged between 0.07 and 0.21 g.

The largest weight increase, i.e. by 0.42 g, was recorded for the plating on specimen 2 (2A, 600 s). In contrast, the coating on lamellar-coated specimen No. 6 was the lightest, 0.07 g (dried at 230°C).



**Figure 5.** Differences in weight gain of specimens with coatings.

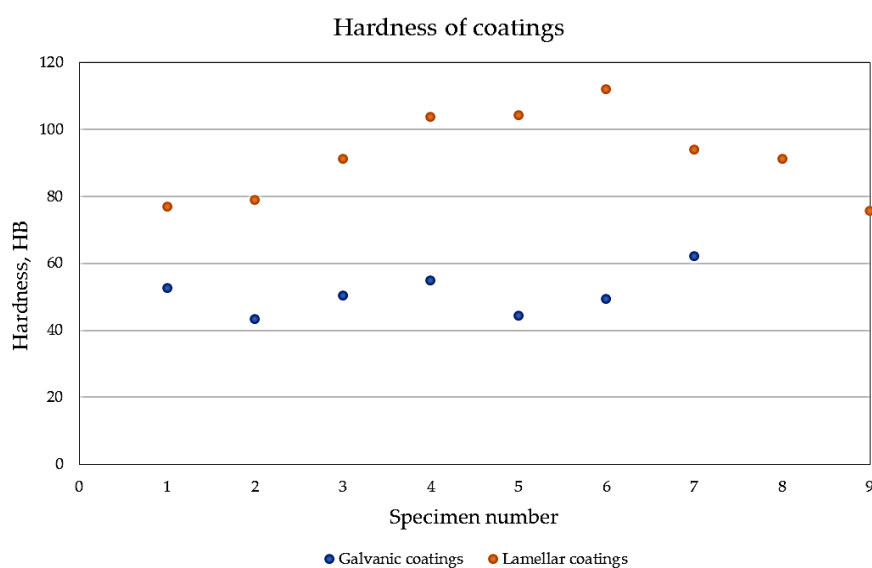
However, despite the implementation difficulties, all galvanic coatings, due to their thickness, meet the requirements of the industry (Rodzynkiewicz-Rudzińska, 1985). It is expected that such a coating should have a thickness in the range of 5 to 40  $\mu\text{m}$ , and the coatings obtained in the experiment had an average thickness in the range of 21.63–33.30  $\mu\text{m}$ , so both the thinnest (in variants 1 and 7) and the thickest in variant 6 are coatings that meet the quality requirements.

For lamellar coatings, a thickness of 5 to 15  $\mu\text{m}$  is required (ISO 10683:2014:2014-05). In the study, the average thickness of the lamellar coatings was found to be between 12.07 and 16.87  $\mu\text{m}$ . Only the coatings on specimens 2, 3 and 4 meet the thickness requirements.

The variance calculated in Tables 6 and 7 shows that lamellar coatings have a higher uniformity (variance in the range of 0.01-1.44), while galvanic coatings differed significantly (variance in the range of 0.36-41.06).

The average hardness of the galvanic coatings was in the range of 43.4-62.3 HB (Figure 6). The hardest galvanic coating was obtained in a bath with a current flow of 6 A (variant 7). Zinc coatings applied using the lamellar method had a significantly higher hardness, with hardness in the range of 75.7-112.0 HB. For these coatings, as the curing temperature increased, the hardness increased, but only up to 230°C. At 250°C, the hardness decreased.

Macroscopic observations of the galvanic coatings indicate that a uniform and tight coating was obtained for specimen No. 1 (2 A, 300 s). No dendritic crystals were observed. As the current increased, the quality of the coatings deteriorated. On specimen No. 5, thickenings of random location were formed. This phenomenon may have been the reason for obtaining different coating thickness measurement results. Coatings of uneven thickness were also visibly rougher. A zinc bath with a current flow of 6 A for 300 s (specimen No. 7) produced the worst coating; excessive hydrogen release caused a spongy structure to appear, which was evident in pitting, sometimes reaching the substrate of the specimen. In order to improve the quality of the coating in this treatment variant, it may be proposed to apply a conversion coating in an additional operation, such as chromating.



**Figure 6.** Comparison of the hardness of the applied coatings.

In contrast, in the case of lamellar coatings, the higher the temperature and longer the curing time, the worse the quality. The best structure was the coating on specimen No. 1 (210°C and cured for 900 s) and specimen No. 2 (210°C and cured for 1500 s) fulfilled the thickness requirement at the same time. Both coatings were uniform and tight, with no visible cavities or cracks. In the case of specimen No. 4, coarsening and fine pitting (230°C, 1500 s) were observed at the edge. In addition, scorch marks appeared on specimens 7, 8 and 9 as a result of excessive heat, particularly evident on specimen 9 (250°C, 2100 s). These may have affected the previously described results of the hardness test of the coatings.

## 5. Conclusions

The application of coatings is justified in the use of products exposed to corrosive agents. The application of coatings can take place in different ways, in which case the correct choice of process parameters is important. Based on the experiment, it can be concluded that the best zinc coating applied in the galvanic bath can be obtained in the galvanizing process at a current of 2 A in 300 s, and when applying the lamellar coating using furnace curing at 210°C in 900 s. However, the lamellar coatings had more favourable characteristics. Lamellar coatings were more uniform than galvanic coatings. Macroscopic examination revealed that the lamellar coatings were continuous, while the galvanic coatings had untightnesses. Lamellar coatings were also harder than galvanic coatings, influenced by the temperature of the furnace during curing.

In terms of decorative qualities, more favourable results were obtained on the specimens with lamellar coatings, as these coatings had a silvery colour and an aesthetically pleasing sheen compared to the galvanic coatings.

Due to the aforementioned characteristics of the coatings, galvanic coatings can be used on parts that are operated in harsh environments, while lamellar coatings can be recommended for products that are required to have a low weight change and certain aesthetics.

## Acknowledgements

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## ORGANIZATIONAL CULTURE AND JOB SATISFACTION OF EMPLOYEES WORKING REMOTELY: A CROSS-CULTURAL ANALYSIS

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**Purpose:** The pandemic has brought new challenges for management and the labor market all over the world, among which the most significant is the transition to remote work. As remote work changes working conditions and communication methods, it is essential to investigate how organizational factors impact the attitudes of remote workers, including satisfaction, which leads to numerous positive outcomes.

**Design/methodology/approach:** This study analyzes the relationship between remote employee satisfaction and organizational culture, exploring the role of specific organizational dimensions. The research is based on a sample of 811 participants- 511 employees from Poland and 300 from the United States. The data was collected online through validated questionnaires: The Denison Organizational Culture Survey (Denison, 1990) and Brief Job Satisfaction Measure (Judge et. al.,1998)

**Findings:** results highlight a positive relationship between remote employee satisfaction and organizational culture's dimensions. The most significant dimensions are: Involvement and Mission, which means that building engagement and teamwork, as well as sharing a clear mission and vision positively impacting overall satisfaction. Interestingly, in the American sample, organizational culture dimensions explained variability in satisfaction over twice as much as in the Polish sample, and the Mission trait has significantly stronger impact on satisfaction than in the Polish group.

**Research limitations/implications:** In future research, it is worth expanding the sample and compare more countries. Also introducing more variables into the model, both organizational and individual (like technical possibilities for remote work, level of social support, as well as personality traits) would be beneficial to comprehensively explain the model of remote work satisfaction.

**Practical implications:** The results provide valuable guidance for cultivating a satisfied remote workforce- managers of dispersed teams can influence satisfaction primarily through transparent communication, setting a clear vision and achievable goals, as well as mutual understanding, promoting teamwork and ensuring that employees feel valued and empowered. It is also essential to analyze the national culture of employees, as it can also influence their satisfaction.

**Originality/value:** The results fill the cognitive gap in the field of remote employees' satisfaction and organizational factors affecting it, taking into account cultural differences, allowing for an interdisciplinary perspective on job satisfaction.

**Keywords:** organizational culture, employee satisfaction, remote work.

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

## Introduction

Both organizational culture and employee satisfaction are issues that have recently gained significant interest. This is linked to the continuously growing awareness of the importance of "soft areas" in human resource management. However, a literature analysis indicates that these two constructs require in-depth research, particularly from the perspective of changes initiated as a result of the SARS-CoV-2 pandemic. The pandemic has reshaped the world and the way work is conducted. In March 2020, many companies had to implement remote work as the prevailing norm. It is estimated that by the end of March 2020, over 3.4 billion people across 84 countries remained in their homes, signifying that many millions of employees transitioned to remote work mode (Bouziri et al., 2020). For the purpose of this article, remote work is defined as a form of work performed outside the employer's premises, utilizing information technology, in a location convenient for the employee while simultaneously meeting the employer's requirements (Bayarma, Dijst, 2012). The challenges posed by remote work to organizations require ongoing focus on organizational factors that can support employees in achieving a balance between personal and professional life, consequently contributing to their job satisfaction, which, in turn, leads to higher effectiveness (Judge et al., 2001). However, some research shows that the level of job satisfaction is similar among employees working on-site or remotely in the same company (Morganson et al., 2010), so the mode of work is not the direct predictor of satisfaction-some other organizational factors play important roles in job satisfaction development. That is why an organizational culture, which shapes the work environment and organizational values, is assumed to be a significant factor influencing the satisfaction (Janićjević et al., 2018).

As this relationship is not broadly investigated in remote work context, there is a need to explore this research area. We designed a study to answer the following research questions: RQ1) Is there a relationship between organizational culture and job satisfaction of remote employees? RQ2) Which organizational culture dimensions are most significant for variability of job satisfaction? RQ3) Are there any differences between samples from different cultures in experiencing job satisfaction and do other organizational culture dimensions explain its variability? We chose the model of organizational culture proposed by Denison as it is focused on four different dimensions of the culture: Involvement, Consistency, Adaptability and Mission (Denison et al. 2012), aimed to strengthen the flexibility of the company, which is

crucial in hybrid and remote work. In the methodological step, Spearman's correlation coefficient between variables were analysed, and in order to determine which organizational culture trait explain the variability of job satisfaction, stepwise multiple regression was used. The results fill the cognitive gap in this field and bring interesting insight in cross-cultural differences.

## 1. The Impact of Remote Work on Employee Satisfaction

Initially, it seemed that introducing remote work could enhance productivity and employee satisfaction, partly due to reduced commuting time. However, changes in collaboration methods, communication, or time management of remote employees were quickly noted. Today, we are well aware that these changes had a direct impact on employees' well-being and their job satisfaction (Azarbouyeh, Naini, 2014). According to the research conducted by the American Gallup Institute, only 33% of surveyed employees reported a good level of overall well-being (Raport MIT Solan, 2023), however, in line with the People at Work 2022: A Global Workforce View report (Richardson, Antonello, 2022), individuals working remotely exhibited a higher level of job satisfaction than their colleagues remaining in the office, while simultaneously indicating that their mental well-being was poorer. From these reports, it emerges that transitioning to remote work can enhance productivity, but it often comes at the expense of employees' well-being (Subel et al., 2022). Therefore, satisfaction may increase in terms of supervisor control or time management, but over time, as well-being deteriorates, it may start to decrease. Research shows that the shift towards a digital work setting has generated an immediate necessity to address the overwhelming amount of data, the detachment from work, and the declining social connections among employees caused by their isolation, leading to reduced trust and a diminished sense of empowerment (Van Wart et al., 2019). Although remote work provides greater autonomy in terms of time and space, it leads to work intensification and additional workload for employees (Bathini, Kandathil, 2019). While working remotely, on one hand, it's easier to experience a collision between professional and personal responsibilities, which results in interference in employees' personal lives (Cortellazzo et al., 2019; Gálvez et al., 2020; Ferreira, Gomes, 2023), on the other hand, remote work offers greater flexibility in fulfilling family responsibilities for many employees, as they can work from anywhere and at any time (Fedakova, 2017; Kłopotek, 2017).

Research shows that the satisfaction of remote employees can change due to pay and progression, work-life balance, wellbeing and family considerations, as well as a company's corporate values (Richardson, Antonello, 2022). That is why we considered organizational culture, defined as a set of shared values, beliefs, and norms guiding an organization's actions, to significantly influence the remote work environment and, consequently, job satisfaction levels.

## 2. Organizational Culture and job satisfaction

Employee satisfaction is one of the mostly discussed construct in relation to organizational behavior. Based on some research, a satisfied employee is quite often more efficient (Judge et al., 2001), more attached to the organization (Qureshi et al., 2011) or more devoted to his or her company (Christian et al., 2011). Satisfaction is usually perceived as the attitude resulting from the individual's reaction to the surrounding work conditions (Judge, Kammeyer-Mueller, 2012). That is why we chose to analyse the organizational culture along with satisfaction. Locke and Latham (Lock, Latham, 1990) even proposed so called high performance cycle model, which purpose is to ensure high efficiency derived from job satisfaction. Although job satisfaction studies have been conducted multiple times (Suyono et al., 2019), they primarily focused on on-site work. Remote work has altered the work conditions and consequently, different values and norms may now have a greater impact on job satisfaction than before the shift to remote work. Examining remote employees' satisfaction is valuable, as it helps determine if individuals find fulfillment in specific work aspects (Oleksa, 2017). This is why exploring the connection between satisfaction and organizational culture can bring valuable insights.

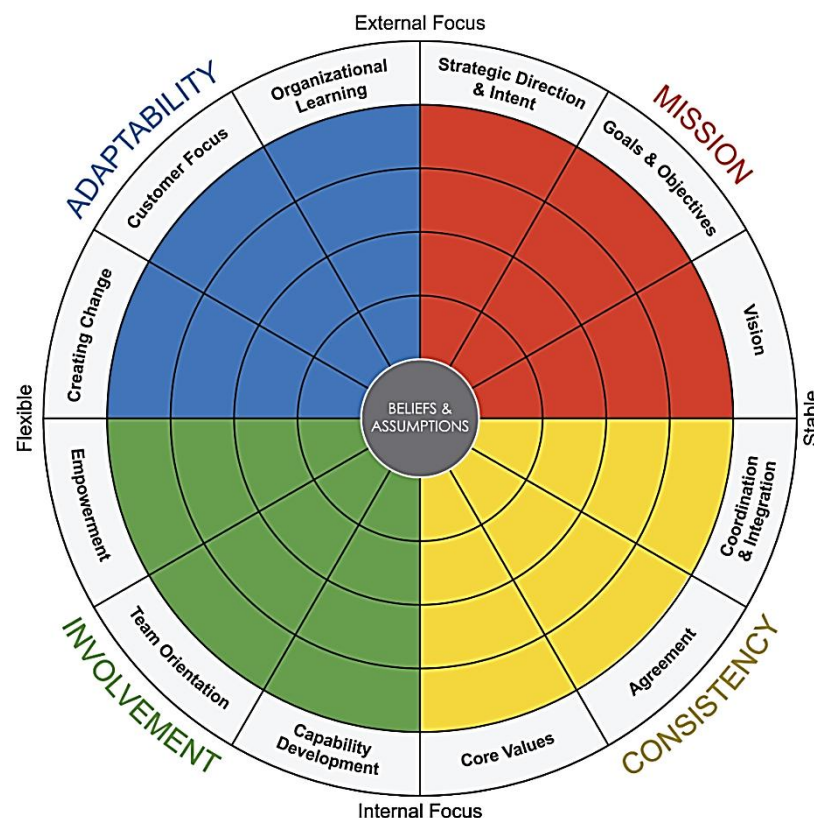
Job satisfaction is closely associated with organizational culture (Spector, 1997; Lund, 2003; Belias, Koustelios, 2014). B. Groysberg et al. (2018) summarized various definitions of organizational culture used in management studies and highlighted four main elements:

- Sharedness – culture must exist within a group, in its norms and expectations, not solely in the mind of an individual employee.
- Universality – culture permeates different levels of the organization, is expressed in the behaviors of employee groups, rituals, symbols, and even in the physical space of the organization.
- Persistence – culture influences employees' behaviors and attitudes in the long term. It develops through critical events within the organization and is not subject to rapid modifications.
- Perceptibility – while not all elements of organizational culture are consciously recognized, organization members internalize its values and instinctively react in accordance with cultural assumptions.

The aforementioned principles indicate that organizational culture constitutes a relatively stable set of diverse values and norms shared by employees, influencing their work, behaviors, and even well-being. Hence, it is worthwhile to explore the relationship between culture and satisfaction. To examine this relationship in the context of remote employees, we selected D. Denison's organizational culture model as the theoretical framework. D. Denison, one of the leading researchers in organizational culture, developed the model after two decades of research, consisting of four main dimensions and subdivided into twelve specific strategies that

differentiate companies by high and low performance. The premise of this model is the presence of fundamental beliefs within companies about organizational functioning, its members, market position, and approach to customers, which shape organizational strategies and structure. Furthermore, companies, while pursuing various goals and tasks, frequently face the choice of actions along two axes: external orientation - internal orientation and flexibility-stability. Given the existence of fundamental beliefs and assumptions along with orientations, the model highlights four core dimensions (Denison et al., 2012):

- Mission - the clarity of the organization's purpose, enabling the formulation of strategies and a vision for the company's future.
- Consistency - the level of integration within the organization in terms of aligning the mission with actions, sharing fundamental organizational values, and the consistency of attributes (attire, procedures) that express the core assumptions of the company.
- Involvement - the degree of emphasis on human capital development, primarily through enhancing employees' skills and building effective teams.
- Adaptability - the level of flexibility and the ability to respond to changes in the environment.



**Figure 1.** Organizational Culture Model of D. Denison.

Source: Denison, Hooijberg, Lane, Lief, 2012, p. 8.

The Denison model stands out from other popular organizational culture models (e.g. the Competing Values Framework coined by Cameron and Quinn (Cameron, Quinn, 2006), or Organisational Culture Inventory by Cooke and Lafferty (Cook, Szumal, 2013)

because it doesn't presuppose the existence of cultural types, but rather the possibility of balancing its dimensions, thereby enabling organizations to operate more flexibly and respond to market needs more swiftly. Departing from typological models allows for the creation of organizational culture tailored to the specific and unique goals of various enterprises. This becomes particularly crucial in the face of dynamic market changes that have been amplified by the pandemic, as well as the widespread shift to virtual spaces (e.g., in terms of hybrid/remote work).

Consciously shaping organizational culture provides the opportunity to enhance organizational efficiency and, as research indicates, elevate the level of employee satisfaction, which is often a result of culture evaluation (Belias, Koustelios, 2014; Mesfin et al., 2020; Oleksa-Marewska, Tokar, 2021). Moreover, culture defines a set of values and the corresponding norms, influencing behaviors, both desired and those the organization seeks to avoid. Employee behaviors will significantly change based on their level of job satisfaction. In light of the above considerations grounded in D. Denison's organizational culture model, the following hypotheses have been formulated:

H1: Higher assessment of organizational culture corresponds to higher level of employee satisfaction.

H2: Higher level of satisfaction are significantly correlated with a positive assessment of all dimensions of organizational culture.

Organizational culture, seemingly to national culture, can vary depending on the mentality of both managers and employees. The Denison model is based on the analysis of primarily American enterprises operating internationally or locally. However, there is a lack of broader research comparing employees from different countries, especially in remote work context. Therefore, it was valuable compare American and Polish employees - the pandemic has led to a substantial convergence in work modes and methods, yet issues of national culture and mentality may still impact the perception of organizational culture and its influence on satisfaction.

H3: There are differences in the level of satisfaction between the studied groups of respondents, depending on the assessment of dimensions of organizational culture.

### **3. Research Methodology**

To validate the stated hypotheses, primary data was collected using a meticulously designed research approach. The research was conducted from February to March 2022. It was imperative to enlist remote or hybrid workers as respondents, ensuring an international scope by including participants from Poland and the United States. It was also important to have an international sample so as to be able to draw conclusions in an extended context.



Because of this, non-probability sampling was chosen, and the selection of respondents was done with assistance from reputable research agencies. The analysis was based on two questionnaires: the Organizational Culture Survey and the Job Satisfaction Survey. Subsequently, statistical methods were applied to analyze the quantitative data derived from the surveys. This allowed for the interpretation of the results and facilitated comparisons of correlations between satisfaction and various cultural traits in both participant groups. Additionally, regression models were utilized to identify the cultural trait that exerted the most significant influence on satisfaction levels.

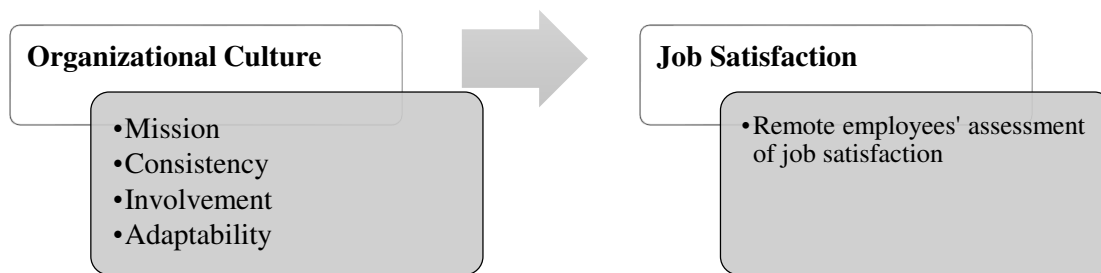
### **Sample, procedure and measures**

The sample comprised of respondents employed in Poland (511) and those employed in the United States (300 individuals). The authors compared the Polish sample with the American one since the culture assessment tool was primarily developed on an American sample, making this aspect particularly interesting. In both samples, a similar percentage of women (59.3% in the Polish sample, 54% in the American sample) and men (40.51% and 46%) were present, and one participant from the Polish sample identified as non-binary. Regarding education, the Polish sample was dominated by individuals with higher education: master's degree (48.92%), followed by bachelor's degree (29.94%), and engineering degree (15.26%). In the American sample, individuals with bachelor's degrees predominated (50.67%), followed by engineering degrees (19.33%), and high school diplomas (18%). Only 8.67% of individuals in the American sample held master's degrees, indicating significant differences in the educational model between the two studied countries.

The sample encompassed individuals with diverse work experience (ranging from a few months to 38 years) working in organizations of various sizes, from small, several-person teams to those employing over 250 individuals. Notably, from the perspective of organizational culture analysis, a significant portion of the participants worked in a remote/hybrid mode after the onset of the pandemic (83% in Poland, 71% in the United States). However, the remaining portion of respondents performed their duties in this manner before the pandemic began. All respondents completed the electronic survey. The data gathered through two questionnaires were analyzed: Job satisfaction was measured on the five-item scale called the Brief Job Satisfaction Measure, proposed by T. Judge et al. (1998), which showed satisfactory reliability (0.88), and the organizational culture was assessed with the use of Denison Organizational Culture Survey (DOCS), which consists of 48 statements investigating 4 dimensions of organizational culture. Reliability of all four subscales of DOCS was also satisfactory (from 0.88 to 0.97) (Gillespie et al., 2008).

## 4. Results of Analysis

Using the R programming language for statistical modeling, correlation analyses between variables, regression models, and group comparisons were conducted. Given that the variables did not follow a normal distribution, Spearman correlations were applied. Figure 2 presents the graphical model of tested variables.



**Figure 2.** Graphical conceptualisation of variables.

Source: Own elaboration.

Correlation analyses revealed significant, moderate correlations between the level of employee satisfaction and the assessment of organizational culture. In the entire sample ( $N = 811$ ), the strength of these relationships was positive and moderate ( $\rho = 0.45$ ). These results allow to confirm hypothesis H1.

Comparing between the Polish and American groups, it was found that there are significant differences in the relationship between these variables. In the American sample, there was a significantly higher correlation between the overall assessment of culture and the level of satisfaction ( $\rho = 0.52$ , whereas in the Polish sample, it was  $\rho = 0.41$ ). All dimensions of culture exhibited moderate, positive correlations with satisfaction, confirming hypothesis H2.

To ascertain significant differences between the surveyed countries in terms of satisfaction levels and assessment of cultural dimensions, a Mann-Whitney U test was conducted. The results of this analysis are presented in Table 1.

**Table 1.**

*Differences between the groups in terms of satisfaction levels and the assessment of cultural dimensions*

Variable	Poland (a)					United States (b)					U Mann-Whitney test			rg
	N	M	SD	Me	Mrang	N	M	SD	Me	Mrang	U	p	Difference a vs b	
Satisfaction	511	4.27	0.95	4.20	406.00	300	4.27	1.02	4.20	406.00	76521.00	0.968	a = b	0.00
Involvement	511	3.66	0.77	3.75	376.00	300	3.91	0.72	4.00	458.00	61128.00	0.000	a < b	0.20
Consistency	511	3.68	0.73	3.83	380.00	300	3.89	0.69	4.00	450.00	63315.50	0.000	a < b	0.17
Adaptability	511	3.63	0.77	3.75	380.00	300	3.85	0.72	3.92	450.00	63449.50	0.000	a < b	0.17
Mission	511	3.68	0.75	3.83	375.00	300	3.94	0.69	4.00	459.00	60735.50	0.000	a < b	0.21

*Mrang* = mean of rang; *U* = U Mann-Whitney statistics; *rg* = Glass's two-way correlation effect size statistic.

Source: Own elaboration.

The results of the analysis indicate significant differences between the surveyed countries in terms of the assessment of organizational culture. In the American sample, all dimensions were rated significantly higher than by respondents from Poland. The level of satisfaction with remote work was similar in both groups.

In the next step, a multivariate linear regression analysis was conducted, separately for both groups. The results are presented in Table 2.

**Table 2.**

*Comparison of linear regression analysis for the Satisfaction variable between the studied groups*

Variable	Group	B	s.e.	t	p
Constant	PL	2.33	0.20	11.41	< 0.001
	USA	0.99	0.29	3.42	< 0.001
Involvement	PL	0.39	0.12	3.23	<0.01
	USA	0.39	0.18	2.09	<0.05
Consistency	PL	0.16	0.12	1.27	> 0.05
	USA	0.16	0.18	-0.89	> 0.05
Adaptability	PL	-0.12	0.11	-1.10	> 0.05
	USA	-0.08	0.15	-0.53	> 0.05
Mission	PL	0.10	0.12	0.83	> 0.05
	USA	0.68	0.18	3.73	<0.001

Source: Own elaboration.

For polish sample (N = 511) regression analysis showed significant prediction ( $F(4, 506) = 26.20$ ;  $p < 0.001$ ), the coefficient of determination ( $R^2$ ) indicated that the regression model, considering the Involvement, Consistency, Adaptability, and Mission, explained approximately 17% of the variability of Satisfaction. One predictor was significant for explaining satisfaction variability and it was the Involvement dimension. While the assessment of other dimensions was statistically significant in terms of correlation with satisfaction, they did not significantly contribute to its increase.

For american sample (300), the regression analysis also showed significant prediction ( $F(4, 295) = 35.72$ ;  $p < 0.001$ ). The analysis of the coefficient of determination ( $R^2$ ) indicated that the regression model explained approximately 32% of the satisfaction variability, which is significantly higher than in polish sample. In american group two dimensions were significant predictors: Involvement and Mission. Both the results of the Mann-Whitney U test and the regression analysis enable us to confirm hypothesis H3.

## 5. Conclusion

The obtained research results demonstrated a significant relationship between the assessment of organizational culture and the level of satisfaction among remote employees. This corresponds with other recent studies conducted on remote workers, which also indicated

that organizational culture impacts key factors contributing to job satisfaction. It can influence motivation levels, which in turn affect the level of satisfaction (Ali et al., 2023), shapes satisfactory communication (Pamula, Zalewska-Turzyńska, 2023), it can foster the development of interpersonal relationships and teamwork (Kocot et al., 2021), which particularly enhances satisfaction with remote work. In the conducted research on the entire sample, the most significant dimensions of organizational culture explaining the variability of satisfaction were the Involvement dimension (employee empowerment, team orientation, and organizational development promotion) and Mission dimension (comprising values like goal clarity, vision, and strategic direction). Similar conclusions have been drawn by other researchers: Pamula and Zalewska-Turzyńska (2023), examining culture with reference to Cameron and Quinn's Competing Values Framework (2006), demonstrated that the highest job satisfaction among remote employees was found in a Clan culture, which emphasizes building engagement and teamwork. Similarly, studies by Bulińska-Stangrecka and Bagieńska (2021) have shown that remote employees' satisfaction is enhanced by positive interpersonal relationships, with this relationship being mediated by a sense of trust within the team. On the other hand, Kocot et al. (2021), focusing on the impact of positive interpersonal relationships promoted within organizational culture, also highlight their influence on job satisfaction in remote work. Also according to Bentley et al. (2016), promoting teamwork and providing social support, especially in a remote context, can enhance job satisfaction. Building positive relationships is an investment in creating an effective organizational culture, where a top priority is maintaining good communication with employees and keeping them informed about decisions that are important to them, so that employees feel like an integral part of the organization (Kocot et al., 2021). In the context of remote work, which lacks regular physical contact with employees and teams, this may appear to be crucial for satisfaction. Employees need to feel that the organization is building a culture of engagement and teamwork, so it is important to find ways to foster team unity and appreciate employees beyond traditional, office-based methods.

An interesting observation arises from the conducted linear regression analysis separately for the Polish and American samples. In the Polish sample, only the Involvement dimension significantly explained satisfaction variability, while the assessment of the Mission dimension among Polish employees did not lead to a substantial, significant increase in satisfaction. This finding might indicate cultural differences between the countries, as well as shifts in the job market. The Mission dimension pertains to the clarity of the organization's purpose, enabling the formulation of strategies and a vision for the company's future. Disparities in regression results could suggest the significance of a clear organizational vision and goals for American employees. Values such as transparency and equality in communication may stem from the specific traits of national culture (Hofstede et al., 2010). Additionally, these differences could reflect certain standards in the American job market, which are still developing in the Polish market, such as involving employees in understanding strategies and

presenting the company's development vision rather than just focusing on tasks to be accomplished by subordinates. Another significant difference is the percentage of explained variance in satisfaction by the organizational culture dimensions. In the American sample, it is almost twice as high as in the Polish sample, suggesting that there are more unaccounted variables or that they have a different degree of influence on the satisfaction of Polish respondents compared to the American sample. Despite cultural differences, the identified organizational traits as drivers of satisfaction exhibit similar effects across both samples.

In future research, it is worth expanding the analyses to compare with other countries. Also introducing more variables into the model explaining the level of satisfaction, both organizational ones like organizational climate or compensation, as well as individual ones (assessment of work-life balance, technical and local possibilities for remote work, social support, and even dominant personality traits) could be beneficial.

In conclusion, this study illuminates the vital connection between organizational culture and remote employee satisfaction. It is worth to balance all dimensions of culture as they are linked to higher satisfaction of remote employees. Based on the obtained results and the analysis of other research, it is crucial to prioritize teamwork and ensure that employees feel understood and accepted. Transparent communication, a clear vision, and achievable goals, as well as mutual understanding, contribute significantly to achieving this. As remote work continues to shape the modern workplace, these insights offer valuable guidance for cultivating a satisfied and motivated remote workforce.

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## DETERMINANTS OF PURCHASE AND CONSUMPTION OF CONVENIENCE FOODS – SURVEY OF POLISH RESPONDENTS

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**Purpose:** The aim of the study was to identify factors influencing consumers' purchasing decisions and frequency of convenience food consumption, including qualitative (gender, generation, income level) and quantitative (attitudes towards new foods, values held and lifestyle) factors.

**Design/methodology/approach:** The research instrument was a survey questionnaire administered through the CAWI method using Google forms. The research was conducted in the spring of 2023 in Gdynia, Pomeranian Voivodeship (Northern Poland). To select the respondents for the survey sample, the snowball sampling technique was used. They also acknowledged the inherent risk factors associated with conducting an interview using the CAWI method. The interview questionnaire consisted of thematic blocks including scales on: lifestyle, food neophobia (FNS), convenience food purchasing habits, frequency of convenience food consumption and intention to purchase convenience foods, and a metric.

**Findings:** The research carried out showed that the use of convenience foods of convenience foods varies widely and can depend on factors such as: gender generation, level of monthly income, lifestyle. It was found that generation Z is more likely, compared to generations X and Y, to express an intention to consume convenience foods, new foods and are interested in unconventional food trends.

**Research limitations/implications:** Our study has some limitations. Identification of factors influencing purchase decisions and frequency of convenience food consumption by consumers belonging to generations X, Y, Z was carried out using snowball sampling among residents of Gdynia. The results of the study are therefore not representative of the entire Polish population and should be interpreted with caution.

**Practical implications:** Our findings can be used as a basis for discussion and reflection on the development of smart food systems using information and communication technologies (ICTs) that provide consumers (Generations X, Y, Z) with knowledge about the range and quality of convenience foods and help them to enjoy convenience foods.

**Originality/value:** The change in consumption trends observed in recent years creates new challenges for convenience foods, which not only simplify meal preparation but also heavily influence the nutritional quality of food. Therefore, convenience food manufacturers should consider the preferences and needs of Generation Z when designing such products.

**Keywords:** food consumption, food trust, new food trends, consumer behaviour of generations X, Y, Z.

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

## 1. Introduction

Consumers play an important role in setting consumption trends in the market (Clark, Tilman, 2017). Food is an expression of people's identity, values and lifestyle (Flemmen et al., 2018). The food market has observed the creation of appealing products for an extended period (Mojka, 2012; Gadzała, Lesiów, 2019). An analysis of consumer trends in the market allows us to distinguish two basic trends in contemporary consumption. These are: 1 - unsustainable consumption (excessive consumption that causes damage to the environment and society); 2 - sustainable consumption (conscious consumption that causes an improvement in the quality of life of the present and contributes to improving the living conditions of future generations) (Komor et al., 2020; Wiśniewska, 2022). Therefore, the analysis of changes in consumer behaviour allows us to propose the thesis that trends in food consumer behaviour are a consequence of the emerging threats, which translate into food and food security (understood as the lack of physical and economic availability and adequacy) (Gadzała, Lesiów, 2019; Kozłowska-Burdziak, 2019).

The research shows that consumer attitudes are influenced by a number of factors including, but not limited to, economic, cultural, social and nutritional awareness (Gadzała, Lesiów, 2019; Topolska et al., 2021). Among the dominant trends in shopping, it is also worth mentioning: eco-consumption (Witek, 2019; Kalińska-Kula, 2016), consumer ethnocentrism (Ratajczyk, 2016), and conscious consumption, which involves ethical and responsible purchasing (Wasilik, 2014; Jasiulecz, 2016). According to the emphasis on conscious consumption, nutrition experts categorise buyers into three groups: 1. Individuals who endeavour to consume healthily and maintain a balanced diet; 2. Individuals who purchase a range of products with little concern for the source of food and its impact on the body; 3. Individuals who make purchases based on their financial means (Gadzała, Lesiów, 2019).

In recent times, there has been a rise in the variety of goods obtainable in the novel food market. These include ethnic products (Maciejewski, 2020), regional products (Wasilik, 2014), vegetarian and vegan products (Maciejewski, 2020), organic foods (Komor et al., 2020; Mazurek-Łopacińska, Sobocińska, 2018), functional and convenience foods (Mojka, 2012). The primary objective of manufacturing convenience food is to create a sustainable product for

immediate consumption or consumption after a short heat treatment (Jeżewska-Zychowicz, 2009; Tuorila, Hartmann, 2020). Convenience food lacks a clear definition, however but all attempts to describe it in the literature have similar elements. The product's purpose is mainly to decrease the time and effort required to prepare a meal (Casini et al., 2019). Consumers have been demonstrated to reap several benefits from accessing new foods. These advantages encompass not only fulfilling nutritional requirements, but also providing food diversity, serving ethical needs (vegan food), convenience, and sustainable consumption (Barska, 2018; Tuorila, Hartmann, 2020). Evidence indicates a shift in Polish dietary habits from traditional home-cooked meals to fast food consumption at street food vendors. The determinants of street food consumption frequency have been identified as service quality, meal quality, personal preference, and price, as noted by Wiatrowski et al. (2021). It has been suggested by some authors that consumers ought to be aware of the risks associated with street food consumption, such as poor production and sales hygiene (Aquad et al., 2019; Kolanowski et al., 2020; Okumus et al., 2014; Tomaszewska et al., 2019). Additionally, several factors including the visual and olfactory characteristics of food, the surroundings, flavour preferences, and even nutrition data have led to customers making pressured or uninformed purchase decisions (Enriquez, Archila-Godinez, 2022). The introduction of cuisine that deviates from conventional dishes has created disputes and mistrust among certain consumer segments. Experts suggest that the Polish food market currently lacks ready-to-eat products, with the majority being traditional options. This may be attributed to the prevalence of food neophobia (Barska, 2018), whereby anxiety and fear of new foods can significantly impact consumers' ability to learn about and experience new products (Socha et al., 2009). The literature suggests that neophobia is associated with gender (Platta, 2019), education, and income level (Siddiqui et al., 2022). As a result, it diminishes demand in the innovative food industry by limiting the range of products bought (Kozioł-Kozakowska, Piórecka, 2013).

In recent times, there has been a shift in the assessment of convenience food. It is no longer viewed as having an adverse impact on health and is now being promoted as a means to aid the dietary patterns of the elderly and other individuals (Nakano, Washizu, 2020). Additionally, in developed nations with aging populations, convenience foods are anticipated to enhance the eating habits of the elderly (Maitre et al., 2014; Soucier et al., 2019; Zhou et al., 2019). Identifying trends in the consumption of convenient food is crucial in ensuring the nutritional needs of present and future generations are met. It is crucial to ascertain the factors that determine purchasing decisions when it comes to convenient food. While literature offers studies on this issue, they tend to focus primarily on organic food. Highlighted by the authors of these studies is a discrepancy between consumers' affirmed positive attitudes towards organic food and their actual purchasing behaviour, where purchases are marginal (Buder et al., 2014; Caniels et al., 2021; Paladino, Ng, 2013; Young et al., 2010). In terms of consumers' willingness to purchase food, particularly convenience foods, factors such as purchase and usage

convenience, perceived need fulfilment, quality, efficiency, sustainability, and trust in the provider and their products are also relevant considerations (Lewicka-Strzałecka, 2015).

Due to differences in awareness of nutritional needs, attitudes towards new foods, lifestyles, and socio-demographic variables, consumer attitudes and behaviours towards convenience foods can vary. Therefore, further exploration in this area is necessary.

## 2. Methods

The main objective of the research was to identify factors influencing consumers' purchasing decisions and frequency of convenience food consumption, including qualitative (gender, generation, income level) and quantitative (attitudes towards new foods, values held and lifestyle) factors.

The research instrument was a survey questionnaire administered through the CAWI method using Google forms. The research was conducted in the spring of 2023 among a group of 393 respondents in Gdynia, Pomeranian Voivodeship (Northern Poland). To select the respondents for the survey sample, the snowball sampling technique was used. They also acknowledged the inherent risk factors associated with conducting an interview using the CAWI method. The survey sample's characteristics are presented in Table 1.

**Table 1.**  
*Study sample characteristics*

Parameters	Number of Respondents [n]	Percentage [%]
<b>Gender</b>		
Female	197	50.13
Male	196	49.87
<b>Generation</b>		
X	134	34.09
Y	130	33.08
Z	129	32.83
<b>Monthly income</b>		
Allows to meet basic needs	118	30.02
I/we can afford some, but not all expenses	184	46.82
I/we can afford everything	91	23.16

Source: own elaboration based on survey results.

The research implemented a semi-standardized interview questionnaire (Jeżewska-Zychowicz et al., 2015), which underwent adaptation to suit the unique features of the study. The interview questionnaire consisted of thematic blocks including scales on: lifestyle, food neophobia (FNS), convenience food purchasing habits, frequency of convenience food consumption and intention to purchase convenience foods, and a metric.

Lifestyle Respondents assessed their own lifestyle by giving their opinion on four statements describing values and lifestyle: "I consider myself to be someone who pays attention to the naturalness of food, values tradition, is very health conscious and pays a great deal of attention to the health value of the food I consume". Opinions were rated on a 5-point scale ranging from "1" defined as disagree, "2" - rather disagree, "3" - neither disagree nor agree, "4" - rather agree, "5" – agree (Arvola et al., 2007).

In contrast, the Food Neophobia Scale (FSN) developed by Pliner and Hobden (1992) was used to assess attitudes towards new foods. The FSN consists of 10 statements on which respondents expressed their own opinions. In order to achieve the intended purpose, statements number 5, 6, 10 of the FNS scale were modified to statements that read: so-called 'healthy food' is too weird-looking for me to eat (5), At parties/when I go out I like to try new foods (6), I like to try new foods (10). Additionally, the scale underwent a revision whereby the 7-point rating scale was replaced with a 5-point scale. The new scale comprised of rating 1 as 'disagree', 2 as 'rather disagree', 3 as 'neither disagree nor agree', 4 as 'rather agree', and 5 as 'agree'. The method used to analyse the responses remained unchanged from the original Food Neophobia Scale. After recoding statements where higher points corresponded to a neophobic attitude, we summed the answers and calculated two indicators from the totals: the mean value (X) and standard deviation (SD). The aforementioned indices differentiated three attitude types, each with a distinct range of scores. These ranges are as follows: below X-SD, from X-SD to X+SD, and exceeding X+SD, which correspond to low, moderate, and high levels of food neophobia, respectively.

Respondents indicated the frequency of consumption of convenience foods, i.e.: ready-to-eat peeled fruit/vegetables, dried fruit/vegetables, pan vegetables, nuts, freshly squeezed juices, hummus, instant soups, ready-to-eat salads, ready-to-eat sandwiches, sweet desserts, dumplings intended for short cooking, pizza from a pizzeria, burgers, fries, kebabs, hot dogs, salty snacks, sweet drinks, vacuum-packed ready lunches, bakery products. When rating the frequency of consumption, respondents gave 1 out of 7 possible answers next to each product presented: 1 - don't know, 2 - know but don't consume, 3 - 1-2 times a month (occasionally), 4 - 1-2 times a week (often), 5 - 3-5 times a week (very often), 6 - once a day, 7 - 2-3 times a day or more often.

Convenience food consumption habits, on the other hand, were assessed on the basis of respondents' opinions on 7 statements: 'I eat convenience foods regularly', 'I eat a variety of convenience foods', 'I eat convenience foods mainly for breakfast', 'I eat convenience foods mainly for lunch', 'I eat convenience foods mainly for dinner', 'I eat convenience foods mainly as a snack between meals (including as a source of fluid)', 'I like to always have convenience foods at home'. Opinions were expressed on a 5-point scale where '1' was 'no', '2' was 'rather no', '3' was 'neither yes nor no', '4' was 'rather yes', '5' was 'yes'.

Intention to consume convenience foods was assessed across various options, including ready-made lunches for quick heating, products for direct consumption, bakery products, fast food restaurant products, and catered lunches. A 5-point rating scale was used: '1' was 'no', '2' was 'rather no', '3' was 'neither yes nor no', '4' was 'rather yes', '5' was 'yes'.

The survey consisted of inquiries that explored the sociodemographic features of the participant, such as sex, age, and viewpoint on income.

A reliability test was conducted using Cronbach's alpha coefficient, with a resulting  $\alpha$  value of 0.86 indicating high reliability. All FNS statements were found to be valid, with factor loading values exceeding 0.700. The Kaiser-Meyer-Olkin test had a value of 0.861, while the Bartlett test produced a value of 1435 ( $df = 45$ ;  $p < 0.001$ ).

The study analyzed qualitative variables, including gender, generation, monthly income, and food neophobia. The results were presented through the percentage distribution of individual responses (% of indications). To determine the relationship between gender, generation, meat income, and food neophobia in the study groups, a Chi-square test was performed with Yates correction, based on statements included in the food neophobia scale. The Mann-Whitney U test was used to compare men and women, while the Kruskal-Wallis test was used to compare groups categorised by generation and monthly income. To investigate the connections between gender, generation, monthly income, neophobia, naturalness of food consumption, traditional values, health consciousness, and significance of health values of food intake, the Spearman's rank correlation coefficient was calculated. For all statistical analyses, a significance level of  $p < 0.05$  was set. The calculations were conducted using Excel 2000 and Statistica 13.3 (Tibco Software, Palo Alto, USA).

### 3. Results

Following the methodology outlined earlier, the study population was categorised into three groups based on the severity of their neophobia towards novel foods. The majority of respondents (67.18%) held an ambivalent attitude towards novel foods, while only 17.04% demonstrated neophilic tendencies and 15.78% exhibited neophobic attitudes (Table 2). Only males and females ( $p = 0.62$ ) showed no statistically significant difference in the percentage allocation of attitudes towards novel foods. Ambivalent attitudes were prevalent across all groups. In Generation Z, the study found a significantly higher occurrence of neophilic attitudes (25.58%) and a lower occurrence of ambivalent attitudes (58.91%) when compared to other generations (Table 2). The greatest differences in attitudes were observed amongst groups with monthly income as the dividing criterion. A tendency towards novelty-seeking was found to occur significantly less frequently among those with insufficient income (8.48%), whereas it was observed significantly more frequently among those with high income

(31.87%). Furthermore, individuals with insufficient income exhibited neophobic attitudes (29.66%) at significantly higher rates than other respondents (those with declared middle income - 11.41% and high income - 6.59%) (Table 2).

**Table 2.**

*Population structure and attitudes towards food neophobia amongst respondents' sociodemographic features [%]*

Population characteristics	Attitudes towards food neophobia		
	neophilic	ambivalent	neophobic
Whole population	17.04	67.18	15.78
<b>Gender</b> (Chi2 = 0.95; df = 2; $p = 0.62$ )			
Men	16.33	69.39	14.29
Women	17.77	64.97	17.26
<b>Generation</b> (Chi2 = 9.95; df = 4; $p = 0.04$ )			
X	13.43	71.64	14.93
Y	12.31	70.77	16.92
Z	25.58	58.91	15.51
<b>Monthly income</b> (Chi2 = 38.04; df = 4; $p < 0.01$ )			
Inadequate	8.48	61.86	29.66
Middle	15.22	73.37	11.41
High	31.87	61.54	6.59

Source: own elaboration based on survey results.

Respondents were asked to respond to the 10 statements of the Food Neophobia Scale. Gender, generation and monthly income were selected as differentiating factors. The most significant differences in responses to these questions were observed in the group where monthly income was the dividing criterion ( $p < 0.05$ ) (Table 3). Throughout the entire sample, individuals with inadequate income for the statement "I am constantly sampling new and different foods" were significantly more prone to responding "disagree" or "rather disagree" (16.54%) in contrast to those with a high income (6.11%). On the other hand, those with a middle income were more inclined to answer 'agree' or 'rather agree' (15.01% of the total group) relative to the other groups. In responses to the statement: "If I don't know what is in a food, I won't try it", people with a middle income (28.24% of total respondents) were significantly more likely to answer "I don't agree" and "I rather disagree", compared to the other groups and the other forms of response while at the same time declaring with this their openness to new foods. "I like foods from different countries" was significantly more often declared by representatives of generation Z (25.44%), X (21.38%) and people with middle income (32.83%) and high income (18.32%). For the statement: "So-called 'health food' looks too weird for me to eat", negative answers were significantly more often given by people from generation Z (24.43% of the total number of respondents) and generation Y (22.90%) and those declaring a monthly income at a middle level (32.56%). Conversely, individuals from Generation Z (20.39% of total respondents) and those with an middle income (31.04% of total respondents) expressed a significantly higher inclination to try novel foods in social settings. Meanwhile, 6.87% of respondents with inadequate monthly income expressed apprehension about trying new food. Additionally, the research revealed that individuals with a stated middle monthly

income (27.22% of all participants) exhibited no apprehension towards experimenting with new culinary options. Significant differences between respondents in the responses given to the statement: "I am very particular about the foods I will eat" was observed for gender (Table 3). Women were significantly more likely, compared to men (15.52%) to declare that they are demanding about the foods they eat. Men (33.33%) were also significantly more likely than women (16.80%) to declare that they were not demanding with regard to the food they ate. In the answers given to the statement: "I will eat almost anything" significant differences were observed in all analysed groups (gender, generation, declared monthly income) (Table 3). Negative answers were given significantly more often by women (18.83%), persons from generation X and Z (10.50% each) and persons with middle and inadequate income (12.72 and 11.37% respectively). "I like to try new foods" was declared significantly more often by people from generation Z (12.63% of total respondents) and those with a middle income (27.74% of total respondents). Mean values for individual FNS statements ranged from 2.20 points, for the statement: "I like foods from different countries", to 3.08 points, for the statement: "I am constantly sampling new and different foods" (Table 3). It should be noted that the mean values for all statements indicate a high proportion of 'neither agree nor disagree' responses. A significant correlation between monthly income and responses to eight out of the ten FNS statements was observed in tests comparing two groups (gender - Mann-Whitney U-test) and three independent groups (generation, income - Kruskal-Wallis test). This effect was also seen in the Chi2 test (Table 3).

To present the findings of the Spearman rank correlation, we selected convenience food products, intentions, and habits that had at least a weak, but statistically significant correlation. Figure 1 displays mostly weak, but significant correlations between gender, generation, and declared monthly income with the frequency of consumption of convenience foods. No significant impact of attitudes towards new foods was detected on the consumption frequency of selected convenience products. In terms of frequency, males were significantly more inclined than females to consume kebabs (0.21), hot dogs (0.27), sugary drinks (0.22), vacuum-packed ready lunches (0.20) and rotisserie chicken (0.22). Generation Z, on the other hand, are significantly more likely to declare consumption of short-cooked dumplings (0.21), pizza (0.20), chips (0.25), kebabs (0.29), rotisserie chicken (0.20) and burgers (0.41) (moderate correlation), compared to representatives of generations Y and X. Respondents with a high income were significantly more likely to consume dried fruit and vegetables (0.28) and stir-fried vegetables and healthy snacks such as nuts (0.20 each).

When analysing the influence of attention to the naturalness of food, appreciation of tradition, health consciousness and appreciation of the health benefits of food on the frequency of consumption of products belonging to convenience foods, it was observed that people who pay more attention to the naturalness of food were significantly more likely to declare the consumption of dried fruit and vegetables (0.25), healthy snacks such as nuts (0.27) and freshly squeezed juices (0.24) (figure 2). In contrast, people who do not pay attention to the naturalness



of food were significantly more likely to declare eating instant soups (0.22), kebabs (0.21), hot dogs (0.27), salty snacks (0.26), vacuum-packed ready-made dinners (0.26), rotisserie chicken (0.21) and sugar drinks (0.35 moderate correlation). Those who do not pay attention to tradition were significantly more likely to declare eating burgers and kebabs (0.21 each). Respondents characterised by high health consciousness were significantly more likely to declare consumption of dried fruit and vegetables (0.28) and healthy snacks such as nuts (0.25). In contrast, those with lower health consciousness were significantly more likely to declare consumption of instant soups (0.20) and sugary drinks (0.26). Dried fruit and vegetables (0.37), healthy snacks such as nuts (0.39) and freshly squeezed juices (0.23) were significantly more likely to be consumed by those who pay attention to the naturalness of food. In contrast, people who do not pay attention to the naturalness of food are significantly more likely to report consuming instant soups (0.36), quick cook dumplings (0.21), crisps (0.21), kebabs (0.26), hot dogs (0.37), savoury snacks (0.31), sweet drinks (0.41), pre-packaged ready meals (0.33) and rotisserie chicken (0.28) (Figure 2).

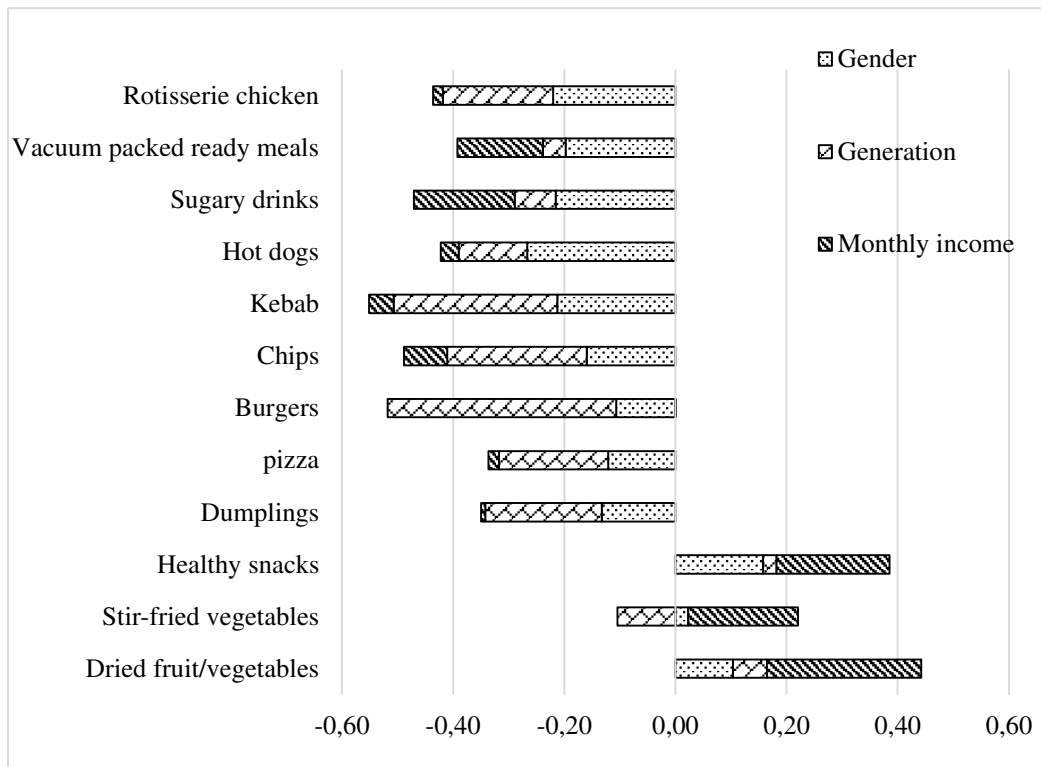
When analysing the influence of factors on the frequency and intention to consume convenience foods and habits, only gender, generation, attention to the naturalness of food and appreciating the health benefits of food were observed to have a significant effect (Figure 3). Men were found to be significantly more likely than women to declare buying meals for quick cooking and products for direct consumption (0.29 each). Men also differed significantly from women in their habits and behaviours towards convenience foods. They were significantly more likely than women to report eating convenience food regularly (0.24), consuming it for lunch (0.23) and keeping convenience food at home (0.25). Generation Z respondents were significantly more likely to declare buying fast food (0.26), compared to Generation Y and X respondents. Respondents from generation Z were also significantly more likely to declare that they regularly consume convenience foods mainly for lunch (0.22). On the other hand, people who pay attention to the naturalness of food and appreciating the health benefits of food declared buying meals for quick cooking (0.29 and 0.35, respectively) and buying products from fast food restaurants (0.25 and 0.29, respectively) significantly less often, compared to those who do not pay attention to these values. These persons also declared significantly less frequently consuming convenience foods regularly (0.20 and 0.28, respectively) and keeping the type of products at home (0.22 and 0.21, respectively). In addition, those appreciating the health benefits of food were significantly less likely to declare consuming convenience foods mainly for lunch (0.24) compared to the others (Figure 3).

**Table 3.***Respondents' attitudes towards the statements of the Food Neophobia Scale*

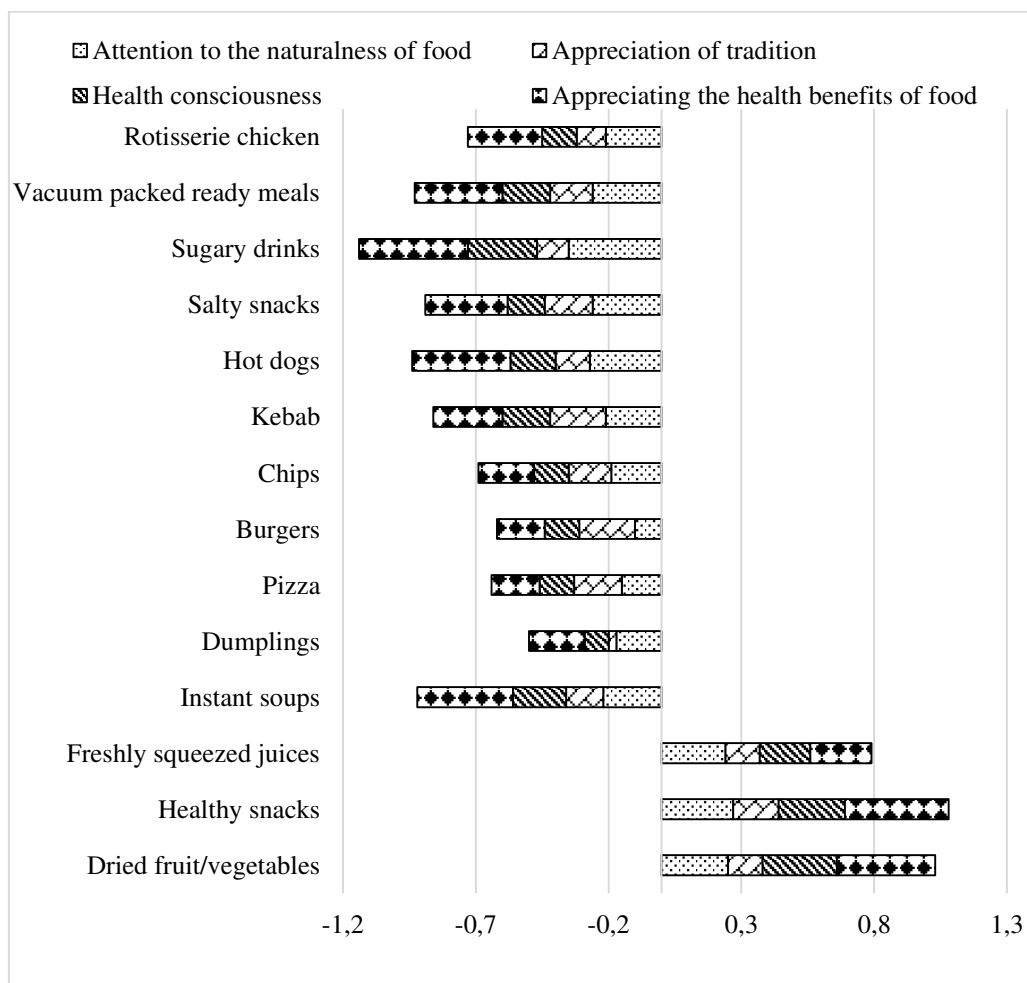
Statements	Gender			Generation			Monthly income			Mean score (rank) ±SD	<i>p</i>		
	Chi2	df	<i>p</i>	Chi2	df	<i>p</i>	Chi2	df	<i>p</i>		Gender <sup>1</sup>	Generation <sup>2</sup>	Monthly income <sup>2</sup>
I am constantly sampling new and different foods	9.05	4	0.06	9.38	8	0.31	33.47	8	<b>&lt;0.01</b>	3.08±1.18	<b>0.01</b>	0.05	<b>&lt;0.01</b>
I don't trust new foods	5.69	4	0.22	10.12	8	0.26	9.51	8	0.30	2.42±1.19	<b>0.04</b>	0.71	0.06
If I don't know what is in a food, I won't try it	3.15	4	0.53	12.09	8	0.15	31.44	8	<b>&lt;0.01</b>	2.27±1.14	0.27	0.23	<b>&lt;0.01</b>
I like foods from different countries	4.08	4	0.39	39.70	8	<b>&lt;0.01</b>	50.20	8	<b>&lt;0.01</b>	2.20±1,08	0.53	<b>&lt;0.01</b>	<b>&lt;0.01</b>
So-called 'health food' looks too weird for me to eat	9.72	4	0.05	18.92	8	<b>0.02</b>	23.49	8	<b>&lt;0.01</b>	2.23±1,08	0.43	<b>&lt;0.01</b>	<b>&lt;0.01</b>
At parties/when I go out I like to try new foods	7.56	4	0.11	21.27	8	<b>0.01</b>	40.11	8	<b>&lt;0.01</b>	2.44±1,20	0.22	<b>0.01</b>	<b>&lt;0.01</b>
I am afraid to eat things I have never had before	7.18	4	0.13	11.35	8	0.18	27.53	8	<b>&lt;0.01</b>	2.74±1,12	0.41	0.89	<b>&lt;0.01</b>
I am very particular about the foods I will eat	9.99	4	<b>0.04</b>	13.43	8	0.09	10.99	8	0.20	2.80±1,26	0.07	0.89	0.12
I will eat almost anything	14.44	4	<b>0.01</b>	18.90	8	<b>0.02</b>	28.41	8	<b>&lt;0.01</b>	2.43±1,07	0.17	0.44	<b>&lt;0.01</b>
I like to try new foods	9.16	4	0.06	29.14	8	<b>&lt;0.01</b>	40.01	8	<b>&lt;0.01</b>	2.22±1,16	0.17	<b>&lt;0.01</b>	<b>&lt;0.01</b>

Explanatory notes: SD - standard deviation; 1 - U-Manna Whitney; 2 - Kruskala-Wallis.

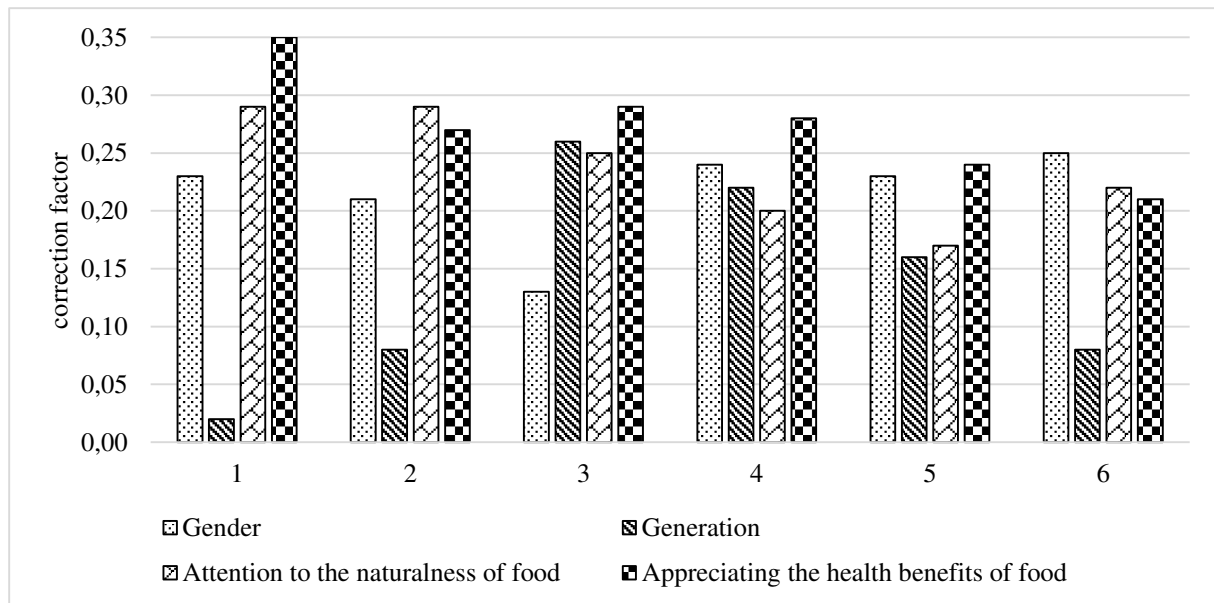
Source: own elaboration based on survey results.



**Figure 1.** Effect of gender, generation and monthly intake on frequency of convenience food consumption.



**Figure 2.** Influence of values and lifestyle on the frequency of convenience food consumption.



Explanatory notes: 1 - Buying meals for quick cooking; 2 - Buying products for direct consumption; 3 - Buying products from fast food restaurants (KFC, McDonald's); 4 - Regularly consuming convenience foods; 5 - Mainly consuming convenience foods for lunch; 6 - Keeping convenience foods at home.

Figure 3. Gender, generation and health values of food vs. intention to consume convenience foods and food habits.

## 4. Conclusions

The assessment of convenience foods has undergone significant changes in recent years, with an increasing interest in their diverse social functions in developed nations. Apart from time-saving benefits, these foods are now viewed as a means of promoting various population groups' eating habits due to several advantages they offer. Furthermore, it is anticipated that convenience foods will enhance the dietary behaviours of both young people (who wish to economise time and energy cooking at home) and older people (who may be cognitively impaired) in developed countries. The results of our survey indicate significant variance in convenience food consumption, depending on factors like gender, generation, income, and lifestyle. Notably, our research found that Generation Z showed the most interest in out-of-the-box food trends, and expressed stronger intentions to consume both new and convenient foods, compared to Generation X and Y. The shift in consumption trends observed in recent years creates new challenges for convenience foods, which not only simplify meal preparation but also heavily influence the nutritional quality of food. Therefore, convenience food manufacturers should consider the preferences and needs of Generation Z when designing such products. In this study, we believe that convenience foods play an important role in meeting the nutritional needs of populations in both developing and developed countries, and we have analysed eating behaviour in terms of the type, frequency and context of their consumption. Our findings can be used as a basis for discussion and reflection on the development of smart

food systems using information and communication technologies (ICTs) that provide consumers (Generations X, Y, Z) with knowledge about the range and quality of convenience foods and help them to enjoy convenience foods. Using a smartphone, both younger and older people can easily access information on food and nutrition to suit their tastes, or buy their favourite foods online from shops.

Our study has some limitations. Identification of factors influencing purchase decisions and frequency of convenience food consumption by consumers belonging to generations X, Y, Z was carried out using snowball sampling among residents of Gdynia. The results of the study are therefore not representative of the entire Polish population and should be interpreted with caution.

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## MANAGEMENT OF A SIMULATION PROJECT IN A MANUFACTURING COMPANY

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**Purpose:** The main goal of managing a simulation project in a manufacturing company regarding the optimization of warehouse preparation and placement of galvanized steel profiles using FlexSim software is to improve logistics processes in the warehouse and increase production efficiency. The aim of the research is to develop an effective package addressing scheme and to introduce a special code that will enable precise management of profile storage and will improve the process of completing customer orders.

**Design/methodology/approach:** The simulation project management methodology is based on several key steps: defining goals and requirements, collecting data and modeling, designing scenarios, performing simulations, and designing an individual addressing scheme for parcels in the warehouse.

**Findings:** Simulations allow you to find the optimal warehouse layout that ensures effective use of the available space. This, in turn, allows you to increase the storage capacity and better organize the storage of profiles, which translates into minimizing losses and costs. Simulations allow you to test different strategies for placing profiles in a warehouse to minimize the time and effort needed to find them. Optimizing the placement process allows parcels to be located faster and more precisely, which speeds up order picking.

**Research limitations/implications:** Simulation-based process optimization requires model accuracy and reliability. Imprecise or inaccurate data can affect simulation results and lead to inappropriate decisions. This requires careful data collection and model validation before implementation. Further research may focus on optimizing routes inside the warehouse and optimizing internal logistics. Investigating the best routes and methods of transport will minimize the time your products pass through your warehouse. Research can introduce an element of random events, such as machine breakdowns or fluctuating demand, into the simulation model to better reflect real conditions and increase the reliability of the results.

**Practical implications:** Improvement of warehouse processes and the introduction of a special code addressing the shipment can significantly reduce the risk of errors and material losses, which contributes to greater accuracy and efficiency of operation and improvement of customer relations.

**Social implications:** Effective optimization of warehouse and production processes contributes to increased work efficiency. Reduction of redundant activities, more precise management of resources, and more efficient order picking can affect employee satisfaction as well as positively affect working conditions and security.

**Originality/value:** The key element of originality is using advanced FlexSim software for modeling and simulation of storage processes and producing galvanized steel profiles. Simulations of this type integrated with real data and the implementation of a special package addressing code constitute a comprehensive approach to optimizing the entire process. The results of such a study can have a significant impact on the practice in manufacturing companies, enabling more effective warehouse management, shortening the time of picking orders, reducing costs, optimal use of resources, and improving the quality of customer service. It is an interdisciplinary approach that combines aspects of production management, logistics, process optimization, and the use of advanced IT tools.

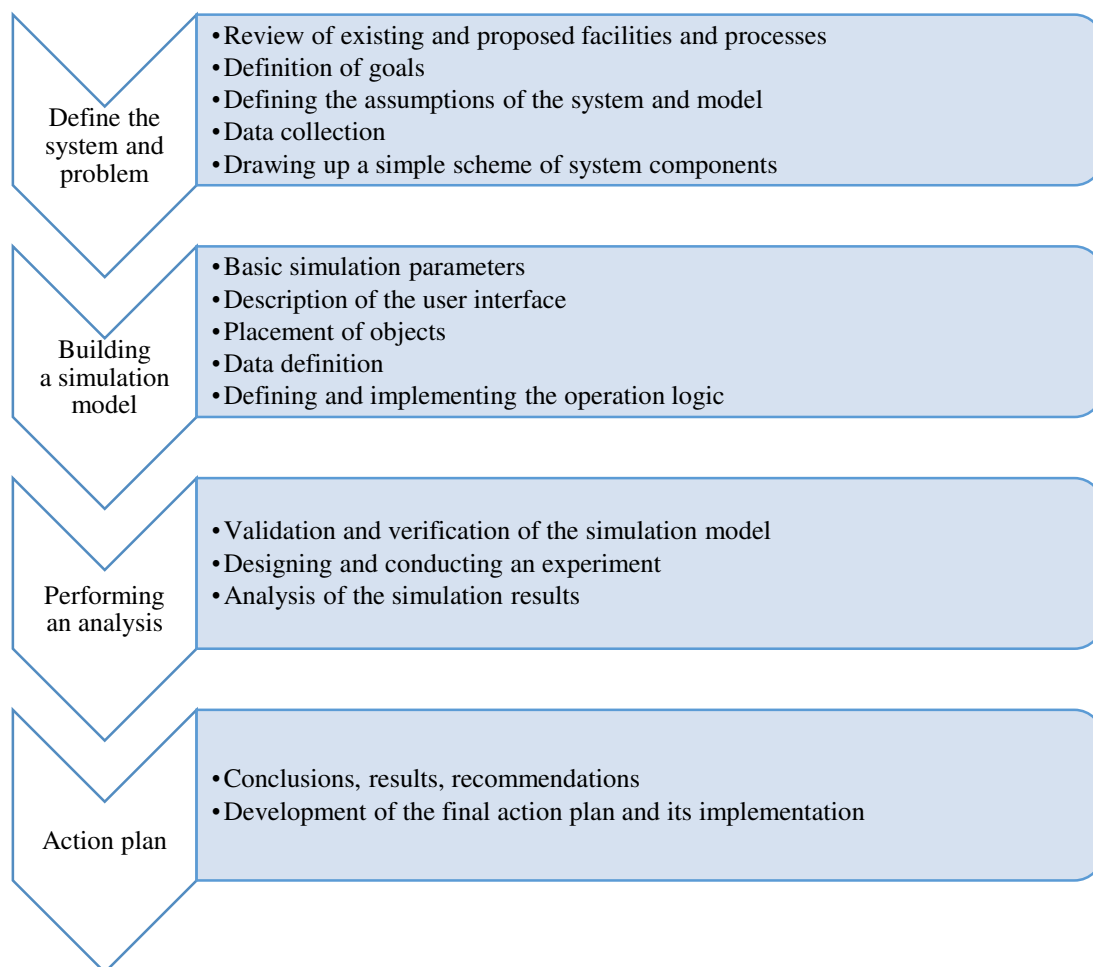
**Keywords:** Simulation project management, process simulation, FlexSim software.

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

## 1. Introduction

In today's rapidly changing environment, business success relies on self-improvement, i.e. preparation and implementation of changes under the pressure of time and costs (Griffin, 2017). The implementation of tasks determined by time and financial resources is an area of commitment often referred to in Polish literature as projects. They combine resources, skills, technologies, and ideas to achieve specific benefits (Kopczewski, 2009). Effective project management ensures that benefits or goals are achieved within the budget, within a specific time frame, and by accepted quality standards (Sołtysik, 2016). As research conducted by Polish companies shows, the largest percentage of implemented projects is related to information technology. At the same time, these types of projects are very complicated. Firstly, this is due to the very nature of information technology. Secondly, the human factor plays an important role in the failure of IT projects, which is much greater than in the case of other projects. Information technology is still a relatively young field of science, and its widespread use in economic life began less than 30 years ago (in Poland even later). Contact with information technology often evokes fear and fear of changes in many users due to their psychological conditioning (Dziekoński, 2010). The effectiveness of the company's operation depends on the ability to quickly and frequently adapt to changes in the market (Trocki et al., 2003). In today's competitive reality, the lack of these adaptive skills can lead to market failure for many organizations. Therefore, the organization must have the ability to manage change, which is often an integral part of project management. The implementation of projects usually changes the way the company operates, its structure, and the way information flows and distributes (Williams, 2005). To be successful in a simulation project, you must go through well-defined stages. The process of creating a simulation model consists in mapping the real system in the

form of a time model (Wyrozębki, 2007). During the observation of the real system, a model is constructed that reflects its functioning. Each observer may have a different point of view or focus on different features of the system (Wysocki, 2013). Since all of these properties can be important, the simulation methodology must facilitate communication and overall understanding of the simulation project. A non-simulation expert does not have to be directly involved in the creation of the model but can define the purpose of the simulation, run the model, and perform the simulation analysis. The degree of detail of each stage of the simulation project is adapted to the level of complexity of the analyzed system (Figure 1) (Abbasi et al., 2018).



**Figure 1.** Stages of the simulation project.

Source: Own elaboration.

The simulation project is divided into four stages, depending on the level of detail related to the analyzed system. In the first stage, it is important to understand and plan the project. The second step is to abstract the behavior of the system and present it as a model. In the third step, the simulation model is used for experiments and analysis. The last stage focuses on operation, collecting information and observations from simulation experiments, which are later used to make decisions about improving the operation of the system (Matwiejczuk, 2018). To effectively organize a simulation project, it is worth using a design template that will allow

for accurate documentation of all activities performed at each stage. Through reliable documentation, everyone involved in the project will have a common and uniform pool of knowledge about it. The first field in the template is the name of the simulation project that makes sense to the project team and other stakeholders. Simulation model names should include the current version number. Since the simulation project has specific goals, it is useful to include a concise summary of the results obtained that reflects its purpose and essence. In the first stage of the simulation project, an important task is to define the system and justify the implementation of this project (Morris, 2010). In this step, the functional specification is created, which is the definition of the project and the materials associated with it. The functional specification can be used as the basis for an inquiry addressed to external entities that will be responsible for the implementation of the simulation model. At this stage, consultations are carried out with the persons responsible for the problem under study (Trocki, 2019). In addition, familiarize yourself with the buildings and processes that will be represented in the simulation model. If the designed system does not yet exist, you can conduct a study visit to the existing buildings or consult the design and operational documentation. In any case, the people involved should have a good understanding and knowledge of the characteristics and functioning of the system under study (Wirkus, 2013). As you familiarize yourself with your infrastructure and processes, you should do the following:

- It may be useful to carry out a thorough survey of the building during the study visit, even if members of the design team are already working there.
- During the study visit, an inventory should be made of all system components, such as machines, production stations in progress, production parameters, storage locations for tools, and other elements used in the production process. In addition, the product components, details, and subassemblies at each stage of assembly should be listed.
- You should also accurately record all resources in your system, such as conveyors, forklifts, AGVs, maintenance workers, machine operators, cranes, robots, and other resources used in the production process.
- After reviewing all the elements of the system, it is worth taking notes on the characteristic features of its operation. This includes the analysis of special operating logic, task selection, and collaboration between workers, equipment, and other system components.
- Record all acronyms and terminology used to describe equipment, parts, and details. The use of these terms will allow for a better understanding of the model by those familiar with the actual process.
- Before the study visit, it is worth obtaining a plan of the building or making a drawing of the spatial layout yourself during the visit. In the drawing, you can mark individual elements of the system and add appropriate notes. Such supplemented drawings will facilitate the analysis of the spatial layout of the designed system without having to visit the building again. The drawings can also be used as a background for the simulation

model being built by importing them into the simulation program, where they will be the scale for the placed model elements.

- A good way to get to know the system under study is to spend time in the production area and talk to the employees who operate it. Accurate knowledge about the capabilities of the system and the processes implemented in it will allow you to construct the correct model.

Formulating the objectives of the simulation project is a key step, as objectives are an important element understood by management and other stakeholders (Witkowski et al., 2007). Through precisely defined goals, you can manage expectations, and by implementing subsequent stages of the project, you can achieve success in its entirety. Clear and specific goals are criteria for project success (Meredith, 2002). While intentions can be expressed in general terms, objectives should be more specific. At an early stage of the project, it is important to get answers to several questions, such as:

- What is the main purpose of creating a simulation model?
- What value will the simulation analysis bring?
- What elements will be included in the scope of the model?
- What answers are expected from the simulation model?
- What performance indicators will be adopted (e.g. productivity, total production time, resource utilization, delays in the system)?

Precisely defined objectives of the simulation project enable effective monitoring of progress and evaluation of the achieved results. They are the foundation for effective project management and allow you to achieve the intended benefits and optimize the operation of the system.

The defined objectives indicate the performance indicators that will be used for the assessment. It is worth determining in what form the responses to these indicators will be presented. In the project, it is worth taking into account the guidelines for the final report, which will determine its layout and key elements. More detailed issues will be clarified during the project implementation (Pawlewski, 2010).

Simulation has been extensively utilized in various industries for process optimization (Beaverstock et al., 2011). In the context of manufacturing, simulation aids in understanding the dynamic behavior of production systems, identifying bottlenecks, evaluating various scenarios, and making data-driven decisions (Garrido, 2009). Previous studies have shown the effectiveness of simulation project management in improving productivity and resource allocation in manufacturing companies (Beaverstock et al., 2017). FlexSim has emerged as a popular simulation software due to its user-friendly interface, powerful modeling capabilities, and ability to integrate with real-world data (Leks et al., 2015). Several researchers have successfully employed FlexSim in different manufacturing environments, showcasing its potential to optimize complex production processes (Kaczmar, 2015).

## 2. Methodology

The research begins with the collection of relevant data from the production company's warehouse operations. This includes information on profile types, customer orders, order frequencies, storage capacities, and handling equipment. Real-world data is crucial for building an accurate simulation model that reflects the actual warehouse dynamics.

Using FlexSim software, a detailed 3D model of the warehouse is constructed. The layout includes aisles, racks, shelves, and storage areas, accurately representing the warehouse's physical characteristics and constraints.

Different profile placement strategies are developed and tested in the simulation model. These strategies consider factors such as order prioritization, storage capacity constraints, profile accessibility, and order-picking efficiency.

The simulation model is executed using various profile placement strategies, and the performance metrics are measured and compared. The results of the analysis inform the identification of the most effective profile placement strategy. The simulation analysis provides valuable insights into the warehouse preparation and profile placement process for galvanized steel profiles. The results obtained from testing different strategies enable the production company to make data-driven decisions for optimizing warehouse operations and meeting customer demands efficiently.

## 3. Using simulation to solve problems

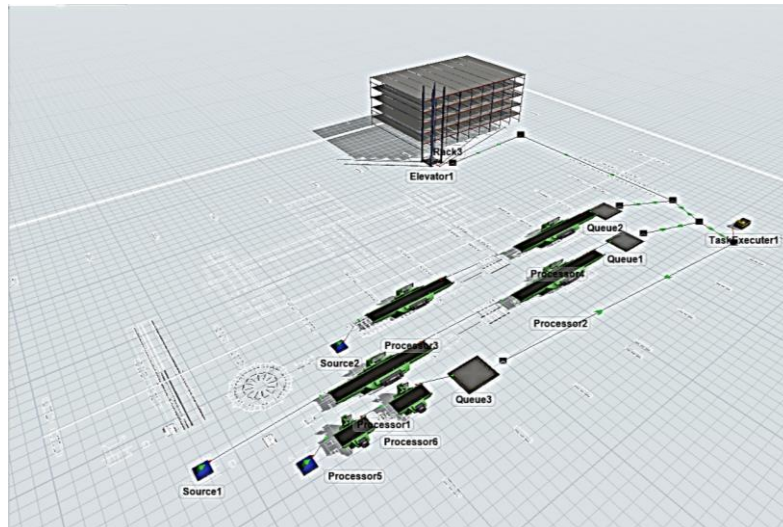
### 3.1. Characteristics of the production process

The production of galvanized steel profiles starts with the creation of the design tools that will be used to profile the steel. The main raw material for the production of profiles is hot-dip galvanized steel. Steel coils are delivered from the steelworks, each coil weighs about 10 Mg. The sheets have different thicknesses, from 1 to 5 mm, and their surface is covered with a layer of zinc with a thickness of 7 to 30  $\mu\text{m}$ . The sheets are about 1250 mm wide, so they are cut into strips, which are then used to produce profiles. The steel coils are placed on the decoiler of the slitting line. After the sheet is unrolled, it goes to the section with cutting knives. One coil can produce up to 30 tapes of various widths, from 40 to 500 mm. To compensate for different winding speeds, it is necessary to use a loop bottom. At the end of the production line, ready-made tapes are collected, which then go to the profiling line. The first step in this process is smoothing the unevenness of the sheet metal with a straightening machine to ensure a smooth production run. In order not to interrupt production, the strip that ends is welded to the material from the next coil. The unfolded sheet metal is stored in the accumulator, which acts as a buffer

for the entire line, and the material from the accumulator is continuously fed to the profiling part. At subsequent forming stations, the tape is gradually bent, which allows to obtain the desired shape of the profile. Depending on the type of profile, it may be necessary to make from 5 to 15 bends. After bending, the two sections of the profile are welded with high-frequency current where they meet. Excess material is removed with cutting knives. The next step is to protect the weld area with a zinc coating. Then the profile goes to the cooling chute, where a special emulsion removes the excess heat generated during the process. This step is necessary before profile calibration, during which the profiles are straightened and reach their final dimensions. After calibration, the operator visually checks the quality of the weld and verifies the dimensions of the profile. The next step is to cut the profiles to the desired lengths using a flying saw. After this stage, the profiles are dried, and the table ensures the gravitational outflow of the remaining emulsion, which is in the profiles after subsequent stages of the process. After the profiling process is completed, two operators place the profiles on the storage table, where the packages are formed. To protect against the formation of white corrosion, the profiles are packed using plastic separators that prevent them from touching each other. After the packing is completed, the ready packages go to the other part of the hall and are placed on the floor. Due to problems with picking orders, packages are not placed on storage racks. The use of the FlexSim simulation model will contribute to the improvement of the warehousing process and will facilitate the completion of customer orders. Thanks to the simulation, it will be possible to optimally plan the warehouse layout, reduce picking time and minimize storage costs, which will bring benefits in terms of efficiency and customer satisfaction.

### **3.2. Analysis of the simulation - discussion**

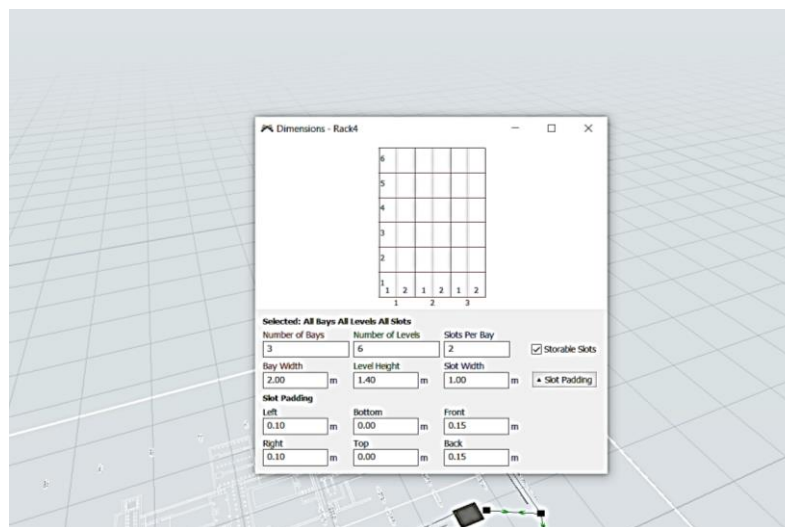
The model was constructed taking into account the loading and unloading operations. The production process focuses on the production of closed galvanized profiles with a circular cross-section. These profiles, made of galvanized sheets, provide long-term protection against corrosion and are commonly used in structures that require increased strength (Jurczyk, 2023). To obtain profiles with a circular cross-section, the cold rolling method was used. In the warehouse, three products (diameter  $\varnothing 27 \times 1$ ,  $\varnothing 30 \times 1$ ,  $\varnothing 40 \times 1$ ) were processed by cutting, then placed on a storage table and formed into packages. The first stage of the work was to build a model based on the current layout (Figure 2) (Guerrero et al., 2022).



**Figure 2.** Magazine layout.

Source: Own elaboration.

The model includes a source, i.e. an order generator, three production lines, and storage racks, built of storage places (slots). The model proposes its addressing scheme for manufactured products. In the analyzed model, each of the three given storage racks will consist of 3 rows with a width of 2 each and 6 levels with a height of 1.40 m each. In each storage cell designated in this way, there are 2 slots with a width of 1 m. The stored parcels will be moved away from the front and rear edges of the rack by 15 cm and by 10 cm from the right and left edges of the designated slot (Figure 3) (Jurczyk, 2020).

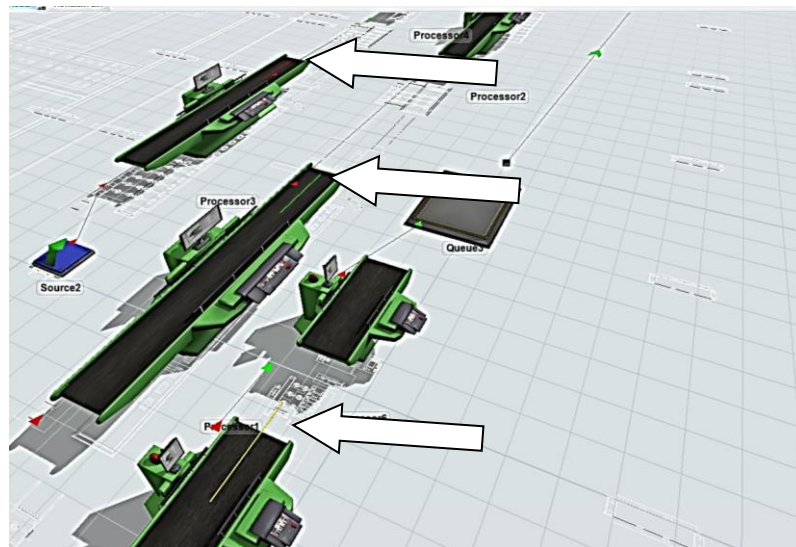


**Figure 3.** Layout and parameterization of the rack.

Source: Own elaboration.

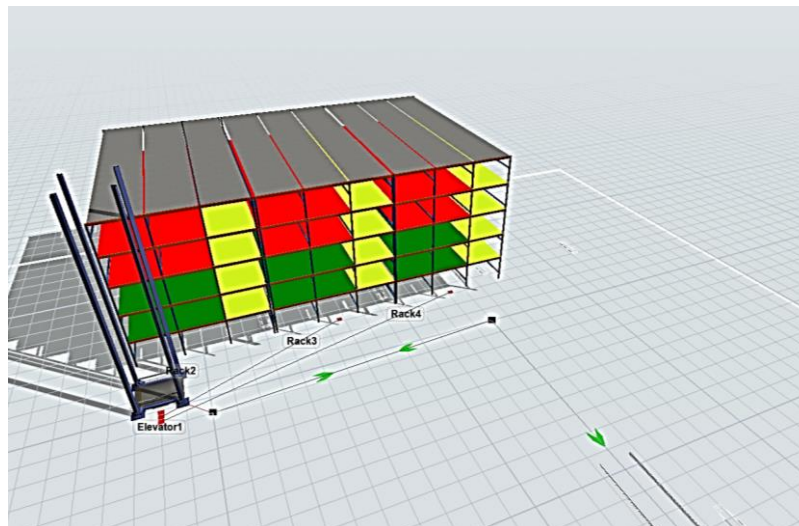
On each production line, through the source, a product is generated that is labeled "type". The model defines the type of product that can be stored in each available place (profile  $\varnothing 27 \times 1$  - green, profile  $\varnothing 30 \times 1$  - yellow, profile  $\varnothing 40 \times 1$  - red) (Figure 4), and slots on the racks are marked with appropriate colors. Each storage location was labeled - each slot was assigned a label called "kind" (Figure 5) (Jurczyk, 2021).





**Figure 4.** Product parameters.

Source: Own elaboration.



**Figure 5.** Defining labels.

Source: Own elaboration.

The addressing scheme is A.R.L.S, where:

- A – rack identifier,
- R – row identifier,
- L – level identifier,
- S – slot identifier.

The initial data regarding the marking of individual storage locations and the initial stock can be generated conveniently: by creating a script or importing data from MS Excel. The database should be filled in such a way as to adjust the values entered into successive cells. The created code responsible for generating the relevant data is shown in Figure 6 (Mourtzis, 2020).

```

1 treeNode link = node (".>objectfocus",c);
2
3 Table baza = Table("DaneMagazyu");
4 int regal = 3;
5 int rzedy = 3;
6 int poziomy = 6;
7 int sloty = 2;
8
9 double q1 = rzedy * poziomy * sloty;
10 double q2 = poziomy * sloty;
11 double pojemnosc = q1 * regal;
12
13 double wypelnieniePocz = Table("Dane")[1][1];
14 int p;
15
16 baza.setSize(pojemnosc,6);
17 for (int i = 1; i <= baza.numRows; i++) {
18     baza[i][1] = Math.ceil(i/q1);
19     if (baza[i][1] == 1) {
20         baza[i][2] = Math.ceil(i/q2);
21     } else {
22         baza[i][2] = baza[i-1][2];
23     }
24     if (baza[i][1] == 1 && baza[i][2] == 1) {
25         baza[i][3] = Math.ceil(i/sloty);
26     } else {
27         baza[i][3] = baza[i-1][3];
28     }
29     p++;
30     if (p > sloty) {
31         p = 1;
32     }
33     baza[i][4] = p;
34     baza[i][5] = baza[i][1] + "." + baza[i][2] + "." + baza[i][3] + "." + baza[i][4];
35     baza[i][6] = "Klient_" + baza[i][1];
36     if (baza[i][3] <= 2) {
37         baza[i][6] = "Grupa_1";
38     } else {
39         if (baza[i][3] <= 3) {
40             baza[i][6] = "Grupa_2";
41         } else {
42             baza[i][6] = "Grupa_3";
43         }
44     }
45     double liczba = uniform(0,1);
46     if (liczba <= wypelnieniePocz) {
47         baza[i][6] = 3 * duniform(1,3);
48     } else {
49         baza[i][6] = 0;

```

**Figure 6.** Variable declaration.

Source: Own elaboration.

The code is responsible for declaring variables after which particular operations are performed. In line 3, the tabular variable database was declared, the value of which is a reference to the Database table. In lines 4-7, the dimensions of the warehouse are declared. In lines 9-10, the variable  $q1$  was declared, which corresponds to the value of a single rack, and the variable  $q2$ , which is responsible for the capacity of a single row. In code line 11, the capacity of the entire warehouse is declared. Line 13 is responsible for the initial filling of the warehouse, and line 14 declares the numerical variable  $p$ , which is used for slot numbering. In line 16, the `setSize` function gives dimensions to the table that will serve as the database. The number of rows in the table is equal to the number of all pallet places, and the number of columns is equal to 6. In lines 17-51 a for loop was used, thanks to which all cells of the analyzed base table were filled. Line 18 contains a mechanism for marking successive storage racks. Lines 19-23 contain a mechanism for marking successive rows in racks. Lines 24-28 contain a mechanism for marking successive levels in individual rows. In line 29, the variable  $p$  is incremented. Then, in lines 30-32, it was checked whether, as a result of this action, the value of the variable  $p$  did not become greater than the number of slots available in each storage cell, if so, the value is reduced to one. In line 33, the current value of  $p$  is assigned as the slot identification number. In line 34, the addressing scheme was created. In line 35, the name of the customers has been assigned to the pallet locations. Assuming that there is a separate rack for each customer, it can be assumed that the customer name will be a combination of the phrase "Customer\_" with the rack ID. In lines 36-44, using the if conditional statement, information about the assortment group from which products can be stored on subsequent pallet places has been introduced. Lines 45-50 contain the mechanism for generating the initial stock. On line 45, we declare a variable called a number whose value is a random number between 0 and 1 (Schuhmacher et al., 2019). The if conditional checks to see if the value of this variable

is less than or equal to the initial fill value (Trott et al., 2019). If so, a random numerical value representing the initial stock level was entered into the appropriate cell of the base table. Otherwise, the value 0 was entered (Pawlewski, 2019). Finally, the parameter responsible for filling the warehouse was set. The minimum allowed value is 0.1, which corresponds to 10% fill of warehouses (Qiao et al., 2021). At the same time, you cannot enter a value greater than 1 into the data cell, because the warehouse can be filled to a maximum of 100%.

#### **4. Summary**

The article presents the use of design simulation in a production company specializing in the production of galvanized steel profiles. Using the FlexSim software, advanced analyzes were carried out to optimize the storage process and the arrangement of profiles. As a result of the research, a package addressing scheme was developed and a special code was introduced to optimize logistics processes.

The project aimed to increase storage efficiency and optimize the profile storage system to effectively serve the growing customer demand. For this purpose, an accurate simulation model of the company was built, which reflects the actual production and storage process.

The simulation allowed for the identification of low-performance areas, which allowed for the implementation of effective solutions. The use of FlexSim software made it possible to test various storage scenarios and strategies, which enabled the selection of optimal solutions for a given situation. The results of the simulation showed the benefits of the new warehouse layout, such as minimizing the waiting time for the profile and increasing the availability of goods. In addition, the use of the address code contributed to the effective management of parcel storage, which allowed for the quick and precise location of the profiles in the warehouse. Optimization of the warehousing process contributed to increasing the efficiency and competitiveness of the company. Quick access to galvanized profiles allowed us to minimize the time of order fulfillment for customers, which resulted in increasing their satisfaction and loyalty.

The study concluded that design simulation using FlexSim software is an invaluable tool for manufacturing companies. It allows you to identify areas for improvement, test different solutions and optimize processes. Thanks to simulation, it is possible to make more informed decisions, which contributes to achieving better business results. As a result, the use of simulation project management at the manufacturing company to optimize the warehouse preparation and placement of the galvanized steel profiles using FlexSim software resulted in numerous benefits. Effective use of this method allows the company to achieve a higher level of efficiency, improve logistics processes and increase competitiveness in the market.

## Acknowledgments

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## ASSESSMENT OF THE SITUATION ON THE RESIDENTIAL REAL ESTATE MARKET IN THE EASTERN AND WESTERN REGIONS OF POLAND

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**Purpose:** The aim of the article is to identify and assess the situation in the residential real estate market in the eastern and western regions of Poland against the background of the entire country.

**Design/methodology/approach:** The article identifies and assesses the diversification of the situation in the residential real estate market in the eastern and western regions of Poland. The empirical material used in the article concerns both the entire country and six voivodeships of eastern and western Poland, i.e. Lublin, Podkarpackie and Podlaskie, as well as Lower Silesia, Lubusz and West Pomerania. The numerical data comes from the Central Statistical Office in Warsaw (Local Data Bank), and the time scope of the research covers the years 2019-2021. The collected and organized empirical material was prepared in tabular and graphic form, using the method of comparative analysis. Additionally, a point assessment was made of all diagnostic features illustrating the situation on the residential real estate market in the eastern and western regions of Poland against the background of the entire country, which is a new approach to the research problem discussed in the article.

**Findings:** The analysis of statistical data confirmed the research hypothesis put forward in the article, assuming that the border location of the eastern and western regions of Poland makes them, on average, characterized by a better situation on the residential real estate market compared to the average for the entire country, however, there are differences in this respect between individual voivodeships of these regions.

**Originality/value:** The originality of the work lies in the author's approach to the analysis of the undertaken research issues and a point-by-point assessment of the situation on the residential real estate market in the eastern and western regions of Poland against the background of the entire country. The work is addressed primarily to central-level politicians and local government officials responsible for the conditions, opportunities, and directions of regional socioeconomic development, as well as to other decision-makers implementing regional development policy in Poland.

**Keywords:** residential real estate market, eastern and western regions of Poland.

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

## 1. Introduction

The real estate market is a very important field for research and considerations both in the sphere of science, business, and social and regional policy. Regardless of the understanding and importance of the real estate market, it is a complex and interdisciplinary area of research that goes beyond the mainstream economics. Investigations in the area of the real estate market are orientated in several main thematic categories, where the authors most often make their considerations from the perspective of sociology, management, law, economics, and finance. The research methods used in this area and the analysis of the number of publications indicate that the real estate market is still a current and important area of research, in the development phase (Borowska, Domańska, 2016).

Nowadays, the classical approach to the real estate market is being abandoned in favour of an institutional, systemic, or network approach, i.e. looking at this market as a network of entities connected by relationships, which results both from the evolution of the market concept and from its objective and subjective specificity. An attempt to move away from the understanding of the real estate market as a resource allocation mechanism is to understand it as all the conditions under which rights to real estate are transferred and contracts are concluded, specifying mutual rights and obligations related to the ownership of a given specific real estate. Shifting the emphasis to the conditions of concluding a transaction reveals the dependence of supply and demand on legal regulations, customs, conventions, organisations, and the political situation, which introduces an institutional dimension, where the real estate market covers three levels. The highest level of this market reveals its connections to the external environment. The intermediate level is the market considered as an institution that reveals its specific characteristics that influence its way of functioning. The lowest level consists of organisations in the real estate market. In turn, in the systemic or network approach, this market is understood as a system composed of several interconnected subsystems with various relationships, each of which consists of different entities, connections between them, and principles of operation (Bryx, 2006; Kucharska-Stasiak, 2006; Borowska, Domańska, 2016).

The basic factors shaping the residential real estate market include: changes in the income level of buyers, changes in the prices of other goods, and buyers' expectations regarding price changes in the future. In turn, important non-market factors influencing the residential real estate market include demographic factors, specific natural factors, buyer preferences, and socio-political factors. However, the real estate market is characterised by its specificity related to its features, including the real estate of the product offered, i.e. its close connection with a specific location, its physical features, lack of substitutes, high capital intensity and durability, individual nature, and confidentiality of the transaction. All this means that we are dealing with a diversity of supply and uniqueness of individual transaction items, unparalleled in other markets (Belniak, 2001; 2008).



The real estate market is in a permanent imbalance, characterized by periodic excess of demand or supply, and the basic cause of this phenomenon is related to its specific nature. As a rule, the imbalance in the real estate market has a structural basis, and consumers (households) and investors are aware that the property they want is in many cases the so-called rare good that can only be purchased at a specific time and under the conditions currently dictated by the market. It should be added that real estate can not only meet the consumption needs of, e.g., households, but can also be a relatively safe form of investing their capital, which means that the residential real estate market is related to the capital market in terms of demand (Belniak, 2008).

The modern client of the real estate market, i.e. the recipient and user of real estate products, has high requirements regarding standards regarding broadly understood functionality, finishing, and construction aesthetics. In practice, therefore, all activities and solutions that improve the final effect (i.e. a specific type and functional property) can be called innovative. This includes both new combinations of production factors and all activities leading to changes, the ultimate goal of which is to achieve newness (Kalinowski, 2010; Prystrom, 2012; Bac, 2014).

Meeting customer requirements by creating new solutions that bring benefits should be the basic determinant of the modern real estate market. This is especially visible in the construction sector, which provides the market with innovative solutions, initiated on the one hand by science and technology, and on the other hand by market and non-market needs reported by customers, e.g. households. Real estate innovations can therefore be described as supply- and demand-driven, with the latter having a predominance, as new construction products are created for a specific client who, on the one hand, is now often aware of technological possibilities, and on the other hand, focusses on quality and wants to live healthier and safer, therefore, it has higher requirements for construction materials and services. It should be added that stimulating innovation in the real estate market is currently closely related to pro-ecological fashion, issues of energy efficiency, ergonomics, and renewable energy sources. However, such targeted innovations in the real estate market benefit all its participants, i.e. entities serving this market, entities from the construction sector, developers, real estate users, and institutions supporting this market. Therefore, these innovations determine the future of the real estate market and shape its development. Because the rising costs of real estate maintenance, constant increases in energy prices and climate change determine the type of construction, and it is the low-energy model, currently the most desired by customers, including, e.g., households, that sets trends and directions of research and development activities in this field. Solar energy is the most important energy in sustainable buildings (passive and energy-saving), hence the focus of the real estate market on research, implementation, and services in the field of innovative solutions of this type. Such activities are believed to be the future of the real estate market (Snyder, Duarte, 2003; Janasz, Koziół-Nadolna, 2011; Bac, 2014).

A very important participant in the residential real estate market is the household, which is an economic entity, separated in the economic sense on the basis of personal property and making decisions regarding consumption and investment based on its own preferences and existing objective constraints (i.e. price and income). The basis for the development of households are decisions regarding the choice of level and field of education, the choice of place of work and residence, and how to spend the money earned. Each household strives to spend its income in such a way as to achieve the greatest possible utility from the purchased goods and services in accordance with its own preferences, and when making decisions, it is guided by both subjective factors (i.e., traditions, preferences, habits, etc.) and objective factors (i.e., traditions, preferences, habits, etc.) i.e., the amount of wages, pensions, interest, prices, taxes, etc.). The consequences of decisions made by households are, on the one hand, a specific amount of demand for goods and services, and, on the other hand, the size and structure of supply. Therefore, households are the basic units of the sphere of consumption, which, having money, material resources and the time and work of their members, finance the purchases of goods and services, produce items of consumption and services and organize the processes of consumption and investment (Zalega, 2007; Kośny, 2013; Grzybowska, 2014; Kozera, Stanisławska, Głowicka-Wołoszyn, 2016; Bywalec, 2017; 2020; Kata, Nowak, Leszczyńska, Kowal, Sebastianka, 2021).

The economic functions of the household result from its participation in socioeconomic processes, both in the local, regional, and national dimension, as well as even globally, which manifests itself in two key figures, i.e., the buyer of goods and services on the market and outside the market provided by enterprises and institutions and a supplier of labour and other resources for these enterprises and institutions. The economic functions of households therefore show their great importance as entities operating in the economy and society (Gutkowska, Ozimek, Laskowski, 2001; Zalega, 2007).

An important factor shaping the situation on the residential real estate market may be the financial situation of households, i.e., their financial situation and the state of their material resources, which inform about the family's wealth and largely influence the level, quality and conditions of its life. The financial situation of a household is therefore determined by both its assets and the level of income, and the impact of these two elements on the economic behaviour of households may be not only substitutive but also complementary, when low income is compensated by previously accumulated assets. In turn, the decisions that households make in the sphere of consumption depend not only on their financial situation or conditions on the market of goods and services, but also on state policy or the economic condition of the country. Through the tools that the state uses to stimulate socioeconomic growth and development and to improve the living conditions of citizens within the framework of social and economic policy, it also influences the level and structure of household consumption. This applies primarily to fiscal and monetary policy, as well as income, price, and public expenditure policy. However, not only the state's policy but also its condition, in terms of the level and pace of economic

growth and development, influences the decisions of entities in the sphere of consumption. Citizens of highly developed countries generally enjoy a higher standard of living than citizens of developing countries. However, the higher the economic growth rate, the faster private consumption grows and the standard of living of citizens improves. Moreover, one of the most important processes affecting the contemporary world economy and, therefore, individual national economies is globalization. Increased flows of goods, services, labour, and capital, which are manifestations of globalisation processes, largely determine the condition of modern economies, which translates into contemporary consumption patterns. For this reason, the concept of globalisation of consumption appears in the literature on the subject, which means the spread of identical or very similar consumption patterns, i.e., the so-called homogenization of consumption on a transnational scale, as well as the creation of the so-called global consumer culture. This is manifested in the greater availability of foreign goods, which means a greater variety of goods on the domestic market and thus great opportunities to meet the consumption needs of households. Increased competition on the domestic market also influences the behaviour of domestic producers, which often results in lower prices of goods and services. It is also worth noting that increased flows, especially of goods, services, capital, and people, contribute to the diffusion of information, ideas, and culture, which has a huge impact on changes in consumption patterns. This leads to the emergence of transnational market segments that include homogeneous groups of consumers, on a transnational or even global scale. This means that a group of consumers in one country has similar preferences, properties, and characteristics as the corresponding segment in another country. In the case of the global segment, these are recipients (consumers, clients) waiting for the same (global) product all over the world, which may also be of great importance and influence the situation on the residential real estate market (Choroś-Mrozowska, Clowes, 2018; Kata, Nowak, Leszczyńska, Kowal, Sebastianka, 2021).

The issue of regional development in the context of socioeconomic growth and development processes is important not only for building social prosperity, but also for maintaining competitive advantages of enterprises, local and regional economies, and the national economy. This also translates into the social and political situation, as well as the development of financial flows, investments, and the settlement network. From the point of view of society and economy as well as the socioeconomic development of the country, regional disproportions are particularly important in this respect and are common in countries with market economies, regardless of their location, history, culture, or level of development. It should be added that the scale of these disproportions in individual countries varies, and their consequences for societies and economies are of different importance. For this reason, reducing regional disparities is the subject of interest of regional and cohesion policy both of the entire European Union and its individual member states. Poland is a member state of the European Union in which there are significant regional disproportions, mainly between its eastern regions and the

rest, and this state of affairs is influenced primarily by historical conditions (Grzebyk, Miś, Stec, Zając, 2019; Kraska, Kot, 2021).

The eastern and western regions of Poland are border regions, the former being voivodeships with a low level of socio-economic development, characterized by low population density, low quality of human, social and intellectual capital, low level of development of technical, social and institutional infrastructure, limited accessibility territorial and low level of income of the population and local government units. However, the western regions of Poland are a better developed part of the country, and their location in the vicinity of Germany and the Czech Republic, as well as in the proximity of Scandinavian countries, creates prospects for further socio-economic development, which can be accelerated primarily by establishing and using mutual relations and economic relations. (cross-border cooperation) (Mogiła, Zaleski, Zathay, 2011; Kudełko, 2013; Balińska, 2015; Czudec, Majka, Zając, 2018; Grzebyk, Miś, Stec, Zając, 2019; Miś, Zając, 2020).

## **2. Research aim, empirical material, and research methods**

The aim of the article is to identify and assess the situation in the residential real estate market in the eastern and western regions of Poland against the background of the entire country.

The article puts forward a research hypothesis assuming that the border location of the eastern and western regions of Poland means that they are, on average, characterised by a better situation on the residential real estate market compared to the average for the entire country, however, there are differences in this respect between the individual voivodeships of these regions.

The empirical material used in the article concerns both the entire country and six voivodeships of eastern and western Poland, i.e. Lublin, Podkarpackie and Podlaskie, as well as Lower Silesia, Lubusz, and West Pomerania. The numerical data comes from the Central Statistical Office in Warsaw (Local Data Bank), and the time scope of the research covers the years 2019-2021. The collected and organised empirical material was prepared in tabular and graphic form, using the method of comparative analysis.

To achieve the aim of the work, that is, to identify and assess the diversification of the situation in the residential real estate market in the eastern and western regions of Poland, the following diagnostic features that illustrate it were analyzed:

- number of residential premises sold as part of market transactions in 2019-2021 (dynamics) – stimulant,
- value of residential premises sold as part of market transactions in 2019-2021 (dynamics) – stimulator,

- average usable area of a residential premises sold as part of market transactions in 2019-2021 (m<sup>2</sup>) – stimulant,
- average price of residential properties sold as part of market transactions in 2019-2021 (PLN) – a destimulant,
- average price per 1 m<sup>2</sup> of residential premises sold as part of market transactions in 2019-2021 (PLN) – a destimulant.

Additionally, the article contains a point assessment of all diagnostic characteristics illustrating the situation on the residential real estate market in the eastern and western regions of Poland in the background of the entire country. Individual diagnostic characteristics were compared with the average for the country, which was taken as 100 points, and their advantage or underweight was evaluated accordingly in the eastern and western regions of Poland together and in individual voivodeships. Then all points were summed up and the average was calculated (Figure 1).

### 3. Results

The data in Table 1 shows that there is a large variation in the number of residential premises sold in market transactions between the eastern and western regions of Poland. The western regions of Poland have a much higher number of such premises compared to the eastern regions, where it is clearly lower. Additionally, the number of residential premises sold as part of market transactions varies more between individual western regions of Poland, with the highest number in the Lower Silesian Voivodeship, followed by the West Pomeranian Voivodeship. In turn, there are no significant differences in this respect between individual eastern regions of Poland, although the highest number of residential premises sold as part of market transactions is recorded in the Lublin Voivodeship.

In turn, the dynamics of this phenomenon in the analysed years, i.e. 2019-2021, is rather small and similar in the eastern and western regions of Poland and close to the average for the entire country. However, there is a clear difference in this respect between the individual eastern and western regions of Poland. In the case of eastern regions, the Podlaskie Voivodeship has by far the highest growth rate in the number of residential premises sold as part of market transactions, while the Podkarpackie Voivodeship has the lowest growth rate. However, in the case of western regions, the highest growth rate in the number of residential premises sold as part of market transactions occurs in the Lower Silesian Voivodeship, and the West Pomeranian Voivodeship is characterised by a decline in this respect (Table 1).

**Table 1.**

*Number of residential premises sold as part of market transactions in the eastern and western regions of Poland compared to the country in 2019-2021*

Specification	2019	2020	2021	Dynamics, 2019 = 100
Poland	208 736	199 318	244 672	117,2
Eastern regions of Poland, including voivodeships:	20 021	19 644	23 523	117,5
Lubelskie	7 410	7 860	8 774	118,4
Podkarpackie	6 916	6 232	7 595	109,8
Podlaskie	5 695	5 552	7 154	125,6
Western regions of Poland, including voivodeships:	42 875	33 197	50 003	116,6
Dolnośląskie	25 774	20 386	33 606	130,4
Lubuskie	6 408	6 319	6 933	108,2
Zachodniopomorskie	10 693	6 492	9 464	88,5

Source: Central Statistical Office in Warsaw.

The data in Table 2 show that there is a large variation in the value of residential properties sold in market transactions between the eastern and western regions of Poland. The eastern regions of Poland are characterised by a much lower value of such premises compared to the western regions, where it is clearly higher. It should be noted that the value of residential premises sold as part of market transactions varies more between individual western regions of Poland, with the highest value in the Lower Silesian Voivodeship and the lowest in the Lubuskie Voivodeship. However, there are no such significant differences in this respect between the individual eastern regions of Poland, with the highest value of residential premises sold as part of market transactions in the Lublin Voivodeship, and the lowest in the Podlaskie Voivodeship.

**Table 2.**

*Value of residential premises sold as part of market transactions in the eastern and western regions of Poland compared to the country in 2019-2021 (PLN)*

Specification	2019	2020	2021	Dynamics, 2019 = 100
Poland	59 270 347 455	62 080 982 379	85 387 596 744	144,1
Eastern regions of Poland, including voivodeships:	4 847 297 139	5 237 081 732	7 030 869 325	145,0
Lubelskie	1 885 507 133	2 178 255 699	2 703 281 845	143,4
Podkarpackie	1 593 678 135	1 577 653 910	2 191 359 732	137,5
Podlaskie	1 368 111 871	1 481 172 123	2 136 227 748	156,1
Western regions of Poland, including voivodeships:	10 470 054 084	8 406 258 262	15 766 752 067	150,6
Dolnośląskie	6 709 263 606	5 473 376 874	11 437 529 761	170,5
Lubuskie	1 136 606 748	1 266 661 311	1 510 475 702	132,9
Zachodniopomorskie	2 624 183 730	1 666 220 077	2 818 746 604	107,4

Source: Central Statistical Office in Warsaw.

In turn, the dynamics of this phenomenon in the analysed years, i.e. 2019-2021, is quite high and similar in the eastern and western regions of Poland and close to the average for the entire country. However, there is a clear difference in this respect between the individual eastern and western regions of Poland, especially the latter. In the case of western regions, the Lower Silesian Voivodeship has the highest growth dynamics in the value of residential premises sold as part of market transactions, while the West Pomeranian Voivodeship has the lowest growth

rate. However, in the case of eastern regions, the highest growth dynamics in the value of residential premises sold as part of market transactions occurs in the Podlaskie Voivodeship and the lowest in the Podkarpackie Voivodeship (Table 2).

**Table 3.**

*Average usable area of a residential property sold as part of market transactions in the eastern and western regions of Poland compared to the country in 2019-2021 (m<sup>2</sup>)*

Specification	2019	2020	2021	Average for 2019-2021
Poland	54,6	54,8	55,1	54,8
Eastern regions of Poland, including voivodeships:	52,1	52,2	52,9	52,4
Lubelskie	52,8	51,9	52,3	52,4
Podkarpackie	52,1	52,7	53,8	52,9
Podlaskie	51,5	52,0	52,5	52,0
Western regions of Poland, including voivodeships:	54,4	54,0	54,5	54,3
Dolnośląskie	55,5	55,6	56,1	55,8
Lubuskie	53,7	52,7	53,0	53,1
Zachodniopomorskie	53,9	53,7	54,2	53,9

Source: Central Statistical Office in Warsaw.

Based on the data in Table 3, it should be concluded that there are no major differences in the average usable area of a residential premises sold in market transactions between the eastern and western regions of Poland, although it is slightly larger and similar to the average for the entire country in the western regions.

Additionally, it should be noted that there are no major differences in this respect between the individual eastern and western regions of Poland, and this especially applies to the eastern regions. In the case of the western regions of Poland, the Lower Silesian Voivodeship has a slightly larger average usable area of a residential premises sold as part of market transactions (Table 3).

The data in Table 4 shows that the average price of residential properties sold as part of market transactions in the eastern and western regions of Poland is lower compared to the average for the whole country. However, there are differences in this regard between the eastern and western regions of Poland, with the eastern regions having a slightly higher average price of residential premises sold in market transactions.

The average price of residential properties sold as part of market transactions also varies between individual eastern and western regions, especially the latter. In the case of the eastern regions of Poland, it is the highest in the Lublin Voivodeship and the lowest in the Podkarpackie Voivodeship. However, in the western regions of Poland, the average price of residential buildings sold as part of market transactions is the highest in the Lower Silesian Voivodeship and it is definitely the lowest in the Lubuskie Voivodeship (Table 4).

**Table 4.**

*Average price of residential buildings sold as part of market transactions in the eastern and western regions of Poland compared to the country in 2019-2021 (PLN)*

Specification	2019	2020	2021	Average for 2019-2021
Poland	283 949	311 467	348 988	314 801
Eastern regions of Poland, including voivodeships:	241 706	265 689	298 411	268 602
Lubelskie	254 454	277 132	308 101	279 896
Podkarpackie	230 434	253 154	288 527	257 372
Podlaskie	240 230	266 782	298 606	268 539
Western regions of Poland, including voivodeships:	227 698	241 866	285 350	251 638
Dolnośląskie	260 311	268 487	340 342	289 713
Lubuskie	177 373	200 453	217 868	198 565
Zachodniopomorskie	245 411	256 657	297 839	266 636

Source: Central Statistical Office in Warsaw.

Data in Table 5 show that the average price per 1 m<sup>2</sup> of residential buildings sold as part of market transactions in the eastern and western regions of Poland is lower compared to the average for the entire country. However, there are differences in this regard between the eastern and western regions of Poland, with the eastern regions having a slightly higher average price per 1 m<sup>2</sup> of residential premises sold as part of market transactions.

**Table 5.**

*Average price per 1 m<sup>2</sup> of residential premises sold as part of market transactions in the eastern and western regions of Poland compared to the country in 2019-2021 (PLN)*

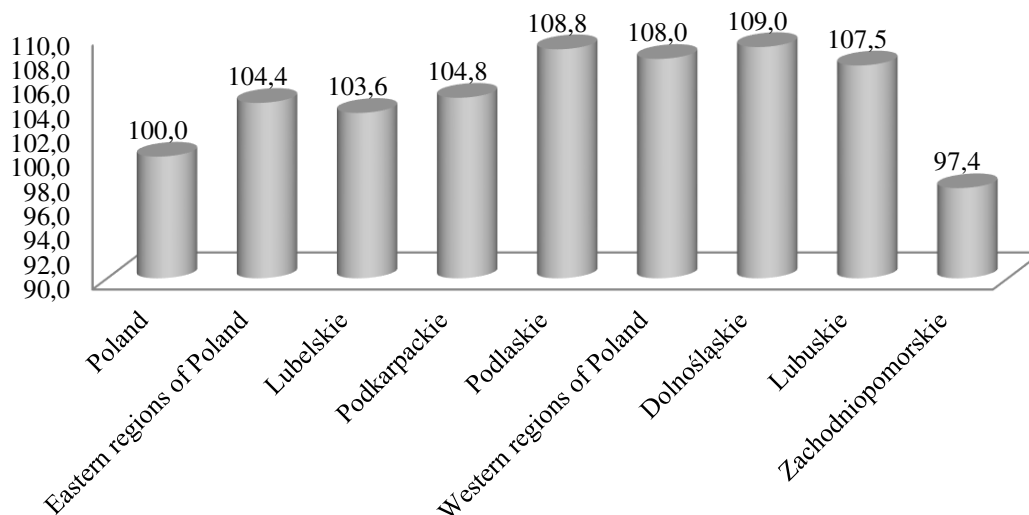
Specification	2019	2020	2021	Average for 2019-2021
Poland	5 202	5 689	6 334	5 742
Eastern regions of Poland, including voivodeships:	4 635	5 087	5 648	5 123
Lubelskie	4 818	5 337	5 888	5 348
Podkarpackie	4 426	4 799	5 368	4 864
Podlaskie	4 660	5 126	5 688	5 158
Western regions of Poland, including voivodeships:	4 182	4 468	5 223	4 624
Dolnośląskie	4 689	4 827	6 062	5 193
Lubuskie	3 305	3 801	4 109	3 738
Zachodniopomorskie	4 551	4 777	5 497	4 942

Source: Central Statistical Office in Warsaw.

The average price per 1 m<sup>2</sup> of residential premises sold in market transactions also varies between individual eastern and western regions, especially the latter. In the case of the eastern regions of Poland, it is the highest in the Lublin Voivodeship and the lowest in the Podkarpackie Voivodeship. However, in the case of the western regions of Poland, the average price per 1 m<sup>2</sup> of residential premises sold as part of market transactions is the highest in the Lower Silesian Voivodeship and it is definitely the lowest in the Lubuskie Voivodeship (Table 5).

Figure 1 presents the results of the point assessment on the situation on the residential real estate market in the eastern and western regions of Poland against the backdrop of the entire country. On this basis, it can be observed that both in the eastern and western regions of Poland, the situation is slightly better than the average in the country.





**Figure 1.** Point assessment of the situation on the residential real estate market in the eastern and western regions of Poland compared to the country (Poland = 100.0 points).

Source: Own study.

Additionally, it should be noted that the situation on the residential real estate market differs between individual eastern and western regions. In the eastern regions, the best situation in this respect is in the Podlaskie Voivodeship, while it is slightly worse in the Lublin and Podkarpackie Voivodeships. However, in the case of western regions, the situation in the residential real estate market is clearly the best in the Lower Silesian Voivodeship and it is definitely the worst in the West Pomeranian Voivodeship (Figure 1).

All this confirms the research hypothesis put forward in the article, which assumes that the border location of the eastern and western regions of Poland means that they are, on average, characterised by a better situation in the residential real estate market compared to the average for the entire country, although there are differences in this respect between individual voivodeships of these regions.

#### 4. Summary and conclusions

In Poland, the dynamics of the number and value of residential properties sold as part of market transactions in 2019-2021 is similar in its eastern and western regions and close to the average for the entire country; however, there are clear differences in this respect between individual eastern and western regions. western ones.

In Poland, there are no major differences in terms of the average usable area of a residential property sold in market transactions between its eastern and western regions, although it is slightly larger and similar to the average for the entire country in the western regions.

Furthermore, there are no major differences in this respect between the individual eastern and western regions of Poland, and this applies especially to the eastern regions.

In Poland, the average price in total and per 1 m<sup>2</sup> of residential premises sold in market transactions is lower in its eastern and western regions compared to the average for the whole country. However, differences in this respect were found between the eastern and western regions, with slightly higher differences in the eastern regions. Additionally, the average price in total and per 1 m<sup>2</sup> of residential premises sold as part of market transactions also varies between individual eastern and western regions, and this applies especially to the latter.

The analysis of statistical data carried out in the article shows that the situation on the residential real estate market in Poland is slightly better in its eastern and western regions compared to the average for the entire country. In addition, it varies between individual eastern and western regions of Poland. Therefore, this confirms the research hypothesis put forward in the article, assuming that the border location of the eastern and western regions of Poland means that they are, on average, characterized by a better situation on the residential real estate market compared to the average for the entire country, however, there are differences in this respect between individual voivodeships of these regions.

It should be added that the results of the analysis of statistical data presented in the article provide important and up-to-date knowledge that may be useful both for central-level politicians and local government officials responsible for the conditions, possibilities, and directions of regional socio-economic development, as well as for other decision-makers, implementing the regional development policy in Poland. At the same time, this justifies the need to continue similar research and analyses.

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## AREAS OF MATURITY IN PROJECT MANAGEMENT IN LOCAL GOVERNMENT ORGANIZATIONS IN POLAND

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**Purpose:** The purpose of this article is to determine the level of maturity in project management in selected areas in local government organizations in Poland.

**Design/methodology/approach:** The analysis conducted for this paper included literature analysis, survey research and analysis of research results. The objectives of the article were achieved by obtaining answers to the formulated research questions.

**Findings:** Based on the literature review, the article identifies project management maturity levels and indicates the areas in which project management maturity is studied. Based on the results of the study, the level of maturity in four areas of project management in local government organizations in Poland is indicated.

**Originality/value:** The study of project maturity in four areas of project management in local government organizations in Poland, allowed us to identify the area in need of improvement. This is very important, because often limitations in one area hinder the achievement of higher levels of maturity in other areas of project management maturity.

**Keywords:** project management, local government organisations, maturity in project management.

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

### 1. Introduction

Project maturity testing is done using maturity models. Currently, there are many different maturity models, most of which have been developed for the purpose of studying the maturity of enterprises. Based on these models, project management maturity models have been developed. They are based on five levels of maturity: initial level, recurring level, defined level, managed level and optimizing level (Kerzner, 2001; Spalek, 2013; Project Management...). These five levels define an ordinal scale for measuring maturity. These levels also help

an organization prioritize its improvement efforts (Cooke-Davies, Arzymanow, 2003). Project management maturity models can therefore be used to measure current capabilities and identify improvement goals for organizations that want to improve project management effectiveness to successfully execute projects (Mittermaier, Steyn, 2009).

Local government organizations carrying out public tasks should treat some of these tasks as projects. This makes the adoption of a project management method a necessity. Taking into account the number of projects implemented by local government organizations and the desire to increase the effectiveness of the activities undertaken in project management, it is important to determine the level of maturity. The study of maturity in project management is most often carried out by means of questionnaires, in which the questions are concentrated in areas related to human resources, to the project management methods and tools used, to the project environment and to project knowledge management.

The purpose of this article is to determine the level of maturity in project management in selected areas in local government organizations in Poland. The objective will be achieved by obtaining answers to the following research questions:

1. What is the level of maturity in project management in local government organizations in Poland in the studied maturity areas, i.e.: methods and techniques, human resources management, project environment management, project knowledge management?
2. Are there differences in the level of maturity in project management in the studied areas between poviats councils and city councils?

Surveys conducted using the method of standardized questionnaire interviews with computer assistance, CAWI, which is a quantitative information gathering technique, were used as the basis for the answers. The surveys were conducted in Poland in December 2019 and January 2020 among randomly selected Polish poviats councils and city councils. As a result of the research undertaken, data was collected from 200 poviats councils and city councils. The presentation of the research results is preceded by theoretical considerations regarding models for assessing maturity in project management.

## **2. Maturity models in project management based on the literature**

Assessing an organization's project maturity status requires the use of appropriate tools, known as project maturity models. In response to this need, project maturity models have been developed to serve as a framework for assessing project management competence and to improve project management competence in an organization. The most well-known project maturity models include:

- The Kerzner Project Management Maturity Model.
- Organizational Project Management Maturity Model.
- OGC Project Management Maturity Model.
- Prince2 Maturity Model.
- PM Solutions Project Management Maturity Model.
- Author's model S. Spalek.

These models assume that the higher the level of maturity an organization achieves, the greater the chances of successful project implementation.

The vast majority of maturity models present project management maturity in a five-level staircase structure (Table 1). The lowest-first level deals with informal project management, while in the second level there are already some defined processes, which, however, are selectively applied. The third level of maturity most often represents the organization's implemented project management methodology, while the fourth and fifth levels of maturity deal with implemented, standardized project management process systems. Organizations at these highest levels of maturity use performance indicators for these processes and, based on the results, continuously improve them.

**Table 1.**  
*Characteristics of project maturity models*

<b>Model</b>	<b>Description (model structures)</b>	<b>Maturity levels</b>
The Kerzner Project Management Maturity Model	An evaluation questionnaire is used to assess the current level and preparation of measures to improve project management.	Five levels ie: 1. Common language. 2. Common processes. 3. Single methodology. 4. Benchmarking. 5. Continuous improvement.
Organizational Project Management Maturity Model (OPM3)	It is a standard of so-called "best practices" for assessing and developing an organization's capabilities in managing project portfolios, programs and projects. The model consists of: Best Practices; Skills; Results; Indicators; Navigating Standards. The assessment cycle consists of 3 elements, i.e., knowledge, assessment and improvement, within which there are 5 activities that make up the cycle, i.e., Prepare for assessment. Conduct the assessment. Plan improvements. Implement the improvements. Solidify the process.	Four levels, ie. 1. Standardization. 2. Measurement. 3. Control. 4. Continuous improvement.
OGC Project Management Maturity Model	It sets the standard against which the maturity level of an organization can be measured. The assessment is carried out in 2 stages. In the first, the approximate maturity level of an organization's project management is identified. In the second stage, the actual maturity level of the organization is determined, and the result obtained is verified by the APMG (Association of Project Management Group), which accredits the maturity level of the applicant organization.	Five levels, ir: 1. Initial. 2. Repetitive. 3. Defined. 4. Managed. 5. Optimized.

Cont. table 1.

Prince2 Maturity Model	Each maturity level corresponds to seven process perspectives, ie: Management Control. Benefits management. Financial management. Stakeholder engagement. Risk management. Organizational management. Resource management.	Five levels, ie: 1. Awareness of the process. 2. Repeatable process. 3. Defined process. 4. Managed process. 5. Optimized process.
PM Solutions Project Management Maturity Model	PMMM integrates two leading project and process management standards, PMBOK® Guide and CMM, respectively.	Five levels, ie: 1. Initial 2. Structured process and standards 3. Organizational standards and institutionalized process 4. Managed process 5. Process optimization
Author's model S. Spalek	Maturity measurement in project management is carried out in the following four areas, i.e.: methods and tools, human resources, project environment, project knowledge management. Maturity is assessed in each area separately.	Five levels, ie: 1. Initial. 2. Standardization. 3. Application. 4. System management. 5. Self-improvement.

Source: own elaboration based on: Harpham, Hinley; Marciszewska, 2019, pp. 39-40.

Analyzing the various models of maturity in project management, one should agree with S. Spalek, who noted that maturity in project management is most often studied in the following areas: human resources, methods and tools, project environment. Attempts are also made to measure knowledge management processes in the aforementioned areas, which, however, according to the author, is insufficient and should be done in a separate fourth area. Such an approach, i.e., the study of the degree of maturity in project management divided into four areas (human resources management, methods and techniques, project environment management, project knowledge management), was used in this research.

The field of human resource management focuses on planning, attracting and motivating employees during projects. The basis of human resource management is the selection of such participants who will most effectively carry out the tasks assigned to them. The right selection of project employees makes it possible to generate profits. Project participants are required to have the right knowledge and skills, as working in a team requires developing a schedule so that it can be completed within the allotted time. In a well-chosen team, employees can demonstrate creativity, responsibility, accuracy of decisions, commitment.

The area of methods and techniques in assessing the degree of maturity in project management is a fundamental area for evaluation, without detracting from the other areas. M. Trocki notes that: "knowledge of project management principles, methods and techniques is becoming an indispensable component of the expertise not only of management specialists, but also of those working in other fields" (Trocki, 2013). Project management methodologies are a source of best practices that act as standards, procedures that describe the activities and processes that the project manager, project team members and other participants must undertake in order to carry out a project successfully (Wyrozowski, 2014).



The area of project environment management includes the environment (context) of the project, along with the factors that affect the success of the project (Engwall, 2003). The environment in which the project is implemented determines the approach to its implementation and affects its ultimate success (Swietoniowska, 2015; Trocki, 2013). The analysis of the project environment makes it possible to examine the conditions for project implementation. The project environment has an impact on projects. This influence can be both positive and negative.

The area of project knowledge management concerns knowledge, that is, an organized set of information with rules for interpreting it (Koźminski, 2004), and the process of knowledge management. It should be noted that knowledge is strongly personified and closely related to the human factor, since people, not the organization, are the main carrier of the knowledge resource. Knowledge management is identified with the process that contributes to the achievement of measurable results (Bukowitz, Williams, 1999; Perechuda, 2005; Perez, Ordonez de Pablos, 2003; Wiig, 1993). On this basis, it can be said that knowledge management should be considered not only in terms of information management, but also in terms of managing knowledge workers.

### **3. Research method**

For the purpose of preparing the article, the research mode was adopted in accordance with the methodological principles of the management sciences. The research mode consists of the following stages: formulation of the research problem and research questions, conducting the research, analyzing the collected empirical material and formulating conclusions in response to the research questions.

The literature research conducted on project maturity in local government organizations in Poland indicates that the level of project maturity of local government units is low. This is confirmed by the results of a study conducted by M. Dolata on the project maturity of basic local government units. They show that half of the surveyed units are at the second level of maturity, and as many as 26% of units at the first level. Only 17% of the surveyed units were included in the third level due to their moderate maturity (Dolata, 2013).

The maturity of the offices of municipalities, cities and county offices was studied by J. Strojny (Strojny, 2019). However, this research focused on the process-project maturity of these organizations. According to the results of this research, most of the surveyed organizations reached a medium level of process-project maturity.

In summary, local government organizations are at a low level of project maturity and there is a lack of dedicated tools for assessing project management maturity measurement in local government organizations in Poland.

With this in mind, it is therefore justified to undertake empirical research to at least partially fill the identified research gap.

The purpose of the research presented in this article is to determine the level of project management maturity in four maturity areas in local government organizations. The main objective will be achieved by obtaining answers to the following research questions:

1. What is the level of maturity in project management in local government organizations in Poland in the studied maturity areas, i.e.: methods and techniques, human resources management, project environment management, project knowledge management?
2. Are there differences in the level of maturity in project management in the studied areas between poviats councils and city councils?

Based on a critical analysis of the literature on project maturity models used in enterprises, a tool was developed to measure and assess project maturity in local government organizations. This approach seems, to be appropriate due to the need to take into account the type of organizations under study, which are local government organizations.

The questionnaire developed for the study consisted of statements rated on a 5-point Likert scale. The questionnaire consisted of a metric and 32 questions grouped into 4 thematic areas, i.e.: human resource management, methods and techniques, project environment management, project knowledge management. The task of respondents representing the surveyed local government organization was to respond to the statements given in the standardized table relating to the surveyed areas.

Determining the degree of maturity in each area required the adoption of the author's algorithm, which was prepared based on the principle of accumulation. This principle means that achieving a higher level of maturity requires meeting all the conditions for that level, as well as all the conditions specified for the preceding levels. According to the adopted algorithm, the local government organization can be classified accordingly:

- at level 1 – when it meets all the conditions specified for level 1 in a given maturity area,
- at level 2 – when it meets all the conditions set for levels 1 and 2 in a given maturity area,
- at level 3 – when it meets all conditions specified for level 3 in a given maturity area and all conditions specified for levels 1 and 2,
- at level 4 – when it meets all the conditions specified for level 4 in a given maturity area and all the conditions specified for levels 1, 2 and 3,
- at level 5 – when it meets all the conditions specified for level 5 in a given maturity area and all the conditions specified for levels 1, 2, 3 and 4.

The local government organization can be classified into levels 1, 2, 3, 4, 5, respectively. The characteristics of the maturity levels in each area are shown in Table 2.

**Table 2.***The characteristics of the maturity levels in each area*

Level	Maturity area in project management			
	Human resource management	Methods and techniques	Project environment management	Project knowledge management
Level 1.	The organization lacks formal guidelines and procedures, in terms of managing human resources in projects.	The organization lacks formal guidelines and procedures for project management tools and techniques.	Local government organization, does not have a system to support project management.	The local government organization does not have defined standards for project knowledge management.
Level 2.	The organization tries to ensure that competent people are available for the project, but this is hampered because there is very rarely a formal evaluation system in place to measure the level of competence of these people.	The local government organization has limited use of project management tools and techniques There are defined project management processes in the organization, but they are used selectively.	There are limited project-specific management processes in local government organizations. Very rarely and to a limited extent are measures taken to manage project stakeholders.	In the local government organization, awareness of the importance of knowledge in effective project management is not widespread, and measures are not taken to collect and store knowledge and experience from completed projects. The organization lacks a culture of sharing knowledge and experience.
Level 3.	The organization tries to provide competent people for project planning and implementation, and cares about the development of project managers and project team members by providing training in this area. However, there are not always elaborate rules for appointing people for project implementation and rules for motivating people who perform particular roles in the project team. The organization only sometimes uses a formal evaluation system to measure the level of competence of those involved in project planning and implementation.	The organization has defined processes as well as tools and techniques for project management and these are used in most projects.	There is an awareness in local government organizations of the importance and value of project management, which translates into taking steps to align management processes with project needs. The authority seeks to use project management as an avenue to achieve strategic goals, and project managers seek to manage project stakeholders.	In the organization, there is an awareness of the importance of knowledge in effective project management, and there are efforts to collect and store knowledge and experience from completed projects. Unfortunately, the accumulated knowledge and experiences are not always used in subsequent projects, and project managers and project team members only sometimes share their experience and knowledge.

Cont. table 2.

<p>Level 4.</p>	<p>The organization always provides competent people for the project, in addition, it provides training and takes care of the development of project managers and people who perform specific roles in the project team. There are developed rules for appointing people to the project and they are often applied in the organization. There are elaborate rules for motivating people performing particular roles in the project team, a formal evaluation system is used to measure the level of competence of people involved in the project.</p>	<p>The organization has and always uses an elaborate project management methodology, in particular, it has a common, defined language for describing project activities and results, it has and uses appropriate tools and techniques, and it has defined processes for initiating, planning, executing, monitoring, controlling and closing the project. Such an organization often has a system for collecting and sharing data on completed projects.</p>	<p>There is a high awareness of the importance and value of project management in local government organizations. The organizational structure takes into account the needs of project management support, so there is often a separate project management organizational unit. The authority uses project management as an avenue to achieve strategic goals, has a plan to standardize, measure control and improve project management processes, and project managers effectively manage project stakeholders.</p>	<p>There is an awareness in the organization of the importance of knowledge in successful project management. Measures are always being taken to collect and store knowledge and experience from completed projects. The accumulated knowledge and experiences are very often used in subsequent projects, and project managers and project team members share their experience and knowledge. A system to support project knowledge management is implemented in the organization.</p>
<p>Level 5.</p>	<p>The organization has and applies a formal system for evaluating the employees involved in the project, applies developed rules for appointing people to the project, and motivates people in specific roles on the project team. In addition, the organization analyzes and implements improvements in processes related to the recruitment of people for projects and processes related to the development of managers and people performing particular roles on the project team.</p>	<p>The organization analyzes and improves the developed project management methodology, particularly with regard to processes related to project initiation, planning, execution, monitoring, control and closure. In addition, the organization has a formal system for collecting and sharing data on completed projects, which allows lessons to be learned and project management processes to be improved.</p>	<p>In the local government organization, awareness of the importance and value of project management is widespread, and the organizational structure is adapted to support project management by, among other things, separating the project management organizational unit. Project management for the achievement of strategic goals is applied to its full extent. There is a plan to standardize, measure, control and improve project management processes. Processes related to project stakeholder management are analyzed and improved.</p>	<p>In a local government organization, awareness of the importance of knowledge in effective project management is widespread. This results in the collection and storage of knowledge and experience from completed projects in such an organization. A full system is implemented to support project knowledge management, and in addition, in such an organization, efforts are made to continuously improve processes related to the collection, storage and use of project knowledge and experie</p>

Source: own elaboration.

## 4. Research results

As a result of the undertaken research conducted in Poland in December 2019 and January 2020 among randomly selected Polish poviats councils and city councils, data was collected from 200 organizations. Fifty-five poviats councils and 145 city councils participated in the survey, which, with a significance level of  $\alpha = 0.05$  and an acceptable error of  $e = 5\%$ , constitutes a representative research sample.

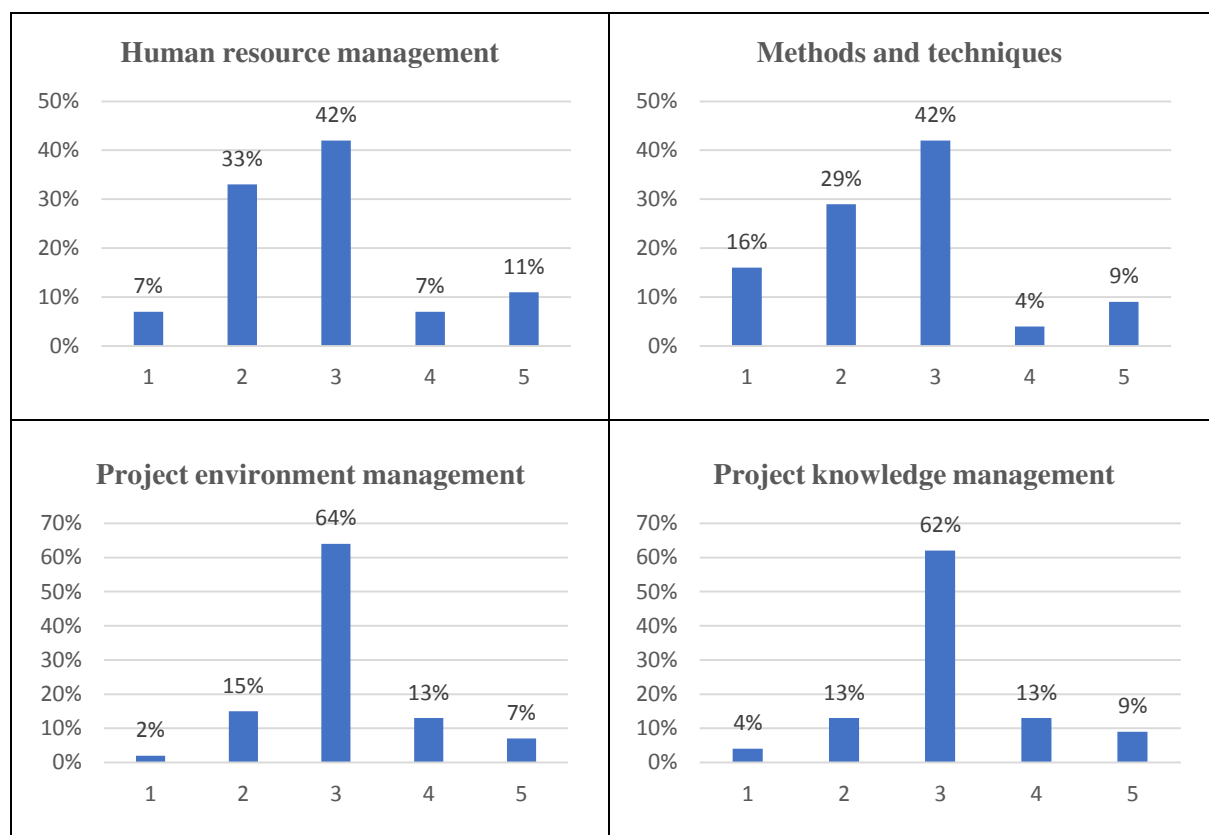
Data were collected using the CAWI (Computer-Assisted Web Interview) method among competent local government administration officials, i.e. deputy mayors, chief executives, directors, department heads, secretaries, specialists and inspectors.

Among the respondents, the largest number (29.5%) are office employees with seniority of more than 20 years. An equally large group of respondents were those with seniority of 16 to 20 years (26%), and with seniority of 11 to 15 years (25%). Respondents with seniority of 6 to 10 years accounted for 11%, with seniority of 4 to 5 years 3%, and with seniority of up to 3 years 5.5%.

By far the largest group of people who completed the survey were those with higher education (97%). Respondents with secondary education accounted for 3%.

Based on the survey, the level of project management maturity in the surveyed local government organizations in Poland ranged from 1 to 5. It reached a minimum value of 1 and a maximum value of 5 in each of the surveyed areas, i.e. human resources management (ZL), methods and techniques (MT), project environment management (ZŚ), project knowledge management (ZW). The highest average value of project maturity level was achieved for the project environment management area (3.04), followed by project knowledge management (3.0), human resources management (2.77). The lowest average value of project maturity level was achieved for the area of methods and techniques (2.47). For the ZW, ZŚ, ZL areas, the median was 3, and for the MT area, the median was 2.

The variation of individual values was highest in the area of method and technique, and decreased in the areas of human resource management, project knowledge management, and the lowest variation of individual values was in the area of project environment management. Analyzing the distributions of project management maturity level scores presented in Figure 1, it is possible to see the differences occurring among the areas that local government organizations in Poland have achieved.



**Figure 1.** Distribution of project management maturity level scores in local government organizations in Poland by area.

Source: own elaboration.

Analyzing the results, the largest number of local government organizations reached level 3 in project management maturity in each area. The largest number, almost 64% of organizations, recorded level 3 in the area of project environment management. Next, 62% of organizations recorded level 3 in the area of project knowledge management. Local government organizations also recorded level 3 maturity in the area of human resource management (42%) and in the area of methods and techniques (35%), but in these areas there is considerable variation in the maturity levels achieved. In the area of human resource management, level 2 project maturity was recorded by as many as 32% of organizations, as in the area of method and technique by 31%.

Considering all the areas surveyed, i.e., ZL, MT, ZŚ and ZW, levels 4 and 5 were achieved by few organizations. With the highest number, 10% of organizations achieved level 5 in the area of human resources management. In contrast, 13% of organizations achieved level 4 in the project environment management area.

Analyzing separately the level of maturity in poviát councils and city councils in the areas studied, one can see some differences occurring between these units.

Poviát councils in Poland obtained the highest average value in the areas of project knowledge management and project environment management (3.1), and the median for these areas was 3. The lowest average (2.6) was recorded in the area of methods and techniques.

Analyzing the value of the standard deviation, it can be seen that the lowest values were recorded for the areas of project environment management (0.8) and for the area of project knowledge management (0.88).

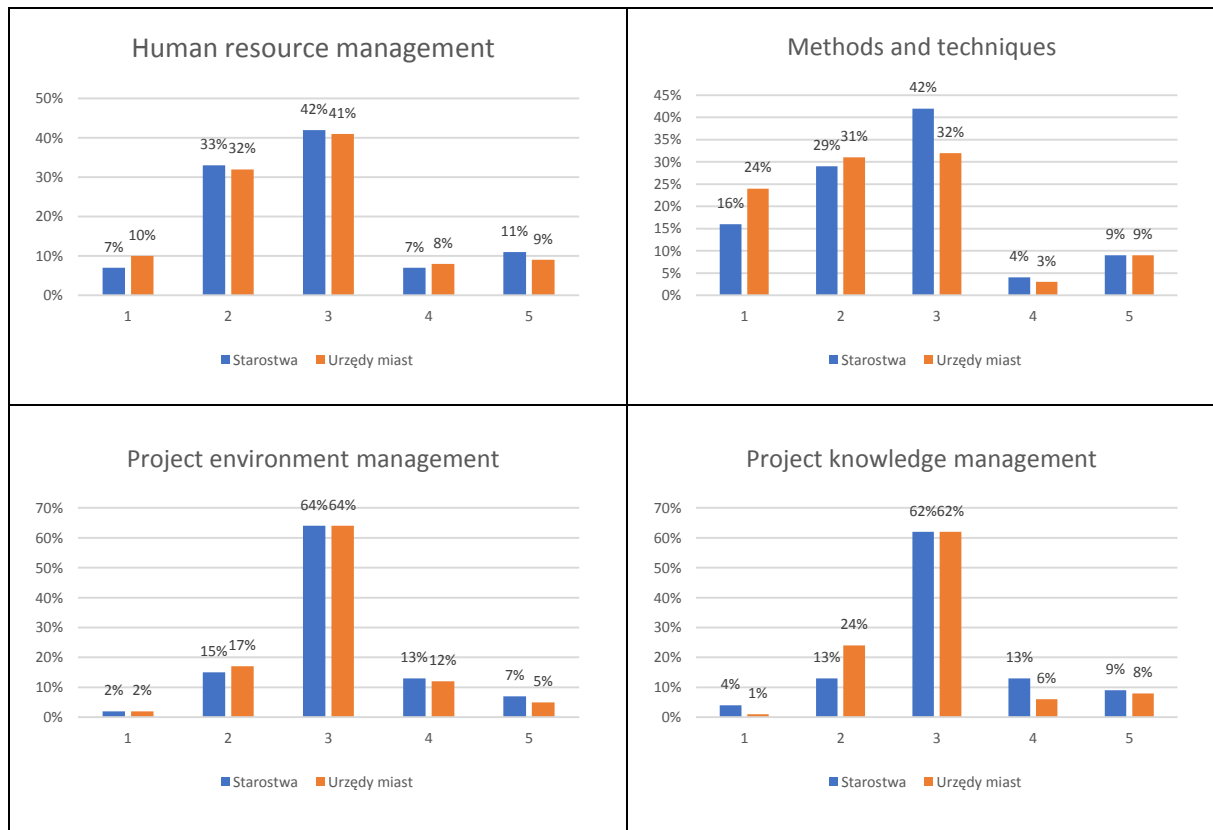
The highest percentage of poviats councils achieved level 3 in the project environment management area (64%) and in the project knowledge management area (62%). Poviats councils in the area of human resource management and in the area of methods and technology also recorded level 3 in project management maturity, with more dispersion in these areas. In the area of human resource management, 33% of poviats councils recorded level 2 in project maturity, and 11% recorded level 5 in project maturity. In the area of methods and techniques, 29% of poviats councils recorded level 2 project maturity, and 9% recorded level 5 project maturity.

City councils in Poland obtained the highest average value in the area of project environment management (3.0), while they obtained 2.95 in the area of project knowledge management and 2.75 in the area of human resource management. The lowest average was recorded for the area of methods and techniques, which was 2.42, and the median for this area was 2. Analyzing the value of the standard deviation, it can be seen that the lowest values were recorded for the project environment management area (0.75) and the project knowledge management area (0.79), and the highest for the methods and techniques area (1.16).

The highest percentage of city councils achieved level 3 in the area of project environment management (64%) and in the area of project knowledge management (62%). In the area of human resource management, level 3 maturity in project management was achieved by 41% of city councils. In the area of methods and techniques, 32% of offices recorded level 3, and 31% of offices recorded level 2. The most scattered results can be seen in the area of methods and techniques and in the area of human resource management. In the area of human resource management, 32% of offices recorded level 2 in project maturity, and 9% recorded level 5 in project maturity. In the area of methods and techniques, 24% of city councils recorded level 1 project maturity, and 9% recorded level 5 project maturity.

Based on the survey, no significant differences can be observed between the level of maturity in project management in city councils and poviats councils in Poland in three areas, i.e. in the area of human resource management, in the area of project environment management and in the area of project knowledge management. Only in the area of methods and techniques are there slightly larger differences in the level of maturity in project management, i.e. 10% in level three and 8% in level one. However, they are not large enough to speak of a significant difference between city councils and poviats councils.

Figure 2 shows the distribution of project management maturity level scores in each area achieved by city councils and poviats councils in Poland.



**Figure 2.** Summary of the distribution of project management maturity level scores in city councils and poviats in Poland by area.

Source: own elaboration.

## 5. Discussion

The literature emphasises that project management maturity is important for organisations because it affects the efficiency and effectiveness of project delivery. Organisations with higher project maturity are more likely to achieve project success, reduce risk and achieve the intended outcomes. Therefore, many organisations strive to continuously improve and enhance their project management competencies through training, implementing best practices and monitoring project performance. At the highest level of maturity, an organisation has effective processes that are continuously improved, has the ability to anticipate and manage risk, as well as a high project culture, and is able to deliver high quality projects as required.

The research carried out in local government organisations showed that, in terms of project maturity level, these organisations most often reach the second or third maturity level. For the area of project environment management, the average value was 3.04, similarly for the area of project knowledge management - the average value was 3.0. The average value of the maturity level achieved in the area of human resources management was 2.77, and for the area of methods and techniques - 2.44.



The study of project maturity in local government units in Poland was conducted by M. Dolata. Her research shows that the average level of project maturity in the surveyed units is relatively low and amounts to 2.04. The author's research also shows that basic local government units in Poland are at the stage of acquiring management knowledge relating to the integration of project management processes with the management methods used so far.

Admittedly, the average level of project maturity according to M. Dolata's research is lower than the one obtained in this research, but it should be noted that the research conducted by M. Dolata was carried out much earlier, which undoubtedly influences the obtained results. In addition, the author (Dolata) pointed out the difficulties of integrating project management processes with the management methods used so far, which indicates deficiencies in the area of methods and techniques. And as M. Trocki, the area of methods and techniques is a fundamental area for assessing the degree of maturity. It seems that this area is of particular importance in local government organisations, as the employees of these organisations are used to carrying out tasks according to specific procedures. Methodologies, methods, standards of project management can be such a procedure, as they comprise a logical and coherent set of detailed recommendations as to how to proceed in managing the entire project, leading to the planned result.

## 6. Summary

The conducted research made it possible to determine the level of maturity in project management in city councils and poviats in Poland in four areas, i.e. human resources management, methods and techniques, project environment management, project knowledge management. The highest average value of project maturity level was achieved for the area of project environment management (3.04), followed by project knowledge management (3.0), human resources management (2.77). The lowest average maturity level value was achieved for the area of methods and techniques (2.44). Generalizing, it can be concluded that the method and technique area is separated from the other areas by approximately a distance of one maturity level. This shows that local government organisations should focus on developing and implementing a structured approach to project management, including having a common, defined language for describing project activities and results, as well as having and using appropriate project management tools and techniques. It is important that the organisation has defined processes for initiating, planning, executing, monitoring, controlling and closing a project.

When analysing the level of maturity in the individual areas separately for the city councils and poviats, no significant differences can be seen in three areas, i.e. in the area of human resources management, in the area of project environment management and in the area

of project knowledge management. Only in the area of methods and techniques are there slight differences in the level of maturity in project management.

The conducted survey contributed to the acquisition of knowledge about the level of maturity in four areas of project management in local government organisations in Poland. The results of the study indicate the need to improve the area of methods and techniques in local government organisations.

Due to the limitations of the research (the size of the research sample and the number of respondents representing a given organisation), the results cannot be generalised to the entire population, but they may indicate the directions of further research within the framework of the undertaken issues.

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## TRANSFER PRICING POLICY CONCEPT MODEL FOR MNEs IN RELATION TO STRATEGIC MANAGEMENT

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**Purpose:** Transactions carried out in MNEs among parent companies and subsidiaries affect the achievement of the strategic and operational objectives of MNEs, their financial results, taxes paid and intra-group relations. The aim of the paper is to justify the need to extend the areas of strategic management in MNEs to include the area of tax, in particular related to the valuation of transactions between entities within a group, and the need to meet the obligations related to transfer pricing. The practical aim of the article is to propose an original transfer pricing policy model for MNEs, which may be adopted to increase the transparency of settlements and have a positive impact on operational and strategic effectiveness within groups.

**Design/methodology/approach:** The paper is based on qualitative research. Content analysis of legal provisions and prior literature was used for the collection of relevant data for building a transfer pricing policy model.

**Findings:** A comprehensive and consistently implemented transfer pricing policy may help in optimizing the tax structure of MNEs, as well as minimizing the risk associated with changes in tax provisions. As an instrument influencing operational relations and performance management in MNEs, it can be a significant element of the strategic management of groups.

**Practical implications:** The research impact upon MNEs is the possibility to apply and adopt the transfer pricing policy model proposed in the paper in order to support performance management within a group.

**Social implications:** The way multinational entities conduct their business is often perceived negatively by society due to issues of tax evasion. The implementation of a comprehensive transfer pricing policy promotes corporate tax transparency and increases employee tax awareness.

**Originality/value:** The originality of the article stems from a coherent combination of various aspects relating to intra-group transactions into one model, which on the one hand supports the management of subsidiaries, and on the other facilitates compliance with Polish and international legal provisions. The proposed model may be subject to further development.

**Keywords:** corporate taxation, subsidiaries, accounting, compliance, tax avoidance.

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

## 1. Introduction

In the face of contemporary changes in the economic environment of enterprises, the scope and structure of strategic management tools are changing. This applies in particular to multinational entities (hereinafter MNEs), which in the globalised world constitute a large part of business entities. An MNE is usually a group of companies constituting a form of integration not only of capital but also non-capital elements related to independent business entities, against the background of the relations between them resulting from civil and commercial law (Remlein, Strojek-Filus, Światło, 2021, p. 61). Management of such groups of companies requires taking into account many complex factors resulting from economic, legal, social and behavioural conditions. The author of the paper focuses on the complicated issues of shaping and valuation of intra-group transactions and their tax consequences. The aim of the paper is to justify the need to extend the areas of strategic management in MNEs to include the area of tax, in particular related to the valuation of transactions between entities in a group and the need to meet the obligations related to transfer pricing.

Related entities operate within a group, but in concluding an intra-group transaction and calculating the transfer price, they are obliged to comply with the arm's length principle, so that the conditions under which transactions are carried out comply with the conditions under which the transaction would be concluded by unrelated entities. Transfer prices are, on the one hand, of interest in tax law while on the other, they reflect the mutual relations in MNEs. In the existing literature, there is a discrepancy between studies on transfer pricing related to tax optimization issues and studies, which were being conducted on organizational intra-group relations. The author attempts to eliminate this research gap in this paper.

The paper is based on qualitative research. As stated by Neergaard and Ulhøi (2007, p. 4), "the goal of qualitative research is to develop concepts that enhance the understanding of the social phenomena in natural settings, with due emphasis on the meanings, experiences and views of all participants". Content analysis of legal provisions and prior literature was used for the collection of relevant data for building an MNE transfer pricing policy model, which is the practical aim of the paper. The model was built on the basis of many years of literature and law provisions analysis as well as the author's practical experience. This original transfer pricing policy model has the cognitive value and may be adopted to increase the transparency of settlements and have a positive impact on operational and strategic effectiveness in groups. Moreover, the implementation of a comprehensive transfer pricing policy may promote corporate tax transparency and increase employee tax awareness. The main rationale of the paper is therefore an attempt to provide managers of MNEs with a tool that combines the requirements resulting from tax regulations with the complex relationships existing in the group. This tool supports the identification and reduction of tax and organizational risks related to intra-group transactions.

## 2. Specificity of management in groups of companies – prior literature

Management in capital groups consists of achieving objectives in the short, medium and long term in order to ensure the continuity and efficiency of the current operation of the capital group (Trocki, 2004). The literature lists a wide range of objectives of capital groups, such as: increasing market share, improving competitive position, using synergies and economies of scale, increasing access to capital, reducing costs, diversifying activities, transferring knowledge and intellectual capital, increasing operational efficiency and improving liquidity and profitability (Nogalski, Ronkowski, 2004). From the point of view of this study, one important objective of creating and managing groups of companies that should be mentioned in particular is tax optimization, which will be discussed in more detail in section 3 of the paper.

The literature presents many factors that affect the specificity of management in MNEs. For example, from the point of view of the purpose of business activity, these can be divided into operational, managerial and financial, whereas in terms of the range of activity they can be divided into local, national, international and global. The business linkage criterion allows vertically and horizontally integrated groups and conglomerates to be distinguished. The complexity of the group structure can be divided into simple two-level groups, complex groups with 3-5 rungs and very complex groups with above 5 rungs (Trocki, 2004; Sikacz, 2011).

A crucial factor determining the management of an MNE is the role of individual subsidiaries and associates, especially since there are usually various intra-group transactions among them. The simplest form of such an assessment is analysis of the functions performed. The management of related entities will be different depending on whether they are treated as cost centres, profit centres, revenue centres or investment centres (Horngren, Datar, Foster, 2006; Sulik-Górecka, 2018). A more detailed analysis should take into account the type and autonomy of the functions performed, i.e. whether related entities are manufacturers, trading companies or service companies. The level of autonomy and independence of related entities may also vary in different ways, significantly affecting the management of these entities from the point of view of the parent company. Table 1 gives the characteristics of the above-mentioned entities.

**Table 1.***Types of entities in MNEs depending on the functions performed*

<b>Business model</b>	<b>Type of entities</b>	<b>Characteristics</b>
Manufacturers	toll manufacturers	Such a model of relations within the group usually assumes the total dependence of the manufacturing entity on the ordering entities from the group. The role of toll manufacturers is to process entrusted raw materials and other materials into semi-finished and finished products, but they do not own these materials. Completed production orders are returned to the customer and priced in a way that allows the costs of production to be covered.
	contract manufacturers	Contract manufacturers are free to make decisions about the choice of suppliers of raw materials and other materials, but bear the full risk associated with the purchase. They start production only after receiving a production order from the customer, who specifies in detail the type of product and its quantity.
	fully-fledged manufacturers	Full functions related to both sourcing and production, as well as sales and marketing, are performed by fully-fledged producers, who should be treated as profit centres.
Trading companies	agents	These perform functions related to the representation of producers, and the main asset of the agent is their knowledge of the sales market.
	distributors with limited functions	These conduct the activity of purchasing goods from a related party and then reselling the purchased goods to external entities. Commercial goods purchased by them become their property. Unlike agents, they conduct minimal marketing and advertising activities and bear little market risk.
	fully-fledged distributors	These operate in the field of full service of a specific sales market. They deal with the introduction to a specific market of goods that they have previously purchased from a supplier, along with conducting promotional and advertising activities supporting sales, and bear the full risk of sales.
	entrepreneurs	These bear a high market risk, which results from the fact that they conduct business activity on a very large scale. They are often the owners of intangible assets for those distributors with limited functions, and they perform the function of a supply centre.
Service companies	share service centres	Their role is to support the conducting of business activity by other entities in the group. The following services are most often provided by a service centre: management and marketing, IT services, administration, accounting, etc. The costs of providing individual support services are divided proportionally between the entities purchasing them.
	R&D centres	These are responsible for the development of new production technologies and new products. Typically, these entities do not have rights to intangible assets as they receive remuneration on an ongoing basis under a cost contribution agreement or a licence agreement from entities using these rights.

Source: own elaboration based on OECD Guidelines, 2022; Bakker, 2009.

The literature draws attention to the need to move away from the typical hierarchical view, where headquarters control subsidiaries and make strategic decisions. This change is due to shorter product life-cycles, rapid technological changes and increased global competition. Contemporary MNEs should rather be defined as global networks of subsidiary operations (Jakobsen, Rusten, 2013). The network model of MNEs allows a subsidiary to move from the position of a subordinate into one of equality or even leadership. Subsidiaries may be “loosely coupled entities rather than a hierarchical monolith” which may support their own unique resource profile (Birkinshaw, Hood, 1998). Control issues are perceived differently because formal control is often less effective than management systems or cultural control (Paterson,



Brock, 2001). MNEs have to deal with the desire for global integration on the one hand and local responsiveness on the other, which depends on the previously mentioned overarching goal of market seeking, resource seeking and efficiency seeking. These factors affect the strategy implemented in MNEs, which can take the forms presented in Table 2.

**Table 2.**

*Types of strategies in MNEs depending on internationalization*

Type of strategy	Characteristics	Responsiveness	Efficiency
international	exporting or importing goods and services while maintaining a head office or offices in their home country.	low	low
multidomestic	Adapts to local requirements within each of its markets.	high	low
global	In various markets, certain minor modifications to products and services can be implemented, but the global strategy emphasises the need to obtain benefits of scale by in principle offering the same products or services on every market.	low	high
transnational	Transnational enterprises have a decentralised organisational structure with subsidiaries in several countries. The dominating unit has limited control over the foreign subsidiaries. A company employing a transnational strategy looks for a golden mean between a multi-country strategy and a global strategy.	high	high

Source: Own elaboration based on: Lovelock, 1999; Harzing, 2000; Cheung, Burn, 1994.

Researchers have created numerous tools that can help classify and sort the various roles that subsidiaries may take on within MNEs. All of the frameworks take into account the importance of the autonomy versus integration (coordination) aspect of a subsidiary's role (Ghoshal, Bartlett, 1988). Moreover, the transfer of competences from corporate headquarters to subsidiaries is not the only way of developing subsidiaries, as these also develop unique competences that can be transferred to headquarters and other related entities (Borini, Fleury, M.T.L, Fleury, A., 2009).

The independence of subsidiaries can increase in particular in unstable times of crisis or pandemic, as confirmed by Sobotkiewicz, whose research shows that during the Covid-19 pandemic, the scope of functions and decision-making powers was increased for subsidiaries (2022). Various forms of management may be used for strategic group management, but the instruments resulting from corporate law and company agreements or articles of association are insufficient and require extension to include, for example, functional supervision (Trocki, Gołąb, 2004).

### 3. Transfer pricing policy in the light of legal requirements

One of the faces of globalization is the enormous economic power of global corporations, within which a significant part of world trade takes place. There are various types of transactions among related entities concerning the purchase and sale of goods or finished goods, the provision of various types of services, the purchase and sale of fixed assets and intangible assets, as well as financial transactions, e.g. loans. In most countries, the basis for legal regulations concerning price calculations in transactions between related parties are the Transfer Pricing Guidelines for Multinational Enterprises and Tax Administrations first issued by The Organisation for Economic Co-operation and Development in 1995 in response to the growing economic power of international corporations. The aim of the OECD Guidelines (hereinafter referred to as “OECD guidelines” or “guidelines”) is “to assist tax administrations in preventing profit shifting” while it also has a useful role for taxpayers in proving compliance of transactions with market conditions. On 20 January 2022, the OECD published a new edition of the Guidelines (OECD, 2022). The document, provides guidance, among others, for applying the arm’s length principle to the pricing of transactions among related entities for tax purposes. However, the scope of the guidelines is much wider, as shown in Table 3.

**Table 3.**

*Structure of OECD Transfer Pricing Guidelines for Multinational Enterprises and Tax Administrations*

Number of chapter	Title of chapter
I	The Arm’s Length Principle
II	Transfer pricing methods (traditional transaction methods, transactional profit methods)
III	Comparability analysis
IV	Administrative approaches to avoiding and resolving transfer pricing disputes
V	Documentation
VI	Special considerations for intangibles
VII	Special considerations for intra-group services
VIII	Cost contribution arrangements
XIX	Transfer pricing aspects of business restructurings
XX	Transfer pricing aspects of financial transactions

Source: OECD, 2022.

The broad scope of the OECD guidelines results primarily from the tax consequences that may occur as a result of intra-group transactions. Subsidiaries do not necessarily function as unrelated entities; on the contrary, group structures are used, amongst others, to manage the profitability of entities as well as to optimize the allocation of resources and minimize tax burdens. Transfer pricing techniques that take advantage of differences in tax rates in different countries by placing subsidiaries in certain locations are the subject of research by many researchers. Tax benefits are one of the reasons why companies conduct transactions to related companies (Chan, Lo, Mo, 2015; Blouin, Robinson, Seidman, 2017; Brychta et al., 2020).

Obtaining tax benefits through appropriate transfer pricing is a significant factor in the development of MNEs (Kim, 2008; Rossing, Rohde, 2014). For example, when selling services and products to subsidiaries in countries where taxes are low, prices are lowered so that later when it comes to sales to unrelated parties at market prices, profits are taxed lower (Stevenson, Cabell, 2022). Transfer pricing is one of the three most far-reaching profit shifting channels under existing tax systems, alongside the use of debt and the location of intangible assets (Chugan, 2007; Elitzur, Mintz, 1996).

In one study, the negative effects of inconsistency in transfer-pricing rules around the world were modelled. There is inconsistency in transfer-pricing rules of allocation income between countries, even if tax administrations claim to adhere to the same transfer-pricing principles, for example the OECD guidelines. Such inconsistencies appear when, as a result of a tax audit, there is an adjustment of the tax base and the value of the tax on a transaction, and this affects the income in the other country, which is also taxed. The inability to make a transfer pricing adjustment in the other country may trigger double taxation for MNEs. The effects of inconsistent regulations include the costs of audits, the costs of obtaining an advance pricing agreement on the preparation of tax documentation, and the costs of resolving disputes and litigation. The authors also put forward the thesis that differences in transfer pricing provisions are part of the competitive struggle between national governments for investment by MNEs (Waegenaere, Sansing, Wielhouwer, 2006; Peraltaa, Wauthyb, Yperselec, 2006).

The tax administrations of individual countries oversee the correct determination of income taxes, and are looking hard for tools that will help them counteract the practices of increasingly powerful global capital groups. Many initiatives are being developed at the international level to prevent the reduction of tax revenues. One such undertaking is the Project of the Organization for Economic Cooperation and Development, entitled "Base Erosion and Profit Shifting", which was created as a result of the analysis of tax revenues in the budgets of individual countries, which did not correspond to the growing revenues generated by MNEs. The initiative aimed to develop tools to counteract aggressive tax optimization, made possible by differences in the tax systems of individual countries. As a result of efforts at the international level, the OECD and the G20 member states published a report in 2013 called "Action Plan on Base Erosion and Profit Shifting", the aim of which was to improve the coordination of tax authorities' action against the tax avoidance practiced by global corporations OECD (BEPS, 2015).

From the perspective of the management boards of parent companies, subsidiaries and associated entities, as taxpayers of the tax system of a given country, the crucial task is to prove to the tax administration that the valuation principles of intra-group transactions do not differ from the rules that would be applied by unrelated entities. In this way, the application of the arm's length principle can be confirmed. From an operational point of view, capital groups in most countries around the world have become accustomed to the need to prepare so-called transfer pricing documentation, which has been mandatory in Poland since 2001, within certain

thresholds (Act on CIT, Regulation of MF 2019, Regulation of MF 2022, Regulation of MF 2023).

Since 2017, in Poland a standardized three-tiered approach to transfer pricing documentation adopted as part of the implementation of the BEPS project has been in force (OECD, 2022; Act on CIT):

- Local File – documentation relating to the company, describing local taxpayers' transactions (hereinafter LF).
- Master File – providing standardized information relevant for all MNE group members (hereinafter MF).
- Country-by-Country Reporting – providing information referring to the global allocation of an MNE's income within the MNE group (hereinafter CBCR).

Related parties whose financial statements are consolidated using the full or proportional method are obliged to prepare local transfer pricing documentation, and attach to this documentation group transfer pricing documentation prepared for the financial year by the end of the twelfth month after the end of the tax year, if they belong to a group of related entities: 1) for which consolidated financial statements are prepared; 2) whose consolidated revenues exceeded PLN 200,000,000 or its equivalent in the previous financial year (Act on CIT).

As part of the international consensus regarding the need for related parties to document transactions, the following instruments supporting tax administrations and MNEs have also been developed:

- Double taxation treaties between the governments of individual countries aimed at eliminating international double taxation by means of legal norms established by the parties to the agreement.
- Advance pricing agreements (hereinafter APA) – agreements concluded between the taxpayer and the tax authority, in which the authority accepts the choice and method of application of the transfer pricing verification method used in the relations between the taxpayer and its related entities. The conclusion of an agreement is a tool to reduce the risk of incorrect transfer pricing and to challenge the manner of their determination by tax authorities (Act on APA).
- The MAPe procedure, which also aims to avoid double taxation arising as a result of an overestimation made by one of the parties to an international agreement in relation to transactions between related parties.
- Safe harbours – for certain transactions, such as low value-added services and loan transactions, complicated documentation and benchmarking can be avoided under the conditions laid down by law (Act on CIT).

In the face of the obligation to apply the above-described complicated legal regulations regarding transfer pricing, and due to the need to achieve the objectives of management of the group discussed in section 2 of the paper, a transfer pricing system and transfer pricing policy

may become a tool supporting the settlement, calculation and documentation of transactions among related parties. The development of a transfer pricing system can support the achievement of goals such as maximizing profits, cash flow, sales and marketing goals, minimizing taxes, duties, tariffs and exchange rate fluctuations, and improving relations with the country of residence (Karen, Cravens, 1997).

A transfer pricing policy can be defined as "a formal document signed by the company's management boards that regulate the method of transfer pricing within each category of transactions with related parties" (Luca, Ciocanea, Pitu, 2019).

Both the OECD guidelines and Polish provisions, including the Act of Corporate Tax and the MF Regulations on transfer pricing documentation, do not require the creation and possession of a separate, comprehensive document containing a transfer pricing policy. However, paragraph 3, Chapter 5 in Annex 1 to the OECD guidelines, as well as the Regulation of the Ministry of Finance of 21 December 2018 on transfer pricing documentation in the field of corporate income tax, require that the following elements, among others, be attached to the master file:

- information on the Group's transfer pricing policy with regard to the allocation of costs of intra-group services and the principles of setting prices for these services,
- description of the Group's transfer pricing policy in the field of research and development activities and intangible assets,
- general description of the transfer pricing policy regarding financing between related parties (regulation).

Furthermore, it should be added that in addition to tax obligations, capital groups are also subject to related party obligations resulting from accounting regulations. Internationally, this is primarily the regulations under the International Accounting Standards IAS 24 – Related Party Disclosures, obliging entities to disclose the nature of their relationship with related parties, as well as information about transactions and outstanding balances, including liabilities, necessary for users to understand the potential impact of the relationship on financial statements (IAS 24 – Related Party Disclosures).

#### **4. Structure and scope of MNE transfer pricing policies on a global scale – proposal of an original model**

As a result of an in-depth analysis of legal provisions and prior literature in the field of transfer pricing issues and strategic management in groups of entities, an attempt was made to create a transfer pricing policy concept model in the form of a document for MNEs. The structure and scope of the transfer pricing policy model is presented in Table 4.

**Table 4.**  
*MNE Transfer Pricing Policy Model*

No.	Title of transfer pricing policy regulation	Scope of transfer pricing policy regulation	Use in transfer pricing reports*
1.	Rules for determining relations in the group	<p>Capital relations: the obligation to inform about changes in this respect, including the sharing of source documents such as notarial deeds, contracts, etc.</p> <p>Personal relations: the obligation to inform about changes in this respect on the basis of statements on relations by members of the Management Board, members of the Supervisory Board, shareholders (natural persons) holding at least 25% of shares or stocks, persons in decision-making positions and related to responsibility for the operation of a given entity. (The declaration should refer to whether they hold 25% or more of the capital of another entity and whether they are directly involved in the management or control of another entity, or whether their spouses or relatives or relatives by marriage up to and including grade 2 have a direct or indirect share in management control, or are employed in another entity and perform control or management duties there).</p> <p>Property relations: the obligation to inform about changes in this area along with the sharing of source documents such as notarial deeds, contracts, etc.</p>	MF
2.	Description of the subject and scope of activities conducted by the group	<ol style="list-style-type: none"> <li>1) Description of the most important factors determining the competitive advantage and development opportunities of the group,</li> <li>2) Description or diagram of the value chain for the five most revenue-oriented groups of products or services and such groups of products or services whose revenues account for more than 5% of the consolidated revenues of the group, together with an indication of the main geographical markets for these groups of products or services,</li> <li>3) Specification and description of material agreements or agreements concluded between related parties of the group in the scope of services other than research and development services, including in particular a description of the ability of major service providers to provide significant intra-group services, and information on the group's transfer pricing policy with regard to the allocation of costs of intra-group services and the principles of setting prices for these services,</li> <li>4) A concise verbal description of the functional analysis showing the significant participation of related parties in value creation within the group, including the significant functions performed by these related entities, the material risks incurred by them and the significant assets involved.</li> </ol>	MF
3.	Guidelines on transfer pricing calculation and verification methods	Rules for the application of the 5 possible transfer pricing methods according to OECD regulations: comparable uncontrolled price method (CUP), resale price method (RP), cost plus method (CP), profit split method (PS), transactional net margin method (TNMM). Guidelines on the application of methods to particular types of transactions. Rules for the use of so-called "other methods".	LF, TPR
4.	Rules for benchmarking and compliance analysis	Defining the scope of comparative and transaction-specific compliance analyses, including whether the analyses are carried out internally or externally with third parties. Determining the frequency of analysis preparation, responsible entities, conditions for submitting the analyses to the other party to the transaction, deadlines and rules for providing result parameters (margins, mark-ups) in the MNE.	LF, TPR

Cont. table 4.

5.	Guidelines on significant intangible assets of the group	<ol style="list-style-type: none"> <li>1) Description of the group's strategy in the field of creation, development, ownership and use of intangible assets, together with information on the location of significant research and development centres and the location of centres managing research and development functions,</li> <li>2) Rules and deadlines for preparing a list of intangible assets or groups of such material from the point of view of transfer pricing, together with an indication of the entities holding the legal titles to these assets,</li> <li>3) Rules and deadlines for drawing up a list of material agreements or agreements concluded between related parties of the group concerning intangible assets, including cost sharing agreements, research and development agreements and license agreements,</li> <li>4) Description of the group's transfer pricing policy in the field of research and development activities and intangible assets,</li> <li>5) The terms and deadlines for obtaining general information, and a description of significant changes in the control, ownership and use of intangible assets, including an indication of the entities involved, their registered office or place of management, and the remuneration or compensation paid for these changes.</li> </ol>	MF, TPR
6.	Guidelines for financial transactions of the group	<ol style="list-style-type: none"> <li>1. General description of the method of financing the group's operations, including the rules and deadlines for obtaining information on material financing agreements concluded with unrelated entities,</li> <li>2. Indication of entities performing central financing functions within the capital group and their registered office and place of actual management,</li> <li>3. Description of transfer pricing policy regarding financing between related parties.</li> </ol>	MF, TPR
7.	Principles of transfer pricing documentation	<p>LF: Indication of which party to the transaction is responsible for creating transfer pricing documentation and preparing a comparative analysis, e.g. the seller or both parties; defining the rules for identifying the obligation to document the transaction; determining the deadlines for preparing documentation and providing information in the group.</p>	LF
		<p>MF: indication of which entity is responsible for preparing the MF, indication of obligations and deadlines for providing information for MF by companies in the group.</p>	MF
8.	Principles of transfer pricing reporting	<p>TPR and other reports required by tax administrations other than Poland (<a href="https://www.oecd.org/tax/transfer-pricing/transfer-pricing-country-profiles.htm">https://www.oecd.org/tax/transfer-pricing/transfer-pricing-country-profiles.htm</a>): Defining the rules and duties of related entities in reporting transactions in TPR. Specifying the rules for reporting specific transactions common to the entire group, e.g. cash pooling, loan. Setting deadlines for intra-group arrangements CBCR: indication of obligations and deadlines in the field of reporting to the tax administration, and regarding the transfer of information to CBC by companies in the group such as: size of business (size of assets, capital company income, number of employees), amount of realized revenues, profits (or losses), tax paid (and due).</p>	TPR, CBRC
8.	Rules for applying transfer pricing adjustments	<p>Presentation of the principles of making transfer pricing adjustments in the group, including the tax consequences of such adjustments.</p>	LF, MF, TPR

Cont. table 4.

9.	Guidelines on exemptions from documentation, benchmarking and reporting	Defining consistent rules for the application of exemptions from documentation, comparability and reporting analyses and obligations to provide information on this subject within the group. Presentation of rules for identifying and informing about the provision of low value-added services and loans that may be exempt from comparative analyses under so-called safe harbours.	LF, MF, TPR
10.	Relations with accounting system, budgeting and controlling systems, financial reporting and auditing procedures	1) Defining the requirements for the accounting system and budgeting and controlling systems in the scope of recording, settlement and reporting of transactions for the purposes of transfer pricing, e.g. in relation to obtaining information on the value of transactions with related parties, costs and results related to a given transaction. 2) Defining the rules for posting and submitting information about related parties in financial reports and auditing reports. 3) Defining the responsibilities, principles and deadlines for budgeting and reporting transactions with related parties in the context of achieving financial objectives.	LF, MF, TPR, financial reports, integrated reports, management accounting reports, CBC reports
11.	Restructuring guidelines	Presentation of the principles and deadlines for informing about significant restructuring transactions and transactions related to ownership changes, including acquisitions, mergers and liquidations, carried out in the reporting financial year of the capital group.	LF, MF, TPR
12.	Advanced Pricing Arrangement Guidelines	Presentation of the rules concerning responsible entities, deadlines and method of financing costs in case of a desire to conclude a prior pricing agreement, inclusion of rules for reporting on concluded advance pricing agreements.	LF, MF, TPR
13.	Cost Contribution Agreement Guidelines	Presentation of the rules regarding responsible entities, deadlines and methods of covering and settling costs if entities wish to conclude a Cost Contribution Agreement.	LF, MF, TPR
14.	Guidelines in case of transfer pricing audits and tax disputes	Presentation of the principles relating to responsible persons, and the principles for sharing information, obtaining corporate permissions and maintaining confidentiality in the case of the need to transfer information.	LF, MF, TPR
15.	Compliance with global changes affecting transfer pricing policy	Presentation of obligations and competences regarding the need to monitor regulations that may affect the transfer pricing policy in the group.	LF, MF, TPR

\* (LF – Local File, MF – Master File, TPR – Transfer Pricing Report, CBCR – Country-by-Country Reporting).

Source: own elaboration based on Act on CIT, OECD Guidelines 2022, Act on APA, Regulation of MF (2019, 2022, 2023).

In order to apply the above model, the following assumptions and comments should be taken into account:

- 1) The model transfer pricing policy assumes consistent consideration of the requirements of accounting regulations and tax regulations, as well as the strategic conditions of the group's management.
- 2) The level of detail of the transfer pricing policy content may vary depending on the complexity of the group concerned, the strategy used, the level of centralisation, and the autonomy and functional profile of subsidiaries. This applies in particular to transfer pricing methods and the indication of specific parameters, e.g. margins or mark-



ups applied. In a centralized group, the values of such parameters may be directly determined in the policy, while in decentralized groups, the transfer pricing policy will contain general guidelines. Similarly, as regards point 10 concerning relations with budgeting and controlling systems, due to the impact of transfer pricing on the results of individual subsidiaries and parent companies, the transfer pricing policy should specify the principles of budgeting and the measurement of achievements in transactions with related parties if the transfer pricing area is to be included in the strategic management of the capital group.

- 3) The transfer pricing policy model may be applied to groups of entities, but it can also serve as a model for creating a transfer pricing policy for a single entity, e.g. a company with its registered office in Poland, whose parent company has its registered office outside OECD countries and/or is not obliged to prepare a master file.
- 4) The model can be used by entities in OECD countries. The part of the proposed model concerning reporting obligations by the tax administration is optional for entities established in countries other than Poland due to the specificity of the transfer pricing information reporting system in the country of residence of the parent company.
- 5) For the correct implementation of the model, it is advisable to appoint a unit within the parent company (or other company, e.g. an accounting centre) to supervise the transfer pricing policy, e.g. the transfer pricing department, compliance department or governance department. Taking into account the importance of individual subsidiaries in MNEs, it is also advisable to appoint a team consisting of representatives of subsidiaries responsible for transfer pricing issues, which is delegated to create a transfer pricing policy, its updating and implementation. The transfer pricing policy in the group should be the result of agreements and compromise between individual companies in the group.
- 6) The agreed transfer pricing policy in the group should be implemented by resolution of the Management Board of the parent company, as well as resolutions of the Management Boards of individual companies in the group.

## 5. Discussion and conclusion

To sum up, from a tax point of view, the arm's length principle requires multinational companies to treat different legal entities in the same way as independent companies maximising profits, but the conditions affecting the management of such groups are very diverse. In addition, the complexity of legal regulations in the field of transfer pricing, their variability and the possibility of various interpretations are very high. The development of a formalized transfer pricing policy in accordance with the model presented by the author can be an extremely important tool for MNEs for many reasons. It allows the tax risk associated

with improper conduct of settlements to be minimised by implementing a consistent transfer pricing compliance system and maintaining consistent calculation methods and uniform interpretations for the entire group. The benefits of implementing a transfer pricing policy model can be multifaceted. Firstly, entrepreneurs can avoid costly disputes with tax authorities during possible inspections, which often involve the need to prove that transactions between related entities were carried out on market terms. In addition, a transfer pricing policy helps to optimize the tax structure of the capital group and to minimize the risk associated with changes in tax regulations. The implementation of these objectives is consistent with the objectives of transfer pricing management described in the literature (Chan, Lo, Mo, 2015; Blouin, Robinson, Seidman, 2017; Brychta et al., 2020; Karen, Cravens, 1997; Luca, Ciocanea, Pitu, 2019).

Protecting MNEs from potential tax consequences is not the only benefit of implementing the proposed transfer pricing policy model, as it can also ensure transparency in transactions between related entities for all those involved. The implementation of a transfer pricing policy that takes into account the objectives of both parent companies and subsidiaries can be a significant added value for these entities, contributing to an improvement in their relations, autonomy, decentralization and stability, and an increase in operational efficiency. These benefits are consistent with the postulates raised in the literature regarding the management of subsidiaries (Ghoshal, Bartlett, 1988; Jakobsen, Rusten, 2013; Birkinshaw, Hood, 1998; Borini, Fleury, M.T.L, Fleury, A., 2009).

The development of formalized procedures, rules and guidelines applicable within the group allows the transparency of settlements between individual entities to be ensured, taking into account the value chains operating in the group and their impact on the relations functioning between the entities. A transfer pricing policy also allows the circulation of documents within the group to be systematised, as well as improving communication, increasing awareness of the importance of the transfer pricing problem in the group, and increasing knowledge about transfer pricing.

In the context of the strategic management of capital groups, the proposed transfer pricing policy will constitute an individually defined model for the transfer of benefits between related parties, which will result in the achievement of the group's objectives. A formalized transfer pricing policy that takes into account the planned functions of related parties (as centres of profit, revenue, costs and investments) may be a tool for managing the group's effectiveness. Covering the entire activity of MNEs based on a system of related entities, it can be used for operational and tax optimization of separate group responsibility centres.

The main limitation of the proposed model is that there is as yet no validation, but the author's intention is to test the model as part of surveys addressed to managers of parent companies and subsidiaries, as well as to members of the Transfer Pricing Centre Association in Poland, which brings together experts in this field. The proposed transfer pricing policy model may be subject to further research development. An example direction of analysis may be the assessment of the application of transfer pricing policy in MNEs and examining its impact on the financial results of entities in the group and tax burdens

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## SIGNIFICANCE OF DIGITAL INNOVATIONS OF INDUSTRY 4.0. FOR POLISH ENTERPRISES ON THE EXAMPLE OF PODKARPACKIE AND LUBUSKIE VOIVODESHIPS

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**Purpose:** The article examines the relevance of specific Industry 4.0 (I4.0) solutions for enterprises in Poland. It also verifies whether there is a positive relationship between the level of digital sophistication of enterprises and their innovation and competitiveness, and whether there is a need to cooperate with external entities in the implementation of these technologies.

**Design:** A survey of 673 enterprises in Podkarpackie Voivodeship and a qualitative survey of 23 experts from Lubuskie Voivodeship were conducted. Data from the quantitative survey were analyzed using the tetrachoric correlation coefficient, the statistical significance test for differences in shares, and logit regression. An Internet query was also conducted.

**Findings:** The research shows that the most complex solutions are still relatively the least implemented. More companies have advanced software than I4.0 solutions. Digital sophistication is higher for medium and large entities, companies with foreign participation, those with a presence in foreign markets, as well as those belonging to the region's strategic innovation industries and companies in the market services sector. The share of entities expecting to increase profits and revenues, as well as R&D expenditures and increase innovation was significantly higher among digitally advanced entities. It was confirmed that implementing digital innovations requires cooperation with external partners. Digital solutions are key to innovative industries in Lubuskie, and public support for digital transformation of businesses is present.

**Research limitations:** The main limitation is the lack of overall domestic survey data.

**Practical implications:** The presence of relevant organizations supporting the successful implementation of I4.0 technologies is needed. They provide expertise for companies. Companies can become more competitive and sustainable by implementing IT solutions. However, dissemination of knowledge about the benefits of I4.0 technologies is required, as well as public support for digital transformation.

**Social implications:** In the face of shrinking labor resources, automation and robotization, with fewer workers, will allow production to be maintained at current levels.

**Originality:** The originality of the article lies in the analysis of the level of digitization versus the innovation and competitiveness of companies, and the analysis of the importance of various external partners for the implementation of I4.0 technologies.

**Keywords:** Industry 4.0 technologies, Enterprises, IT solutions, Podkarpackie Voivodeship, Lubuskie Voivodeship.

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

## 1. Introduction

Industry 4.0 is a manufacturing concept that includes industrial automation and modern digital solutions to improve working conditions and increase productivity and quality in industry (Milošević et al., 2020). In Industry 4.0, companies are shifting from mass production to mass personalization, allowing customers to customize the final product to their individual taste, choosing from a range of options (Weiking, 2020). In the era of Industry 4.0, digitization encompasses a wide range of data operations, automation, digital interface, and connectivity (Abdelkader et al., 2016, Sehlin et al., 2019).

Industrial change is being driven by global competition and the need to digitize to remain competitive. Urbanization and a growing middle class in developing countries are also driving demand for niche industrial products. The demands of sustainability and reducing resource waste and pollution are also driving the development of new digital technologies (EFFRA, 2013).

Companies are using the Internet to gather information and increase customer engagement. Increasingly, they are offering "products as services," for example, with special features tailored to the needs of individual customers. In addition, the potential of smartphones and remote working technologies are increasing the mobility of employees and managers. Real-time connectivity, through sensors, automation controllers and embedded systems, enables seamless and bidirectional interaction with objects and systems on a global scale in the form of the Internet of Things. The competitiveness and innovation of companies increasingly depend on the ability to analyze large amounts of data from business processes, products, and systems in real time.

In the Industry 4.0 paradigm, automation supports human labor not only in production, logistics and data collection, but also in business management. In the era of Industry 4.0, people do not need to operate physical systems and can control them using digital systems (Mentsiev et al., 2020). Unlike the concept of Computer Integrated Manufacturing, which aimed to create fully automated factories without people, Industry 4.0 seeks to effectively apply technology to assist and collaborate with people (Rauch et al., 2020).

The fourth revolution is linked to the large-scale introduction into use of new information technology (IT), mobile technology, machine learning and artificial intelligence (Walentyńowicz, 2020). It is characterized by widespread access to the Internet, a decrease in the cost of digital storage, portable devices, smart sensors, the use of renewable energy sources



and artificial intelligence. The fourth revolution is characterized by autonomous vehicles, advanced robots like robots cooperating with humans in manufacturing plants, caring for the elderly or cleaning, the use of scanners and 3D printing, new smart materials like self-cleaning clothes and other (Furmanek, 2013; Bongonomin et al., 2019; Sycz, 2023). While the fourth industrial revolution focused on using technology to optimize the means of production, the fifth is about the combination of man and machine. Industry 5.0 considers human brainpower, creativity, and fault tolerance capabilities. It combines human abilities with system abilities which embraces skilling, up-skilling, and re-skilling of workers. Human needs and interests, health and well-being are central for the industry (Wang et al., 2024). In addition, Industry 5.0 emphasizes clean industrial technologies that promote sustainability and conserve natural resources (Ruiz-de-la-Torre et al., 2023).

Digital innovations originating from industry also result in the implementation of innovations in the sphere of operation of public and social organizations, manifested, for example, in renewable energy installations supported by digital systems, clean air sensors, intelligent traffic management system, electronic document circulation, online portals for public consultations, monitoring (cameras in public spaces), lighting sensors, parking space information based on sensor data, mobile applications for parking space payment, urban bicycle systems, etc. using digital management systems, carsharing, virtual city/municipality/museum guides based on sensors, electronic management systems, self-driving vehicles, smart homes, e-government, telemedicine, and many others (UMWL, 2022).

The objective of the article is to test the relevance of solutions related to Industry 4.0 for enterprises in Poland using the example of entities from the Podkarpackie and Lubuskie provinces. For this purpose, a survey was conducted on a representative sample of 673 enterprises of the Podkarpackie Voivodeship in the second half of 2020 and a qualitative study based on a Delphi survey of 23 experts from entities related to innovative key industries - areas of smart specialization of the Lubuskie Voivodeship in the autumn of 2021. In addition, the article sets quantitatively verified hypotheses:

- H1. There is a positive relationship between the level of digital sophistication of enterprises and their innovation and competitiveness,
- H2. Implementing digital innovation requires combining different sources of knowledge, that is working with external partners.

Data collected in the direct quantitative survey in the Podkarpackie province were analyzed using statistical and econometric methods, that is correlation analysis, frequency tables and test for statistical significance of differences in shares, and logit regression. Direct qualitative research data from the Lubuskie Voivodeship from 2021 was supplemented with a web query of further activities of the entities of this voivodeship for the implementation of Industry 4.0 solutions.

The following sections of the article include a review of the literature related to the characteristics of digital innovations related to Industry 4.0 and 5.0, presentation of research methods, research results, and conclusions and discussion.

## **2. Digital innovations related to Industry 4.0 and 5.0**

Digital technologies associated with Industry 4.0. and 5.0. include Big Data analytics, cloud computing, the Internet of Things, robotization of processes, artificial intelligence, blockchain, augmented and virtual reality, digital twins of plants and people, autonomous vehicles, 3D printing, nanotechnology, sensors, cybersecurity, blockchain, cyber-physical systems, or green IT (Delloite, 2020; Seager et al., 2020).

With Big Data analytics, the collected data, which is nowadays available in huge volumes, is subject to analysis and, as a result, becomes information for decision-making. However, digital security solutions are also becoming necessary to secure this flow of information (da Silva et al., 2020). Cloud computing is the ability to use shared ICT resources made available over the Internet. It implies the use of Infrastructure as a Service (IaaS), Software as a Service (SaaS), and Platform as a Service (PaaS) (Ocicka, 2017).

Digital innovations also include efforts for direct machine-to-machine and business-to-business communication and the broader Internet of Things (IoT). The Internet of Things is the incorporation of objects into a network that acquire, collect, and process data, and are therefore smart. The Internet of Things works through sensors that enable machines to communicate with each other. Automatic identification technology, such as radio frequency identification (RFID) and beacons, works similarly (Han et al., 2020). Fog computing bridges the gap between remote data resources available through the cloud and IoT devices that generate large amounts of data for real-time processing (Anderson, 2013; Nowicka, Szymczak, 2020).

The Internet of Services, on the other hand, reflects services and their functionality, according to new business models, provided by different providers, available for use on demand, with the possibility of mutual integration (Furmanek, 2018).

Industry 4.0 technologies also include virtual and augmented reality and digital simulations in, among other things, product design using a digital twin, as well as in other enterprise systems. With virtual reality (VR), users are transported, usually using a set of headsets and glasses, into a virtual world. In augmented reality (AR), applications show the illusion of layers of graphical information superimposed over a certain portion of the user's field of view. The combination of the two technologies is mixed reality (Bongomin et al., 2020).

Digital twins are dynamic copies of real objects. They make it possible to make corrections in the functioning of machines and devices connected to the network. Digital twins supported by blockchain technology make it possible to track the flow of finished goods in a distribution

system and to design their flow in such a way as to avoid risks (Nowicka, Szymczak, 2020; Bongomin et al., 2020, Piróg et al., 2021).

The use of new technologies in logistics also includes digitally controlled warehouses, robotic and autonomous transport devices (AGVs), mobile, voice and visual systems to assist in picking parts, geolocation, RFID chips (Walentynowicz, 2020). Industries using Cyber-Physical Production Systems (CPS), arising from sensors and identification technologies, are more flexible. This is due to IT's support for the operation of networks of different organizations and networks within organizations, reconfigurable and modular systems, and good communication between manufacturers and customers (Beier et al., 2020).

Additive manufacturing, like using 3D printers, makes it possible to develop high-standard complex products in small batches, in decentralized plants. This enables highly customized production at an acceptable cost because excellent connectivity between machines and people reduces work-in-progress inventories (di Nardo, 2020).

Industry 4.0 also means extensive use of artificial intelligence, and therefore robots. In the era of Industry 4.0, autonomous robots can work alongside humans and in dangerous places for humans. They can often reduce human mistakes. Robots will reduce manual labor and enable improved ergonomics. All routine tasks will be performed by machines. The robot coordinator will perform both routine and emergency maintenance and repair tasks, and will involve other experts as needed. For example, some work on assembly lines requires lifting heavy parts. Robotizing them allows the worker to do the work in an easier and more ergonomic way and prevents errors and accidents (Weiking, 2020; Beier et al., 2020).

Automated vehicle systems are becoming an integral part of manufacturing systems. These are unmanned vehicles used to move materials along specific routes - so-called AGV technology (Bednarz, Popiel, 2018). The self-driving vehicle system is connected via mobile technologies, and communication between the machine and workers occurs through easy interfaces. Information circulates throughout the system, so each vehicle knows the status of itself and others, so that an order is assigned to a vehicle that will complete it more efficiently. Drones, on the other hand, are unmanned aircraft and therefore flying robots (di Nardo et al., 2020).

The primary challenge associated with Industry 4.0 relates to data security and privacy (Mantsiev et al., 2020; Ingaldi, Ulewicz, 2020). Data and information shared as part of Industry 4.0 solutions must be protected by cybersecurity solutions. Their loss, alteration or theft threatens the misuse of machines, resulting in a loss of customer confidence, production interruptions or loss of intellectual property (ENISA, 2019).

Blockchain enables cyber-security through identity proofing. The technology is an electronic list that chronologically records transactions between users. Each transaction is recorded as a block with data about its value and the time of its conclusion. This block is attached to the previous ones and together they form a chain. The technology stores data in multiple locations rather than in one central repository, which increases security. Blockchain in

industry can be used, for example, to validate products in the supply chain or verify payments (Rot, Zygala, 2018).

Digital transformation in the coming years will also support the conservation of natural resources, which is important within the Industry 5.0 paradigm. Green ICT refers to the reduction of infrastructure energy use using IT systems, resulting in a reduction of CO<sub>2</sub> emissions and the cost of operating companies (Bokolo, 2020; Abraham, Dao, 2019). Green IT systems support sustainable business operations. They include environmental management systems and green supply chain management systems. A green IT system involves the use of real-time data to reduce the environmental impact of business operations. Green manufacturing should include only energy-efficient equipment, connecting voltage stabilizers to servers and other computer equipment. Green distribution is environmentally friendly delivery strategies by introducing more efficient operations and increasing the reuse of ICT infrastructure. Green procurement is the acquisition of electronic products with green labels. For green sourcing, companies can also use environmentally friendly purchasing practices that include reducing purchases, buying recycled ICT infrastructure. Green sourcing means reducing the use of energy to power and cool ICT infrastructure, by improving the energy efficiency of data centers. Replacing or getting rid of ICT infrastructure should involve eco-friendly disposal and recycling, which reduces handling costs associated with disposing of ICT-generated waste in landfills. Old ICT equipment can continue to be useful and can be refurbished and restored for use in other enterprises (Abraham, Dao, 2019).

Industry 5.0 is human centered. In comparison with automation, humans create unique values in the manufacturing system like creativity, decision-making ability, or cognition. Human workers achieve higher productivity thanks to automation. Human Digital Twins (HDTs) are digital representations of humans. This technology may harmonize humans and smart devices by usage of real-time sensing, analysis, and automated feedback. Thanks to HDTs, humans' natural senses and cognitive abilities are integrated into the smart manufacturing system (Wand et al., 2024).

Another trend within the industry of the future is the development of predictive analytics for remote machine maintenance. Predictive analytics allows manufacturers to monitor equipment performance using any number of performance indicators and automate the data collection process using IoT technology. In addition, IoT systems monitor who is entering facilities and what people or equipment employees are interacting with, which promotes safety in the workplace (Bogges, 2023).

### 3. Methods and data

In July-August 2020, a survey of a representative with respect to the industry, size, and territorial structure of a sample of enterprises in the Podkarpackie Voivodeship was conducted to assess the level of implementation of modern IT solutions in the form of technologies related to Industry 4.0 and various types of modern software. The territorial scope of the survey was defined by the survey's funder, the Marshal's Office of Podkarpackie (Piróg et al., 2021; Sycz, 2023). The survey was conducted during the COVID pandemic, which increased the use of IT tools, especially remote working solutions. The survey covered 673 companies. The survey consisted of telephone- and/or computer-assisted interviews, depending on the respondent's preference.

The results of the study were presented in the form of dichotomous variables, where 1 meant the presence of a trait and 0 meant the absence of a trait. Due to this form of data, the tetrachoric correlation index for dichotomous variables was used for the analysis (Ekström, 2011). In addition, contingency tables were drawn up showing the co-occurrence of two characteristics, that is the intensity of use of digital innovations and variables reflecting the development prospects of companies. This made it possible to calculate the share of entities, like those showing a profit, in populations of entities that have not implemented digital solutions and those with different levels of implementation intensity. This was followed by a statistical analysis of the significance of differences in proportions between groups depending on the percentage and size of the population in question (Szymczak, 2010). In addition, a model was estimated using logit regression to assess which characteristics of the surveyed entities (company size, foreign share, export activity, industry specifics) increase the chances of high sophistication in terms of implementations of Industry 4.0 and modern software solutions. An odds ratio was also calculated to determine how much more likely it is that an entity with a given characteristic stands out in terms of high intensity of implementations of Industry 4.0 and modern software technologies (more than 9 IT solutions).

Logit regression is a type of multivariate nonlinear regression with a binary dependent variable, that is, it can take only two values "0" or "1" (like the  $i$ -th respondent of the survey has implemented more than 9 digital innovations ( $y_i = 1$ ), and another has not ( $y_i = 0$ )).

Logit regressions are used to determine the probability that the explanatory variable will take the value of 1 or that it will take the value of 0 given the parameters and values of the explanatory variables, which should also, but need not, be expressed in binary terms:

$$\text{Prob}(Y = 1) = F(\beta'x) \quad (1)$$

$$\text{Prob}(Y = 0) = 1 - F(\beta'X) \quad (2)$$

The set of structural parameters ( $\beta$ ) reflects the effect of changes in the explanatory ( $X$ ) variables (independent; causes and stimulants) on the explanatory (dependent; effect) variable ( $Y$ ) (Greene, 2003).

In addition, in the second half of 2021, a Delphi survey was conducted among experts from companies and institutions/consulting firms in the smart specialization areas of Lubuskie Province. Lubuskie province's smart specialization areas are green economy, health and quality of life, and innovative industry. Part of the survey focused on future technologies, according to experts, for their industries. The survey consisted of sending the questionnaire to experts three times. In the second round, the experts' average responses were presented, and they were asked to respond to the most common responses and accept or not. Most of the experts agreed with the consensus answers in the second round, some were sent answers for a third time and, if not accepted, they submitted dissenting opinions. Twenty-three experts responded to the survey. Two responses each were from medical technology, the agri-food and bio-economy sector, tourism and recreation, and the automotive industry. Four each were from the metal and energy industries, while seven were from the ICT (information technology and computer industry) and R&D and technical expertise sectors. The survey was conducted as part of the preparation of a diagnosis for the Innovation Development Program of Lubuskie Voivodeship by 2030 (UMWL, 2022).

### **3.1. Research in the Subcarpathian Voivodeship**

The most common Industry 4.0-related solutions used by Podkarpackie enterprises included remote work technologies in 2020, which was intensified by the pandemic (about 40 percent). One in three industrial enterprises had customized manufacturing technologies, and 7 percent planned to implement them. About 30 percent of entities had mesh networks, and 6.4 percent planned to implement them. Big Data or cloud computing, providing services remotely and geolocation, as well as self-controlling components of manufacturing systems were used by about one in five entities, and about 8 percent each planned to implement them, in addition to geolocation, which less than 4 percent of companies planned to implement. About 14% of entities had sensors and RFID systems as well as automated remote communication with business partners.

Blockchain, 3D printing or nanotechnologies, Internet of things, virtual or augmented reality (VR/AR), drones were used by less than 10% and more than 5% of respondents. The least popular were the most comprehensive solutions that is: collaborative robots (co-bots), artificial intelligence as chat bots, digital twin of a customer and/or plant, digitally controlled warehouses, autonomous vehicles, and exoskeletons. However, some companies were planning to introduce them. Continuously, therefore, many entities are not using many digital innovations, demonstrating the need for digital transformation. According to a Eurostat survey, 28% of large companies in Poland had robots in 2020-2021, and this was quite high in the EU, at the level of Denmark, Austria, and Slovakia, with Slovenia's highest score at 40% and Cyprus' lowest at 3%. Big data was used by 16% of large companies, an average low score for European countries (ranging from 9% in Lithuania to 36% in Belgium). Artificial intelligence (AI) and 3D printing were used by 17% of large companies each, which is average and average

low in the EU, respectively. Internet of things and cloud computing were used by 51% and 70% of large Polish enterprises each, respectively, similarly average compared to other countries. However, the rates for small and medium-sized enterprises are much lower, at 2% for Big Data analytics and artificial intelligence, which especially for AI is low in the EU, 3% for 3D printing (low level in the EU), 5% for robots (average level in the EU), 27% for cloud computing (average level) and 18% for Internet of things (average low level against the EU) (Prokopiuk, 2022).

**Table 1.**

*Shares of firms using specific I 4.0 solutions (n = 673 or n = 128 in the case of solutions for manufacturing)*

<b>I4.0 solutions</b>	<b>We are using (%)</b>	<b>We are not using, but we plan to use (%)</b>
Remote work	37.8	5.7
Customized manufacturing (n = 128)	33.6	7
Mesh networking	29.4	6.4
Big Data or cloud computing	23.5	8.5
Providing services remotely	23	8.2
Geolocation	22.9	3.7
Self-controlling (via software) components of manufacturing systems (n=128)	20.3	7.8
Sensors and RFID systems	14.9	7
Automated remote communication with business partners	13.7	10.3
Blockchain	9.1	6.4
3D printing or nanotechnologies	7.9	6.7
Internet of things	6.6	7.1
Virtual or augmented reality (VR/AR)	6.4	6.5
Drones	5.7	7.9
Collaborative robots (co-bots)	4	4.9
Artificial intelligence E.g. chat bots	3.9	8.6
Digital twin of a customer and/or plant	2.5	3.4
Digitally controlled warehouses	2.4	5.8
Autonomous vehicles (self-driving)	1.3	4.5
Exoskeletons	0.74	3.12

Source: research in Podkarpackie province for Piróg et al. (2021).

In the Podkarpackie region, more entities have advanced software programs than strictly digital solutions related to Industry 4.0. Nearly 45% of entities have introduced electronic document workflows, and another 7.6% plan to implement them. One in four/five companies has software for work control, customer relationship management, knowledge management, or working in virtual teams.

About a dozen percent each of companies have implemented software to manage inventory, supplier relations and infrastructure (Table 2).

**Table 2.***Shares of firms using specific advanced software (n = 672)*

Advanced software	We are using (%)	We are not using, but we plan to use (%)
Electronic documentation workflow	44.5	7.6
Work control software	25.9	8.2
Customer relationship management software	22.9	9.1
Knowledge management software	21.4	7.9
Software for working in virtual teams	19.1	6.7
Inventory management software	17.7	6.6
Supplier relationship management software	16	8.6
Infrastructure management software	14.2	9.2

Source: research in Podkarpackie province for Piróg et al. (2021).

As shown by the logit regression model, the implementation of more than 9 solutions from Industry 4.0 and/or modern software is favored by being a medium and large company, having a foreign share, conducting export activities, as well as belonging to key innovative industries in Podkarpackie, that is smart specializations. In addition, many digital innovations were implemented by companies in the market services sector. Belonging to industry in general, except for industries from smart specializations, was statistically insignificant. The odds ratio showed that the chance that an exporting company implemented more than 9 IT solutions was more than four times higher than for those not exporting. Companies with foreign participation and medium and large companies were more than three times more likely to have been digitally advanced than domestic entities and small and medium-sized companies. The chance that a company was highly digitally advanced was more than twice as high for entities in smart specialization industries than for others, and for companies in the market services sector than for others (Table 3).

**Table 3.***Logit regression for dependent variable: firm that introduced more than 9 IT solutions (of Industry 4.0 or advanced software)*

Independent variable	Coefficient (Std. Error)	Odds ratio (Std. Error)
Constant	-3.565*** (0.316)	0.028 (0.009)
Foreign share	1.167 ** (0.495)	3.213 (1.589)
Export activity	1.483*** (0.292)	4.404 (1.288)
Medium or large company	1.163*** (0.298)	3.201 (0.954)
Smart specialization area	0.807*** (0.305)	2.242 (0.684)
Market services	0.854*** (0.337)	2.350 (0.792)
Industry	0.343 (0.361)	1.409 (0.509)
n	648	
Pseudo R <sup>2</sup>	0.214	

Note. \*\* - statistically significant at p=0.05, \*\*\* - statistically significant at p=0.01, Std. – standard.

Source: own calculations in Stata based on research in Podkarpackie province for Piróg et al. (2021).

The percentage of entities expecting an improvement in financial performance: revenue and profit was higher for entities with any digital solution or advanced software than for those without and was rising for groups of entities with higher intensity of the use of IT solutions (Table 4). There was a significantly higher percentage of entities expecting an increase in R&D



expenditures in the group of companies with IT solutions than without them, and entities with high intensity of the use of IT solutions also stood out particularly here. Thus, modern technologies favor R&D, which in turn increases the chances of implementing solutions that are new to the market. Similarly, significantly more entities expected to implement new products and services among companies with IT solutions than without them. At the same time, greater digital sophistication of companies meant a significantly higher percentage of companies planning to innovate. In the case of R&D+I activities, statistically significant differences were also noted in the share of entities planning to increase R&D expenditures and innovation with higher digital sophistication compared to the total of entities with any IT solution. In the case of financial performance, such a statistically significant difference occurred only in terms of the expectation of profit by more entities with more than 9 IT solutions than those with any IT solution. Digitalization, therefore, particularly enhances the R&D and innovation potential of companies.

**Table 4.**

*Percentage of entities that have implemented a given number of Industry 4.0 solutions expecting to see an increase in performance and R&D+I activities and the statistical significance of differences compared to those without Industry 4.0 solutions and those with any solution (in parentheses)*

Expected growth	Lack of IT solutions (n = 259)	Any solution i4 (n = 414)	More than 5 solutions I4 (n = 84)	More than 9 IT solutions (i4 and advanced IT programs) (n = 90)
profit	0,16	0,25***	0,33***(ns)	0,36***(**)
revenues	0,16	0,26***	0,33***(ns)	0,33***(ns)
R&D expenditures	0,03	0,15***	0,29***(***)	0,3***(***)
introduction of new products and services	0,14	0,31***	0,49***(***)	0,52***(***)

Note. \*\*\* - statistically significant at  $p=0.01$ , ns - statistically not significant.

Source: own calculations in Stata based on research in Podkarpackie province for Piróg et al. (2021).

Companies that implemented differentiated IT solutions often collaborated with various external entities for this purpose, confirming the importance of reinforcing knowledge from the innovation system for technological upgrading. The highest correlation rates were for cooperation with business support organizations, scientific institutions, non-academic experts and, in the case of Industry 4.0-only solutions, with business customers. However, also in the case of cooperation with the other type of partners like consulting firms, cluster partners and suppliers such positive correlation with IT solution implementations occurred. The least important was cooperation with public administration, such as applying for a grant, but there was also a positive correlation coefficient for IT solutions. At the same time, there was a negative correlation regarding IT solution implementations and the situation of lack of any cooperation in this implementation, that is stand-alone implementation. This also means that

specialized skills are needed, which companies do not have internally, to implement advanced IT solutions successfully.

Respondents noted the positive effects of implementing at least 5 IT solutions. Particularly high positive correlation coefficients were for implementations of differentiated solutions and reduction of mistakes and errors, increase in the flexibility of production and its adjustment to current demand ("pull" system), increase in the customization of production and increase in innovativeness and revenues, as well as entering new markets (through product/service differentiation, export). This means that the implementation of several IT solutions improves operations within the organization and allows for better customization, stimulates innovation, and thus increases the competitiveness of companies, as manifested, for example, by entering new markets and increasing revenues.

**Table 5.**  
*Statistically significant tetrachoric correlation coefficients*

Variables	Firms with:		
	over 5 I4.0 solutions	over 5 IT solutions	over 9 IT solutions
Cooperation during implementation of the solutions with:			
Business support organizations	0.407***	0.589***	0.551***
Public administration	ns	0.232**	ns
Scientific institutions	0.582***	0.428***	0.522***
Consulting firms	0.365***	0.328***	0.425***
Suppliers	0.428***	0.344***	0.383***
Cluster partners	0.324**	0.405***	0.402***
Business customers	0.511***	0.370***	0.482***
Experts not from science	0.609***	0.624***	0.538***
Implementation without cooperation	-0.373***	-0.314***	-0.393***
Effects of implementation of the solutions:			
Reduction of mistakes and errors	0.400***	0.500***	0.439***
Reduction of waste of materials, energy, time	0.360***	0.363***	0.468***
Reduction of operating costs	ns	0.190**	0.238***
Increase in work safety	0.215**	0.336***	0.369***
Increase in innovativeness	0.519***	0.521***	0.552***
Increase in the required qualifications of employees	0.398***	0.380***	0.353***
Increase in revenues	0.458***	0.439***	0.463***
Increase in the flexibility of production and its adjustment to current demand ("pull" system)	ns	0.498***	0.476***
Increase in the Customization of Production	0.499***	0.455***	0.587***
Entering new markets (through product/service differentiation, export)	0.409***	0.442***	0.474***

Note. \*\* - statistically significant at p=0.05, \*\*\* - statistically significant at p=0.01.

Source: own calculations in Stata based on research in Podkarpackie province for Piróg et al. (2021)

### 3.2. Research in Lubuskie province

In the Delphi survey, experts from key industries in the Lubuskie region were asked, among other things, about the direction of technological development in their industries. The answers

obtained indicate the crucial importance of IT solutions and digital innovations as the future direction of development of these industries.

Experts from all industries considered the following to be very important and quite important in the next 3 years: design of new products using new technologies (like ICT), development and improvement of existing products/services, digital innovations and/or their implementation in the industry, and new forms of product promotion and marketing. Experts also identified the most important specific new technologies/research areas that will be important in their industries in the next 3 years. Digital innovations and IT solutions will be important especially in metal, ICT, medical technologies and services, and specific solutions in this area were indicated by representatives of the automotive and tourism industries. These specific key IT solutions to be researched and implemented in Lubuskie industries are: design of new products using new technologies, development of algorithms for comprehensive patient care, IT booking techniques and tourist information; robotics, automation, Big Data, Internet of things, cyber security, augmented reality, additive printing, optometry, electromobility, blockchain, acceleration of data exchange (5G, 6G), automation of even more services previously handled by humans (autonomous cars), security issues related to digitization of electronic communication processes, solutions for confirming and securing identity (like in e-services, in tools for data circulation, or in electronic communications); solutions for realizing as many processes as possible in electronic form, including ensuring accessibility for as many services as possible: offices, medical institutions, etc. in digital form; use of artificial intelligence for, among other things, monitoring of water supply networks.

As part of the competition announced by the Office of the Marshal of the Lubuskie Voivodeship for Key Areas within the framework of smart specializations in September 2022, partnerships were selected that include the development and implementation of digital innovations, that is: Lubuskie Center for Digital Medical Technologies, Industry4Future<sup>1</sup>, Innovative Industry - Sub-area: Industry 4.0 - Smart Factory 4.0<sup>2</sup>, Smart City and IoT - smart management of resources in the economy, as well as Transport, Logistics and Autonomous Vehicles<sup>3</sup>. In addition, partnerships have been selected for space technologies that can support the development of new solutions in industry, as well as the Green Transformation partnership, which is now also supported by IT solutions. The partnerships include not only companies, but also research and development units, or pro-innovation institutions and social organizations. On September 28, 2023, selected partnerships signed Key Area Development Agreements within the Lubuskie Smart Specialization<sup>4</sup>. The example of the Lubuskie Voivodeship demonstrates the crucial importance of Industry 4.0 digital solutions for innovative industries

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<sup>1</sup> <https://innowacje.lubuskie.pl/inteligentne-specjalizacje/partnerstwa/Industry4Future>, 28.09.23.

<sup>2</sup> <https://www.lubuskiklaster.pl/partnerstwo-smart-factory-4-0-wyniki-konkursu/>, 28.09.23;  
<https://www.lubuskiklaster.pl/partnerstwo-smart-factory-4-0/>, 30.09.23.

<sup>3</sup> <https://lubuskie.pl/wiadomosci/19297/wybrano-partnerstwa-w-ramach-lubuskich-inteligentnych-specjaliza>, 30.09.23.

<sup>4</sup> <https://lubuskie.pl/wiadomosci/21242/te-partnerstwa-sa-kluczowe-dla-rozwoju-lubuskiego>, 30.09.23.

and the efforts being made by various regional agents to transform the digital economy, as well as the public support occurring for this transformation.

#### **4. Conclusions and discussion**

Solutions related to Industry 4.0 are being implemented by companies in Poland, and the role of these implementations is growing. Research conducted in the Podkarpackie region, showed that still the relatively most complex solutions such as digital twin of a customer and/or plant, digitally controlled warehouses, autonomous vehicles (self-driving), exoskeletons are implemented least often. The most widespread, on the other hand, are remote work, customized manufacturing, mesh networking, Big Data or cloud computing, providing services remotely, geolocation and self-controlling components of manufacturing systems. More companies have advanced software such as Customer Relation Management or Enterprise Resource Planning than Industry 4.0 solutions. Digital sophistication is higher for medium and large entities with foreign participation, presence in foreign markets, and belonging to the region's strategic innovative industries, and market services companies. The share of entities expecting an increase in profit and revenue, as well as R&D expenditures and an increase in innovation was significantly higher among digitally advanced entities. This means that strong equipment with a modern digital solution is positively related to greater innovation and competitiveness of enterprises, which confirmed the first research hypothesis. In addition, it was confirmed that the implementation of digital innovations requires combining different sources of knowledge, like cooperation with external partners. Most often, digitally advanced companies collaborated on the implementation of digital innovations with business support organizations, scientific institutions, and non-academic experts. Hence the presence of suitable supporting organizations for successful implementation of I4.0 technologies is needed. They provide specialized knowledge for companies. An analysis of the correlation coefficients between the high intensity of implementations and the effects of these showed that the implementation of several IT solutions improves operations within the organization and allows for better adaptation to the needs of customers, stimulates innovation, and thus increases the competitiveness of companies, as manifested, for example, by entering new markets and increasing revenues. The example of the Lubuskie Voivodeship demonstrated the crucial importance of Industry 4.0 digital solutions for innovative industries, as well as the existing public support for digital transformation of enterprises.

At the same time, it should be noted that Polish companies are still focusing on Industry 4.0 solutions, although sustainability issues and the use of IT to reduce environmental impact are also noticeable. A recommended direction for further research and implementation in companies is the importance and potential of solutions related to better cooperation between

people and machines for combining the cognitive, decision-making and creative abilities of people with the speed of action and a smaller scale of mistakes, like due to fatigue, of machines. Thanks to broader implementations of Industry 4.0 and 5.0 technologies, Polish companies will be better able to face competition from cheaper manufacturers, like from China - it will be unprofitable to import customized products. They will also increase their competitiveness vis-à-vis European Union companies, which are also intensively implementing new technologies to reduce their costs and provide customized products and services. In addition, by implementing digital innovations, it will be possible to integrate supply chains in the European Union. The use of solutions such as co-robots, exoskeletons or solutions that reduce the negative impact on the environment will make it possible to relocate again to Poland those stages of production in the metal industry, for example, which have been moved out of here due to the lack of people willing to work hard or the environmental pollution caused by processing. The use of IT systems should also promote safety in the workplace through better monitoring. In the face of dwindling labor resources, automation and robotization, with fewer workers focused on creative work and machine control, will keep production at its current level. However, it is important to expand the knowledge of entrepreneurs and their representatives about Industry 4.0 and its solutions, as they are often unaware of the importance and potential of digital innovation<sup>5</sup>.

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<sup>5</sup> Authors' experience from the 2021 workshop with Lubuskie enterprises.

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## KEY SUCCESS FACTORS IN MANAGING DEVELOPMENT PROJECTS

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**Purpose:** The article presents an original model of the structure of a real estate development investment project, based on which 18 key success factors in development activities in Poland were identified. Then, an analysis of these factors was carried out in the context of four different investment projects carried out by the developer. The study is based on the results of the analysis of investment projects in which the author participated from the beginning. Success factors assessed included: location, market analysis, attractiveness of the architectural design, organization of the construction process, quality of workmanship, cooperation with business partners, project management, marketing, sales, risk analysis, financing, team management, meeting administrative requirements, technological innovations, and ecological aspects. The conclusions from this study may be valuable for real estate development companies planning to implement further investment projects.

**Design/methodology/approach:** The main research methods used for the purposes of this article were: participant observation as part of several real estate development projects completed by the author, interviews with stakeholders of individual projects and analysis of available literature sources. The theoretical scope of the thesis includes the subject of project management. The study is based on the results of an analysis of development investment projects in which the author participated as a manager. The identified and defined success factors of development projects were evaluated. On the basis of the assessments and analyses made, conclusions were drawn.

**Findings:** The results of the study show that the success factors of individual projects differed depending on the nature of the project and the developer's experience. All the analysed investment projects were carried out by the same developer, but at different times and in different locations. That is why the developer drew conclusions after the first projects, which resulted in the fact that in subsequent projects he did not make any more previous mistakes. The benefits resulting from the experience gained by the developer allow him to better understand which factors are crucial for the success of subsequent investment projects. In the course of the analysis, it was also proven that the role of a competent project leader plays a key role, as he is able to shape and influence most of the other success factors.

**Research limitations/implications:** The paper did not encounter any limitations in the research process, because the author, being both the investor and the manager of the developer's enterprise in the analyzed projects, had a complete set of information and full insight into all qualitative and quantitative data concerning the analyzed projects. The lack of this information would certainly be a significant limitation for conducting this type of research.

**Practical implications:** The conclusions drawn from this study may be valuable for real estate development companies planning to implement further investment projects. In the course of the research, the structure of the development project was comprehensively systematized, then the most important KCS were indicated and evaluated depending on the project. According to the analyses carried out, achieving high effects of the project is largely dependent on professionalism in the development project management process, which results from the competence of the project leader. The role of continuous improvement in operations, learning through experience and the ability to adapt the strategy of the project to specific conditions was also emphasized.

**Social implications:** The results of the study will have no impact on the societal implications.

**Originality/value:** The article presents the author's model of the structure of a real estate development project. The article is addressed to managers of development companies and persons/development companies planning the implementation of further investment projects. Structured theoretical information can also be useful for management students who are interested in project management and real estate investing.

**Keywords:** real estate development company, development process, investment process, key success factors.

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

## 1. Introduction

In today's world of dynamic and competitive business environment, effective development project management plays a key role in achieving the success of development enterprises. In Polish conditions, a developer is an entrepreneur who, as part of his business activity, comprehensively implements investment projects aimed at increasing the value of real estate (Królikowska-Olczak, 2014).

The real estate development industry, which is an inseparable part of the real estate sector, is dominated in Poland by changes in legal regulations (Osajda, Gliniecki, 2022; Bartoń, Poławski, Łapiński, 2023), changing market trends (Bieńkowski, 2018; Białas, 2021) and the evolution of customer preferences (Gawron, 2012; Home, 2023). Development projects, such as the construction of residential complexes, commercial real estate or urban infrastructure, are highly complex undertakings (Kucharska-Stasiak, 2016; Geltner, Miller, 2007), requiring the integration of diverse processes, resources, and stakeholders (Dydenko, 2015). Their implementation is complicated not only due to technical aspects, but also due to the constantly changing political, economic, social and technological environment (Kania, 2013).

The issue of key success factors in real estate development projects in Poland is not widely discussed. The author notices the lack of studies in this area. Most often, the research concerns project management in general (Kozuch, Sienkiewicz-Małyjurek, 2013; Kalinowski, 2015)

or focus on research areas other than real estate development (Zaleski, Michalski, 2020; Whirlpool, Trykosko, 2011; Lachiewicz, Wojsa, 2014).

Taking into account the above conditions and taking into account the current state of knowledge in this area, the author has set himself the goal of creating an original structure of the development process, identifying the key success factors occurring in the development process and then verifying them on the example of the analysis of four projects completed by the developer. The author's considerations refer to Polish conditions, but they can also be cautiously applied to international markets.

The following research hypotheses are presented in the article. First of all, there is a model of the structure of the development process, which more precisely than other models indicates how to implement this process in order to achieve success. Secondly, there are many factors in the development process that can contribute to the success of development projects. Thirdly, the more key success factors there are in the development process, the better the results will be, with the proviso that this is largely dependent on the professionalism of the leader. The main research methods used for the purposes of this article were: participant observation as part of several development projects carried out by the author, interviews with stakeholders of individual projects and analysis of available literature sources.

## **2. The structure of a development investment project**

Real estate development projects, regardless of their nature - construction of apartments, commercial facilities or infrastructure - are usually much more complex than standard projects in other areas. These challenges result from the need to coordinate many processes, taking into account changing regulations and standards in the real estate industry. In a development project, many processes must be precisely synchronized for the project to be implemented as planned. Delays in one phase can impact the entire project schedule and budget. Coordinating this process is particularly difficult because the developer often does not implement all aspects of the project on its own, and often cooperates with service providers on an outsourcing basis.

Moreover, development activity in Poland is closely related to legal regulations and market conditions. Changes in regulations regarding spatial planning, sustainable development or construction standards can significantly affect schedules, costs and the entire project. An example is the so-called Development Act (Act, May 20, 2021). Additionally, dynamic changes in the real estate market, such as fluctuations in land prices or changing customer preferences, require a flexible approach to designing and investing in this sector of the economy.

The complexity of development projects is also influenced by the fact that they usually involve very diverse stakeholders, such as: investors, clients, public administration offices,

suppliers of materials and services, contractors, and the local community. This forces the developer to effectively and efficiently manage contacts and communication with them and understand their expectations, which can be a serious challenge.

In the context of the development industry, a project is not only the implementation of specific construction or infrastructure tasks. It is a comprehensive process, covering stages from the identification of investment opportunities, through market and risk analyses, planning and construction, to sales and property management. All these stages require in-depth planning, monitoring and cooperation between various units in the organization.

According to the methodological order proposed by the UNIDO organization, a development project can be divided into three phases: preparatory, implementation and operational (Dziworska, Trojanowski, 2007). The preparatory phase includes three stages: initial analysis, followed by the conceptual and design stages. In the initial stage, it is necessary to collect and analyze information regarding the future location of the project, market interest and legal regulations related to the implementation of the development project. In order to better understand the strengths and weaknesses of the project, it is advisable to use the popular SWOT analysis (PMBOK, 2021). At the conceptual stage, a general design concept is created, including architectural and functional assumptions. Potential risks and benefits are assessed. The developer works closely with designers to develop a vision of the final product (Wysocki, 2014). After the investor's approval, the conceptual stage moves into the design stage. At this stage, after obtaining connection conditions from the relevant operators of the technical infrastructure network, detailed architectural, technical and engineering designs are developed, i.e. land development, power, water and sewage, telecommunications and gas networks. Drawings, documentation and specifications are created. Constant and effective communication with the project team is crucial to achieving consistency and quality of plans (Turner, 2019). At this stage, the developer should also plan the concept of financing the project and identify the possibilities of obtaining financing for the project. The preparatory phase should be culminated in obtaining a building permit, which will enable, in accordance with the law, the commencement of the implementation phase.

In this phase, the project implementation begins. The terms of contracts with contractors are negotiated, and after their completion, target companies are selected. During construction, construction works should be properly organized, supervised and monitored for compliance with plans and quality of workmanship. Regardless of the above, a factor necessary for the proper execution of construction is constant coordination of the design team and investment contractors (Kerzner, 2009) and proper communication between the people involved (Schwalbe, 2015). As construction progresses, tests of the quality and functionality of the facility are carried out. Ensuring compliance with regulations and investor expectations is crucial. Corrections and adjustments may occur during this phase. In Polish conditions, this phase usually involves the commercialization of the project - i.e. the initiation of the sales process, which is sanctioned by applicable legal provisions (Act, May 20, 2021).

After completion of construction works and successful inspection and testing, the project is handed over to the investor or users. These activities begin the last phase, the so-called operational, which includes, among others: completing all formal documents necessary to obtain an administrative decision to put the constructed facilities into use. The initial period of operation and quality monitoring is important to ensure that expectations for the facility are met and operating as planned. In this phase, after-sales service for customers is also carried out, as well as the transfer of rights to manage residential facilities to appropriate institutions/companies. In Polish conditions, this takes place under the provisions of the Act on the ownership of premises (Act, June 24, 1994). The final stage of this phase is the project closure stage. A project evaluation is performed and the lessons learned from experience can be used to improve future projects (Wysocki, 2014). Table 1 presents the structure of the real estate development project, according to the author's concept.

**Table 1.**

*Structure of the real estate development investment process*

<b>Phase I preparatory</b>	
Market and needs analysis	Real estate market analysis Analysis of local competition Examination of demand for offered products Identification of customer preferences, i.e. the most desirable/attractive products (apartments) for potential customers
Preparation of the project concept	Choosing the right location for a residential project Development of the project concept Obtaining appropriate arrangements from the operators of the utilities network in the field of water supply, sewage collection, energy, gas, access roads
Designing	Preparation of an architectural project, which includes building plans, apartment layout, floor layout, etc. The choice of building materials and technologies Determination of aesthetic and functional aspects Obtaining the necessary permits and building permits
Financing	Determining the project budget Cost estimation of the project Obtaining financing for construction, which may include bank loans, private investors or other sources of capital.
<b>Phase II implementation</b>	
Construction	Site preparation, i.e. cleaning and preparation of land for construction Negotiation of conditions and signing contracts with contractors and suppliers Preparation of the construction schedule Implementation of construction in accordance with the project Ongoing cost control, close monitoring of the project budget Supervision of construction works, including quality and timeliness control, tests of installation sections Ensuring compliance with building regulations and standards
Marketing & Sales	Initiation of promotional and marketing activities aimed at attracting potential customers, including the preparation of market communication tools, i.e. website, marketing materials, active social media profiles, collecting positive feedback from existing customers and using them as a marketing tool. Presentation of the design of apartments, including the preparation of apartment models for sightseeing Commencement of the apartment sales process

Cont. table 1.

<b>Phase III operational</b>	
Closing the project	Finalization of construction Completion of all formal documents necessary to obtain an administrative decision to put into use the constructed facilities Obtaining an occupancy permit Transfer of real estate to new owners Archiving project documentation
After-sales service	Providing support to clients and solving possible problems after buying an apartment. Management of possible complaints and repairs
Property maintenance and management	Handing over property management to a professional manager: common cost management, maintenance of common areas

Source: own study based on the research carried out.

As previously mentioned, in a development investment project, many processes must be precisely synchronized so that the project can be implemented according to plan and be successful. Synchronization is important because different activities and project stages are interconnected and influence each other. For example, design processes as well as obtaining the necessary approvals and permits must be completed before the planned start of construction. Activities related to acquiring resources, such as obtaining financing, should be initiated earlier, already during the preparation phase of the construction project. Financial management and cost control and adapting the budget to actual needs must be constantly monitored on an ongoing basis. Marketing and sales activities should be synchronized with the progress of the project. Project promotion should start early enough to attract potential customers, but not too early to avoid customer disappointment with delays. If the project is planned to be expanded, the processes related to this stage must also be synchronized with the ongoing project.

Lack of process synchronization may result in improper organization of work, failure to meet planned deadlines, which consequently increases the costs and risk of a given project. Therefore, managing a development project requires careful coordination and management of all processes and resources. In practice, this responsibility falls to project specialists, project managers or developers who have experience in managing this type of projects. The rest of the article focuses on describing the key success factors that are most important from the developer's point of view in the individual phases of the project implementation.

### **3. Key success factors in completed real estate development projects**

Key success factor analysis (KSF) is the process of identifying and assessing the most important elements or factors that have a decisive impact on achieving success in a specific industry, venture or project. KSF analysis is used in strategic management and helps companies and projects focus on the most important areas that matter most to achieving their goals.

Considerations on the key factors of enterprise success in management science and practice have been conducted for several decades. One of the first works on this topic in world literature was *In Search of Excellence* by T. Peters and R. Waterman (1982). It presented the results of research on the success factors of 62 large, well-known and, in the authors' opinion, well-managed American companies. Since then, scientific research on this topic has become fashionable in the global management science (Ansoff, 1994; Collins, 2001; Stankiewicz, 2002; Dahlgard-Park, Dahlgard, 2006; Simon, 2010). In the Polish literature on the subject in the 1990s, there was also an extensive discussion on this topic (Koźmiński, 1996; Kieżun, 1997; Dwojacki, 1995; Niestrój, Hadrian, 1999; Olszewska, 2000; Obłój 2003, Walentynowicz, 2005). These considerations are most often carried out by industry (service enterprises/ manufacturing enterprises); depending on the size or type of activity of enterprises; for functional areas (strategic, marketing, finance, human resources or quality management) or for various types of problem areas of the functioning of modern enterprises (implementation of IT systems, implementation of new management concepts, project management, or crisis management) (Jenster, 1987; Johnson, Friesen, 1995; Spałek, 2004; Wong, 2005, Zakrzewska-Bielawska, 2007; Skalik, Strzelczyk, 2013; Szreder, 2015; Austen, Kotas, 2016; Danielak, Gębska, 2017; Gicała, Sobotka, 2017; Walentynowicz, Machel, 2018 ). The literature on this subject is very rich.

In real estate development industry, key success factors can vary depending on location and type of projects. Nevertheless, there are some common key success factors that often make a big difference in achieving success in this industry. Table 2 presents the most important, in the author's opinion, key success factors in real estate development industry.

**Table 2.**

*The most important key success factors in real estate development industry*

No.	Key success factor	Description
1.	Location or idea for the development of the available opportunity	Choosing the right location is of paramount importance. The attractiveness of the location is crucial for the strategy and objectives of the venture. Locations with good access to public transport, infrastructure networks and services, in a topographically and recreationally attractive location, can attract a larger number of potential buyers or tenants.
2.	Good market analysis	Thoroughly understanding customer needs, market trends and customer preferences is very important. As a consequence, it leads to offering them a more attractive product and, consequently, to the financial success of the project.
3.	Attractiveness of architectural design and land development	The quality of buildings and careful design of rooms and common areas can significantly affect the attractiveness of the project for potential customers. At this stage, the choice of a professional designer who understands the needs of the developer becomes important.
4.	Efficient organization of the construction process	Effective construction management, including deadlines, costs and build quality, is crucial to success. Delays or problems can lead to a loss of customer confidence and additional costs.
5.	Satisfactory quality of construction works	It is also important to maintain high standards of building quality or development of common areas to satisfy customers and meet market expectations. Maintaining high quality will avoid complaint problems in the future, after the completion of the construction process.

Cont. table 2.

6.	Cooperation with trusted and competent business partners	It is very important, because already at the pre-investment stage, in which they will be able to act as technical advisors to the developer, and at the implementation stage they will advise him in a professional manner. Advising the developer in the preparation and during the implementation of the project will try to pursue the developer's interest.
7.	Competent management of the investment project	Competent management of an investment project consists in effectively planning, organizing, implementing and controlling activities related to the investment in order to achieve the intended investment objectives within a certain period of time and in accordance with the available budget.
8.	Effective marketing	Developing an effective marketing strategy and sales plan to attract potential buyers and increase the profitability of the project.
9.	Effective sales	In addition to having your own sales channels, it is also good practice to establish cooperation with competent real estate agents. Good customer service before, during, and after a project can affect a developer's reputation and ability to win recurring customers.
10.	Ability to carry out risk analyses and contingency planning	Conducting a comprehensive risk analysis to identify potential threats and ways to minimize them is crucial for the efficient implementation of the project and obtaining beneficial and reliable financing of the project. Real estate development industry entails a large number of risks resulting from, m.in changing market conditions during the implementation of the project or unexpected construction problems. Therefore, good contingency planning and flexibility in responding to unexpected situations are important. The possibility of staging investments is of great importance, allowing for a significant reduction of market risk (no sale or sale at reduced prices) and financial risk (inability to cover the costs incurred).
11.	Securing the financing of the project	Securing sufficient financial resources and maintaining cash flow for the entire duration of the project, taking into account possible delays and additional costs, is also crucial for the project's success.
12.	Competent task force management	Effective management of a project team includes: proper division of tasks, ensuring clear roles and responsibilities, maintaining effective communication, an atmosphere of commitment and proper motivation of team members. The task force includes both the developer's employees and external partners.
13.	Ability to meet administrative requirements	It is very important to ensure compliance with local laws, building standards and legal regulations for development projects. The ability to effectively navigate the complex conditions and meanders of Polish construction law is very important. This has a cardinal impact on the timely start and completion of the project.
14.	Technological innovation	Smart building technologies, such as intelligent energy management systems, the use of alternative energy sources, air quality monitoring, warm installation technology of window joinery, allow the creation of more efficient and environmentally friendly buildings. The effect of this is to improve the efficiency of construction, increase the functionality of the property, which can also bring measurable marketing benefits.
15.	Taking into account the green aspects of investments	The growing importance of sustainable construction means that developers who take ecological aspects and energy efficiency into account in their projects can be more attractive to customers. The introduction of sustainability elements such as energy efficiency, green materials and social responsibility is important not only for meeting increasingly demanding building standards, but also for marketing and image.
16.	Effective supervision over the implementation of the project	In the process of supervision over the implementation, the developer should engage a professional team to carry out the tasks of the construction manager and the building supervision inspector (Act, 7.07.1994). They should have the appropriate powers to take immediate corrective action if deviations from the plan are identified.



Cont. table 2.

17.	Relations with stakeholders	Developer must maintain positive relationships with stakeholders, such as investors, public administration bodies and the local community. Positive relationships are influenced by, among others, the quality of communication, understanding the needs of stakeholders, approach to resolving conflicts, transparency and honesty in relationships.
18.	Competent project leader	The project leader plays a key role in building harmony, efficiency and commitment in the team, which has a direct impact on the course of the project and the achievement of goals. The complexity of development projects and the number of existing processes cause that many interests intersect, which results in the emergence of conflicts. The project leader must skillfully deal with conflicts, not allowing them to negatively affect the progress of work. Effective problem solving and decision-making in difficult situations can significantly affect the positive outcome of a project.

Source: own study based on the research carried out.

As previously mentioned, key success factors may vary depending on the local market, project type (e.g. apartments, offices, shopping centers) and changing industry trends. Therefore, it is important for developers to carefully analyze the market and adapt their strategies to the current market situation. As part of various investment projects, they should focus on those factors that are most important for the success of a specific project.

#### **4. Verification of identified key success factors based on the analysis of completed real estate development projects**

##### **4.1. Case A: Kaszubska Ostoja (KO)<sup>1</sup>**

The "Kaszubska Ostoja" development project is a complex of comfortable single-family houses located in the Kashubian Landscape Park. Based on macro-location analyzes carried out by the developer, limited advantages for the tourist development of the commune were found. Despite this, the investor attempted to build a holiday resort and promote it. The idea of the analyzed project was to build a modern, thematic holiday park in an area with a total area of 7.5 ha, consisting of 77 independent holiday houses with accompanying infrastructure. The accompanying infrastructure included: a restaurant building, an artificial lake - a special fishing ground with an area of 2.2 ha, a recreational and sports complex (volleyball court, bicycle rental, outdoor fitness), a modern playground for children, a covered shelter, with a fireplace for organizing events. The charm of the place is enhanced by the fact that the developer uses the natural terrain and spatial conditions, i.e. the existing natural lake, attractive topography and several-year-old trees in the area where the center was built.

<sup>1</sup> <https://www.kaszubskaostoja.pl/>

The holiday cottages, together with a plot separated by geodetic measurement, were intended for sale as separate developed properties with separate land and mortgage registers. Buyers could hand over their property (house) for management and rental by the developer. In this case, they treated the purchase of the house as a capital investment. Other buyers who did not want to use the house for rental purposes could use it on their own, as a second home.

#### **4.2. Case B: Łebska Ostoja (LO)<sup>2</sup>**

The project is located in the buffer zone of the Słowiński National Park. It covers an area of 1.4 hectares and is located approximately 4 km from the seaside beach and 1 km from the beach with a pier over the lake. The project involved the construction of a holiday resort consisting of 60 independent residential premises located in five multi-unit buildings. The architecture of the buildings is "timeless", which means that the buildings are not shocking with their modernity, but refer to regional construction in their appearance and details. In addition to the buildings, the center includes: an open heated swimming pool complex, a beach volleyball court, a set of outdoor fitness equipment, a professional playground and mini golf.

The product intended for sale were independent residential premises with a common area where the above-mentioned attractions are located. The developer's intention was to use the unique location features (direct vicinity of the sea and lake, location in the buffer zone of the Słowiński National Park) and functional features of the project for the purposes of organizing tourist activities. The premises were sold to buyers from the so-called rental option, which means that the developer has also become the operator. His tasks include facility management and organizing the rental of premises on behalf of apartment owners.

#### **4.3. Case C: Łebska Piaskowa (LP)<sup>3</sup>**

Due to the success of the Łebska Ostoja project, a decision was made to implement another project in the same location, called Piaskowa. The project assumed the construction and sale of another, independent holiday resort operating on the same principles as the Łebska Ostoja project. The project included the construction and sale of 42 holiday apartments with accompanying infrastructure, i.e. an outdoor swimming pool, a playground for children, a recreation area and a common playroom for spending free time. The project uses modern solutions and technological innovations, including: modern but timeless architectural solutions, heating systems for buildings and swimming pools using heat pumps, remote control systems for apartments. The project, implemented following the success of the previous project, was intended to create an attractive space for relaxation on the Baltic Sea or lakes, while maintaining harmony with the natural surroundings and providing various recreational opportunities.

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<sup>2</sup> <https://lebskaostoja.pl/>

<sup>3</sup> <https://piaskowa.lebskaostoja.pl/>

#### 4.4. Case D: Ostoja Bukowo (OB)<sup>4</sup>

The project assumed the construction of a holiday resort located on an area of 9 hectares in a unique place, surrounded by forests and by a large, attractive lake. The project consists of 100 houses, luxuriously finished. The subject of the sale were real estate with a holiday home. As part of the project implementation, the following were designed and built: external technical infrastructure networks, i.e. water, sewage, energy networks and a network of internal roads. In the common areas belonging to all owners of the facilities, infrastructure was located to increase the tourist attractiveness of the project, i.e. a large playground, a beach volleyball court, a rope park and a chill-out zone in the forest areas, a beach by the lake with a recreational pier, a pier for mooring boats, a covered a shelter with a place for a bonfire. The investment, like the two previous ones, was a response to market needs in the holiday real estate sector. Buyers can hand over their property (house) for management and rental (e.g. by a developer) or they can use it on their own, as a second home.

Each of the presented cases illustrates the unique challenges, strategies and solutions that can be used in real estate development project. Table 3 presents an assessment of the occurrence of previously identified key success factors in the four projects analysed.

**Table 3.**

*Assessment of key success factors in individual investment projects*

No.	Project phase	Type of key success factor	Real estate development project			
			KO	OB	LO	LP
1.	I	Location or idea for the development of the available opportunity	+	+	+	+/-
2.	I	Good market analysis	+	+	+	+/-
3.	I	Attractiveness of architectural design and land development	+	+/-	+	+/-
4.	II	Efficient organization of the construction process	-	-	+	+
5.	III	Satisfactory quality of construction works	+	+/-	+	+/-
6.	I, II, III	Cooperation with trusted and competent business partners	+/-	-	+	+
7.	I, II, III	Competent management of the investment project	+/-	-	+	+/-
8.	I, II	Effective marketing	+	+	+	+
9.	II	Effective sales	+/-	+/-	+	+
10.	I, II, III	Ability to carry out risk analyses and contingency planning	+/-	-	+	+/-
11.	I, II	Securing the financing of the project	-	-	+/-	+
12.	I, II, III	Competent task force management	-	-	+/-	+/-
13.	I, III	Ability to meet administrative requirements	+/-	+	+	+
14.	I, II	Technological innovation	-	-	-	+
15.	I, II	Taking into account the green aspects of investments	+	+	-	+
16.	II, III	Effective supervision over the implementation of the project	-	-	+	+/-
17.	I, II, III	Relations with stakeholders	+	-	+	+/-
18.	I, II, III	Competent project leader	+	-	+/-	-
<b>THE SUM OF THE KEY SUCCESS FACTORS</b>			<b>10,5</b>	<b>6,5</b>	<b>14,5</b>	<b>12,5</b>
<b>FINAL EFFECT OF THE PROJECT (SCORE ON A SCALE OF 0-10)</b>			<b>10</b>	<b>6</b>	<b>10</b>	<b>8</b>

<sup>4</sup> <https://ostojabukowo.pl/>

Note: The assessment of key success factors was carried out by the author after consultation with project stakeholders. Each success factor is marked as "+", "+/-" or "-". "+" means that a given factor is crucial to the success of the project, "+/-" means that the factor is of some importance but is not crucial, and "-" means that the factor is not crucial.

Source: own study based on the research carried out.

Based on the results presented in Table 3, it can be concluded that the identified success factors were distributed differently in individual projects. All of the above the projects were implemented by the same developer, but at different times and in different locations. Therefore, the developer drew conclusions after the first projects, which resulted in him no longer making the same mistakes in subsequent projects. Examples of this include the efficient implementation of the construction process or competent management of the investment project, which turned out to be important success factors in subsequent projects. The benefits resulting from the experience gained by the developer allow him to better understand which factors are crucial to the success of subsequent investment projects. Acquiring negotiation skills through experiential learning allows you to develop better terms with business partners and suppliers.

In the author's opinion, the factor of a competent project leader becomes of great importance, because he is able to shape some of the other factors: e.g. relationships with stakeholders or cooperation with trusted and competent business partners. He is also the one who makes decisions that influence effective marketing, which will result in effective sales. Its high credibility, reflected in successes in previous projects, has a significant impact on securing financing for subsequent planned projects and, ultimately, on customer satisfaction and the developer's market image. In the author's opinion, a competent project leader is the most important factor in the success of real estate development project.

## 5. Summary

The author is aware of the fact that the conclusions drawn from the conducted research cannot be generalized for all development projects, but they can be a valuable source of information for real estate development companies planning further investment projects.

To sum up, it should be said that the purpose of the article was achieved because, based on completed projects and literature analysis, the author's structure of real estate development process was presented. This structure has been systematized based on individual phases and spheres of the developer's activity in Polish conditions. Then, the key success factors occurring in a typical real estate development process were identified in detail, and in the final part they were verified, based on the results obtained from the implementation of four independent development projects.

Referring to the research hypotheses set out in the introduction, it should be stated that there are many key success factors that may contribute to the success of development projects. However, they vary depending on the specific location and the implementation time of the project. The hypothesis was confirmed that the more key success factors there are in the development process, the better its effects will be. The Pearson correlation coefficient between the number of success factors and the independent assessment of the completed project was 0.764, which may indicate a quite strong correlation in this case.

As the analyzes conducted show, achieving high project effects is largely dependent on professionalism in real estate development project management, which results from the competences of the project leader. Its role seems to be invaluable because it has a significant impact on many other success factors, such as relationships with stakeholders, cooperation with business partners and effective marketing. Building the developer's reputation, credibility and history of success influenced its ability to easily and effectively obtain financing for subsequent projects. This, in turn, combined with experiential learning, continuous improvement and adapting the strategy to a specific situation can bring success in the dynamic environment of the real estate development industry.

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## TECHNOLOGICAL AND MARKET ASPECTS OF VEGETABLE PRODUCTION ON A FARM

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**Purpose:** The article analyzes the market for technologies used to support production processes in directed agriculture. The state of vegetable farming in Poland was analyzed and references were made to the country's market and economic potential in relation to vegetable cultivation. Also analyzed were the directions of distribution of vegetables on a national and international scale. The vegetable farm surveyed in the case study has been cooperating with a chain of super and hyper markets for several decades.

**Design/methodology/approach:** The subject of observation and profitability assessment included industry reports, technological flowcharts and price calculation using methods of calculating the arithmetic mean based on VAT invoices provided by the surveyed business entity. The presentation and detailed examination of available data took the form of tables and bar charts which were justified descriptively. The source of information for this paper was the subject literature, statistical data and many studies of the Central Statistical Office and Eurostat, reports in the industry section, an interview with the owner of a vegetable farm, an analysis of financial documents made available by the business in question as well as the author's own observation. The business's characteristics, revenues, costs and sales market were examined. Also, the machine park of the surveyed business and the level of employment therein were analyzed over the years.

**Findings:** The surveyed farm produces goods for over 10 months a year, which significantly affects the continuity of supplying the customer with fresh vegetables. The article presents the characteristics of the farm and analyzes the production possibilities for individual vegetables. Manufacturing large quantities of goods requires an adequate supply of warehouse space, vegetable processing halls and the necessary human resources. The surveyed farm has been recording a steady increase in investment opportunities as well as introduction and improvement of recycling and ecological activities.

**Research limitations/implications:** The analysis was limited to one vegetable farm.

**Keywords:** cost, production, agricultural machinery, cultivation, tractor.

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

## 1. Introduction

One of the most dynamically developing market sectors in the country is the food market (Dzudzor, Gerber, 2023). Part of this sector is the production and sale of vegetables on a large scale (Scur et al., 2023). A number of changes regarding vegetable production were initiated mainly as a result of Poland's accession to the European Union (Santeramo et al., 2021; Bielska et al., 2023). Numerous legal and technological regulations have since been introduced to increase the quality and safety standards of goods and the environment. The adopted legislation requires producers to carry out appropriate organization, investments and technological modernization (Witczak et al., 2018; Kowalczyk, Cupiał, 2020). The fruit and vegetable market in Poland is covered by the regulations of the Common Organization of the Fruit and Vegetable Market (COFVM), which was established in 1996 in the European Union (COFVM, 2023).

Wholesale markets are an important part of the institutional infrastructure of the horticultural market – they refer to the network of entities located in Poland that organize trade in food and horticultural goods (Fałkowski, Chlebicka, 2021). The wholesale market can be run by concentrating trade turnovers, which means locating them in a specific place (Dan et al., 2023). They take the form of organized markets, where transactions are concluded between sellers and buyers. By way of the organization of the existing wholesale market system, the markets were divided into cross-regional, regional and local markets (Gołębiewski, Sobczak, 2017). This measure was aimed at introducing an orderly market system and increasing the availability of goods. Considering the specificity of the vegetable-oriented agricultural sector, the issue of export and import of vegetables cannot be ignored (Duque-Acevedo et al., 2022). The introduction of the unification of countries as well as the implementation of appropriate policies between the countries of the world have both contributed to a significant development of product imports on the market. The society's ever-increasing demand for vegetables contributes to the development of competitiveness on the market. The domestic vegetable production is at a relatively high level, compared to other European Union countries. Over recent years, Poland has seen an increase in the area of cultivation and the volume of vegetable harvest. In 2021, Poland was one of the leading countries producing onions and carrots (GUS, 2021). Management of vegetable farms is largely determined by the quality and extent of mechanization of a given production unit as well as the human workload. By way of the gradual introduction of automatic solutions, the number of people employed on farms can be significantly reduced and the cultivated area can be increased. The main aspect of production is the level of consumerism and demand, especially in Poland, but also as its exports abroad. Some of the factors that affect the significant volume and quality of the product include the climate, soil and atmospheric conditions. An important aspect is ensuring proper fertilization, i.e. providing vegetables with the necessary minerals and nutrients, which significantly improves the yield per hectare. Proper fertilization also replaces natural climatic, atmospheric

and soil factors, to a certain extent. The continuous development and purchase of equipment improve the status and importance of the farm on the market. Farmers willingly choose multi-task machines to be able to use the equipment as efficiently as possible, with optimal investment spending.

## **2. Current state of the fruit and vegetable industry**

63 million tons of all vegetables were harvested in the EU countries (EU-27) in 2022; in the previous year (2021), the harvest was 65.7 million tons (EU, 2022, Annual activity report, 2022). Based on data provided by the Central Statistical Office (GUS – Główny Urząd Statystyczny) in 2018, over 150 thousand hectares were sown with vegetables, while the number of individual farms was 58,626. In 2021, the total area of vegetable cultivation in Poland amounted to 169.5 thousand hectares. In 2022 it was only 163 thousand hectares. The total production of all vegetables amounted to 5,278.9 thousand tons in 2021, and, despite the smaller cultivation area in 2022, it amounted to 5,387.0 thousand tons. The dominant crops are field vegetables which were cultivated on an area of 157.8 thousand hectares and their harvest amounted to 3.85 million tons. Vegetables under the shelter were grown last year on an area of 5,220 hectares, while the harvest is estimated at 1.53 million tons.

For many years, farms that operate in large-scale vegetable cultivation have been trying to develop the most effective long-term solutions that will allow them to gain a market advantage over the strong position of their competitors (Fałkowski, Chlebicka, 2021; Knook et al., 2022). It is estimated that the membership in cooperatives in the food industry in the EU countries is above 50%, depending on each individual country. Such forms and types of cooperation initiated by the European community may include farming cooperatives or various types of unions, associations or groups of agricultural producers. One of the barriers that affect farmers' association into groups is in their mentality – particularly a fear of losing independence as well as some administrative barriers. Joining a producer group is intended to reduce costs directly related to the use of industry machines or the group implementation of quality certificates. It is also important to reduce transaction costs, which involve saving time for negotiating the scope of sales. The statistical data included in Table 1 confirm the existence of few fruit and vegetable producer groups in Poland. Despite constantly increasing funding, a decline in the number of such groups can be seen in recent years.

*Number of recognized producer organizations that manufacture fruit and vegetables in total, by Polish Provinces in 2017-2023*

Province	Measurement period						
	06.2023	10.2022	10.2021	10.2022	10.2019	10.2018	10.2017
Dolnośląskie	6	6	6	6	8	8	8
Kujawsko-Pomorskie	14	14	18	23	29	33	38
Lubelskie	18	19	21	23	26	29	27
Lubuskie	1	1	1	3	5	5	4
Łódzkie	15	15	15	16	17	17	17
Małopolskie	8	8	10	11	12	11	11
Mazowieckie	56	58	61	74	82	84	84
Opolskie	5	5	5	5	5	5	5
Podkarpackie	3	3	3	5	6	6	6
Podlaskie	1	1	1	1	1	1	1
Pomorskie	4	4	4	6	7	7	7
Śląskie	3	3	3	3	3	3	3
Świętokrzyskie	10	10	11	11	12	14	14
Warmińsko - Mazurskie	1	1	1	2	2	2	2
Wielkopolskie	15	15	18	25	36	46	46
Zachodniopomorskie	1	1	1	1	1	1	0
Total	161	164	179	215	252	272	273

Source: Author's own study based on statistical data (ARMiR, 2023).

From the analysis based on data from the Central Statistical Office, it can be seen that the average monthly consumption of vegetables per a city resident in 2018 was 7.7 kg, while in the countryside it was 8.3 kg. Comparing fruit consumption respectively, it was 4 kg and 3.3 kg. In 2016, the corresponding amount of consumption of vegetables in the household was 8.59 kg, and fruit – 3.66 kg. Vegetable consumption in 2021 was 7.43 kg per month, while in 2004 this value was 12.3 kg (GUS - Local Data Bank, 2021).

The basic factor in vegetable production invariably remains the soil, regardless of technological progress. It is extremely important to adapt the possibilities of using soil to natural conditions and ensure that their use does not affect the environment adversely, while allowing for the economic development of the areas. According to the statistical data from the Central Statistical Office and the Agency for Restructuring and Modernization of Agriculture (ARMA), the average size of a farm in Poland is over 10 hectares (Table 2).

**Table 2.**

*The average size of agricultural acreage a farm, by individual Provinces (hectares)*

Province	2022	2021	2020	2019	2018	2017	2010
Dolnośląskie	18.00	17.79	17.29	17.1	16.72	16.46	15.72
Kujawsko-Pomorskie	17.01	16.83	16.58	16.43	16.14	15.77	15.01
Lubelskie	8.16	8.07	7.98	7.93	7.86	7.73	7.4
Lubuskie	23.03	22.75	22.29	21.9	21.52	21.18	20.32
Łódzkie	8.10	8.06	7.98	7.92	7.84	7.72	7.42
Małopolskie	4.28	4.22	4.16	4.13	4.1	4.04	3.83
Mazowieckie	8.90	8.85	8.77	8.75	8.68	8.57	8.44
Opolskie	19.66	19.50	19.16	19.02	18.69	18.51	17.83
Podkarpackie	5.10	5.03	4.94	4.9	4.83	4.77	4.47
Podlaskie	12.73	12.66	12.55	12.51	12.44	12.27	12.11

Cont. table 2.

Pomorskie	20.16	19.97	19.62	19.58	19.42	19.16	18.84
Śląskie	8.45	8.32	8.14	8.02	7.85	7.7	6.83
Świętokrzyskie	6.00	5.94	5.88	5.82	5.77	5.67	5.42
Warmińsko-Mazurskie	23.63	23.55	23.25	23.25	23.05	22.79	22.95
Wielkopolskie	14.41	14.27	14.09	13.99	13.74	13.56	13.43
Zachodniopomorskie	32.80	32.58	31.75	31.44	30.78	30.35	30.3
Average	11.32	11.20	11.04	10.95	10.81	10.65	10.23

Source: Author's own study based on data from the Central Statistical Office and ARMA (GUS - Statistical Yearbook of Agriculture, 2022; ARMiR, 2022).

In Poland, the area of vegetable cultivation in 2018 amounted to a total of 158.9 thousand hectares, which constitutes 1/6 of all crops sown. The most favourable vegetable production, considering the countrywide area of cultivation over 10 years, was recorded in Kujawsko-pomorskie and Dolnośląskie Provinces of Poland. However, many administrative units had a negative growth in the area of vegetable production, the smallest number of which included: Lubelskie, Podlaskie and Łódzkie Provinces (Table 3).

**Table 3.**

*Sowing areas for field vegetables (in thousand hectares)*

Province	2021	2020	2018	2015	2008
Dolnośląskie	9.1	9.8	12.1	8.6	9.6
Kujawsko-Pomorskie	25.7	29.7	30.4	24.5	17.5
Lubelskie	17.7	15.9	12.7	15.8	23.3
Lubuskie	4.2	4.9	4.8	4.5	5.2
Łódzkie	17.2	15.7	14.1	17.4	22.3
Małopolskie	15.3	14.5	14.1	17.5	17.4
Mazowieckie	20.2	21.1	23.4	25.6	28.1
Opolskie	2.4	2.1	2.8	3.3	2.8
Podkarpackie	4.6	3.7	3.5	4.8	8.4
Podlaskie	1.4	1.4	0.7	1.8	3.8
Pomorskie	7.1	8.1	8.9	7.3	8.8
Śląskie	1.7	1.7	1.8	2.6	3.7
Świętokrzyskie	10.8	10.6	9.6	13	15
Warmińsko-Mazurskie	7.5	7.1	3.5	3.1	3.5
Wielkopolskie	21.7	20.1	16	23.4	24.2
Zachodniopomorskie	3.1	3.9	3.3	2.9	4.2

Source: Author's own study based on data: (GUS - Production of agricultural and horticultural crops in 2018; GUS - Production of agricultural and horticultural crops in 2020; GUS - Production of agricultural and horticultural crops in 2021).

Poland is a leader in vegetable production among other EU countries. As early as in 2017, the harvest reached significant volumes. In 2017, the total of over 4,583 thousand tons of field vegetables were collected in the country. In 2018, over 4,109 thousand tons were collected (on yearly average). Vegetables grown under the shelter constituted just over 1,161 thousand tons in 2018 (GUS - Production of agricultural and horticultural crops in 2018). Respectively, tomatoes under the shelter constituted a harvest of 675.8 thousand tons, cucumbers 293.3 thousand tons, other vegetables grown under the shelter accounted for 192.5 thousand tons. Among ground vegetables, the highest yield was from cabbage (913.2 thousand tons), which constituted almost 22% of all vegetables grown in the field. The second highest yield

were edible carrots (726.4 thousand tons), which accounted for almost 17% of the harvest of ground vegetables. Onion (562.9 thousand tons) took up over 13%.

In 2021, a total of over 3,803 thousand tons of field vegetables were harvested. The total production of vegetables grown under the shelter amounted to 1,220 thousand tons. Respectively, tomatoes under the shelter constituted a harvest of 655 thousand tons, cucumbers 305 thousand tons, other vegetables grown under the shelter accounted for 260 thousand tons. Among ground vegetables, the highest yield was from cabbage (687 thousand tons), edible carrots (637 thousand tons), and onions (617 thousand tons).

In the years 2017-2021, there was a decrease in yield from field vegetable crops. This resulted from the insufficient amount of water in the soil, which was partly due to global warming as well as less waste, and maintaining relatively unprofitable sales prices of vegetables compared to the production costs incurred. The yield of field cucumbers decreased by almost half, but the main reason for the decline in the harvest of vegetables grown in the field was the gradual reduction of the cultivated area (Table 4).

**Table 4.**

*Harvest yield volume of selected vegetables in Poland in 2021-2017 (ground and grown under the shelter, in thousands of tons)*

Item	Yield (thousand tons)					Cultivation area				
	2021	2020	2019	2018	2017	2021	2020	2019	2018	2017
Total vegetables	5023.0	4900.2	5019.0	5270.5	5704.8	152.9	151.3	181.8	183.8	183.6
Ground vegetables including:	3803.0	3868.3	3845.0	4109.0	4583.3	144.7	143.2	176.2	176.1	177.6
Cabbage	687.0	710.2	837.0	913.2	1010.5	13.7	13.6	20.8	20.7	20.5
Onion	617.0	660.4	535.5	563.0	667.4	22.8	24.8	24.	24.8	26.0
Edible carrot	637.0	671.3	678.3	726.4	827.1	17.6	17.4	22.2	22.4	22.1
Beetroots	239.0	261.0	281.0	298.2	336.4	7.1	7.2	10.4	10.2	10.0
Cucumbers	127.0	181.3	223.3	245.4	249.1	5.4	5.2	15.1	14.6	14.0
Tomatoes	158.0	186.0	240.5	253.0	254.5	6.2	6.0	10.0	9.7	9.3
Cauliflowers	138.0	150.0	207.0	219.9	238.3	5.4	5.1	9.4	9.3	9.1
Vegetables grown under the shelter including:	1220.0	1032.0	1170.0	1161.6	1121.5	8200.0	7114.5	5586.4	5670.0	5629.0
Tomato	655.0	555.0	677.3	675.8	643.5	3000.0	2560.5	2102.6	2141.0	2150.3
Cucumbers	305.0	267.3	297.1	293.3	294.6	1700.0	1451.0	1110.8	1115.4	1139.6
Other vegetables grown under the shelter	260.0	209.6	194.9	192.5	183.4	3500.0	3103.1	2373.0	2413.5	2339.0

Source: Author's own study based on data: (GUS - Production of agricultural and horticultural crops in 2017; GUS - Production of agricultural and horticultural crops in 2018; GUS - Production of agricultural and horticultural crops in 2019; GUS - Production of agricultural and horticultural crops in 2020; GUS - Production of agricultural and horticultural crops in 2021).

Over recent years, the purchase prices of vegetables, both for the fresh market and for food processing, have fluctuated significantly, depending on the yield and demand in a given season (Table 5).

**Table 5.**

*Rates paid to producers for vegetables (PLN/kg)*

Item	For the fresh produce market				For the needs of food processing industry			
	2018/19	2019/20	2020/21	2021/2022	2018/19	2019/20	2020/21	2021/2022
White cabbage	1.30	0.80	0.75	1.10	0.70	0.60	0.70	0.80
Onion	1.65	1.10	0.90	1.00	2.10*	1.50*	1.10*	1.40*
Carrot	1.50	0.85	0.70	1.10	0.35	0.30	0.30	0.35
Beetroot	0.80	0.70	0.65	0.90	0.45	0.40	0.40	0.45
Ground tomato	1.00	1.00	1.50	1.70	0.60**	0.70**	0.75**	0.75**
Ground cucumber	2.10	1.80	2.70	3.50	1.50***	1.60***	1.80***	2.20***

\*peeled onion; \*\*tomatoes for freezing; \*\*\*cucumbers for pickles.

Source: Author's own study based on data: (GUS - Production of agricultural and horticultural crops in 2018; GUS - Production of agricultural and horticultural crops in 2019; GUS - Production of agricultural and horticultural crops in 2020; GUS - Production of agricultural and horticultural crops in 2021).

According to the Central Statistical Office data, the average annual consumption of vegetables, mushrooms and their products per capita was 54.96 kg in 2020, and 57.84 kg in 2015 (Table 6).

**Table 6.**

*Average annual consumption of vegetables in households (in kg/person)*

Item	2020	2019	2018	2017	2016	2015
Vegetables, mushrooms and preserves	54.96	55.2	56.4	58.2	59.04	57.84
Fresh and chilled vegetables and mushrooms:	44.88	44.04	45.84	47.64	48.6	47.88
Cabbage	4.44	4.32	4.68	5.04	5.28	5.4
Onion	5.28	5.04	5.16	5.4	5.4	5.4
Edible carrots	5.16	4.92	5.28	6	5.88	5.64
Beetroots	1.92	1.92	2.16	2.4	2.52	2.4
Cucumbers	5.28	5.64	5.76	5.88	6.36	6.12
Tomatoes	9.6	9.48	9.72	9.6	9.96	10.08
Cauliflowers	1.8	1.8	1.8	1.8	1.8	2.04
Other vegetables	10.92	10.92	11.28	11.52	11.4	10.8
Frozen vegetables	2.16	2.04	1.92	1.92	1.92	1.8
Vegetable preserves	7.92	9.12	8.64	8.64	8.52	8.16

Source: Author's own study based on (GUS - Household budget survey in 2020; Statista, 2022).

In 2021, Polish exports of vegetables and vegetable products reached EUR 1.9 billion and were 7% higher than in 2020. Among fresh vegetables, mushrooms, tomatoes and onions were the most exported, and processed vegetables exports were dominated by frozen vegetables, potato products (chips and chips) and dried and preserved vegetables. The export of vegetables and vegetable products in 2021 accounted for 5% of the value of all Polish agricultural food exports. The largest recipients were the EU countries, and the revenues obtained amounted to EUR 1.3 billion, which constituted 70% of the value of total foreign sales of vegetables.

The largest EU recipients were Germany (EUR 415 million – 22% of this group's exports) and France and the Netherlands (EUR 118 million and EUR 103 million respectively – 6% each), and from outside the EU - Great Britain (EUR 226 million – 12%), the Russian Federation (EUR 78 million – 4%) and Ukraine (EUR 61 million – 3%).

The Institute of Agricultural Economics and Food Economy forecasts that, in the 2022/23 season, the export volume of fresh vegetables will be approximately 13% higher than in the previous season and will amount to 630-632 thousand tons (IERiGŻ, 2023). Exports of processed vegetables will increase from 722.3 to 746 thousand tons, including frozen vegetables – an increase from 432.3 to 445 thousand tons.

According to the data from the Central Statistical Office, there were 1.448 million agricultural tractors in Poland in 2020. Compared to 2010, this number increased by almost 30,000 units. (2005 – 1.437 million, 2010 – 1.418 million, 2013 – 1.436 million, 2016 – 1.492 million, 2020 – 1.448 million). The vast majority of machines operate on individual farms – in 2020 it was 1,430 million pieces. The average nominal power of the tractors used in Polish agriculture is systematically increasing and reached 46.9 kW in 2020 (2005 – 39.3 kW, 2010 – 37.9 kW, 2013 – 42.5 kW, 2016 – 45.3 kW, 2020 – 46.9 kW). In 2020, statistically, there was one tractor per 10.1 hectares of agriculturally usable land. The largest number of hectares per tractor is in Zachodniopomorskie Province (29.4 ha), Lubuskie Province (22.2 ha) and Warmińsko-mazurskie Province (18.9 ha). Currently, 66.9 % farms have an agricultural tractor in their machinery. As far as the farm size is concerned, the data is as follows: up to 1 ha - 31.5%, 1.01-1.99 ha - 35.6%, 2-4.99 ha - 58.7%, 5-9.99 ha - 80.7%, 10-14.99 ha - 89.3%, 15-19.99 ha - 91.3%, 20-49.99 ha - 91.4%, 50 ha - 89%.

The selected basic forms of market organization include: agricultural and horticultural trade centers, commodity exchanges, fairs, auctions and tenders. The construction of food wholesale markets in Poland was initiated by a ministerial program in July 1996. As a result of its implementation, 13 wholesale markets were created, with the largest one created on the outskirts of the capital - Warszawski Rolno-Spożywczy Rynek Hurtowy S.A. in Bronisze. Currently, there are 29 wholesale markets in Poland, including 5 cross-regional, 9 regional and 15 described as local. The wholesale markets take organizational and infrastructural measures to optimize trading conditions. These companies do not conduct commercial activities themselves, their basic activity being the rental of commercial space to operators - entrepreneurs and agricultural producers. The basic income of the wholesale markets are the revenues from the rental of commercial space and entry fees for buyers. There is certain infrastructure in the markets' premises - shopping halls, commercial and warehouse pavilions and shelters or stalls. The facilities are designed for year-round operation, some have the ability to adjust the temperature to optimal conditions for storing goods, which helps maintain the appropriate quality of the products offered. Some of the markets have some specialized infrastructure, such as ripening rooms, storage rooms, cold stores. The functioning of wholesale markets plays



an important role in the distribution of agricultural and food products. Despite growing competition from large-scale retail chains, the wholesale markets maintain their position on the market, primarily by offering high-quality, fresh goods. The total area of cross-regional, regional and local markets in Poland is presented in Table 7.

**Table 7.**

*Selected cross-regional, regional and local markets in the country, including the area and location of a given market*

Cross-regional markets		
Lubelski RH (Rynek Hurtowy) "Elizówka" SA	Lublin	47.3 ha
Warszawski Rolno-Spożywczy RH SA	Warszawa-Bronisze	42.5 ha
Wielkopolska Gildia Rolno-Ogrodnicza SA	Poznań	38 ha
Pomorskie Hurtowe Centrum Rolno-Spożywcze SA „Renk”	Gdańsk	24.7 ha
Dolnośląskie Centrum Hurtu Rolno-Spożywczego SA	Wrocław	37 ha
Regional markets		
Małopolski RH	Tarnów	18 ha
Podlaskie Centrum Rolno-Towarowe SA	Białystok	10 ha
Rolno-Spożywczy RH SA	Radom	6 ha (Radom) + 3 ha (Kielce)
Podkarpackie Centrum Hurtowe "Agrohurt" SA Rzeszów	Rzeszów	7 ha
Rolno-Spożywczy RH "Giełda Elbląska" SA	Elbląg	3 ha
Rolno-Przemysłowy RH "Giełda Hurtowa" SA	Legnica	No data
Małopolski Rynek Hurtowy SA Tarnów	Tarnów	18 ha
Wałbrzyski RH SA	Wałbrzych	4000 m <sup>2</sup>
Zielonogórski Rynek Rolno-Towarowy SA	Zielona Góra	No data
Local markets		
Łódzki Rynek Hurtowy "Zjazdowa" SA	Łódź	14 ha
Gorzowski Rynek Hurtowy SA	Gorzów Wielkopolski	12.7 ha
Pilski Rynek Hurtowosp. z o.o.	Piła	3 ha
Beskidzki Hurt Towarowy SA	Bielsko Biała	11.3 ha
Praska Giełda Spożywcza SA	Ząbki	12 ha
Giełda Kaliska sp. z o.o	Kalisz	7.4 ha
Rynek Hurtowy Rolno-Spożywczy „Fasty” sp. z o.o.	Białystok - Fazy	5 ha
Sandomierski Ogrodniczy Rynek Hurtowy SA	Sandomierz	5 ha
Śląska Giełda Kwiatowa „Synergia” sp. z o.o.	Tychy	5 ha
Śląski Rynek Hurtowy „Obroki” sp. z o.o.	Katowice	10 ha
Świętokrzyski Rynek Hurtowy sp. z o.o.	Kielce	3 ha
Zachodniopomorskie Centrum Hurtowe „Rolhurt” SA	Przeclaw - Szczecin	3 ha
Targpiast sp. z o.o.	Wrocław	12.7 ha

Source: Author's own study based on data published by trading markets.

### 3. Case study

The object of the research was a family horticultural farm managed and run by a married couple. The surveyed farm is one of the leading producers of selected vegetables in the country. The manufacturer's wide offer is aimed at wholesale, industrial and retail markets, and willingly adapts to market trends. The analyzed farm is located in the county of Warsaw. The steady, consistent development of the farm is possible with EU support and investments that affect the

possibilities and improvement of production, as well as the efficiency of the appropriate use of resources in order to increase the profit and value of the activity.

The surveyed company has been allowed to deduct VAT (value-added tax) from purchases since 2006, which is why it pays taxes on general terms. Such a tax deduction makes it possible to recover part of the costs incurred, but the necessary condition for such a possibility is to submit a tax declaration to the Tax Office each month. The farm was additionally supported by subsidies from the "European Agricultural Fund for Rural Development, specifically Europe investing in rural areas". The farm was also included in the Rural Development program for 2014-2020. Given this extent of support, the business introduced some new investments, e.g. the construction of a cold storage facility.

The production farm is a large-scale vegetable cultivation operation, with a small percentage of cereal growing. The report which summarizes the yield volume on the farm for 2019 shows that the largest area on the farm is occupied by potato farming, with the annual yield of this vegetable of approximately 1,500 tons. The farm sells vegetables for 10-12 months of the year. The availability of the potato throughout the year is recorded from July 15 of the production year to March 15 of the following year. The onion is the second largest plant yield of about 700 tons, and the period of this vegetable's availability is from July 15 of a given year to April 30 of the following year. The next largest is the carrot yield of 400 tons and this vegetable is available from July 22 this year until April 30 of the next year. Apart from that, approximately 180 tons of Hokkaido pumpkin and common pumpkin were obtained in the period from September 15 this year. until April 30 of the next. All vegetables produced on the farm are sold on the domestic market.

The farm area is 35 hectares of own land, including 5 hectares of permanent meadows, which the farmer uses mainly for the disposal of natural waste, and 30 hectares leased from private individuals. The leased lands are located at a maximum distance of 10 km from the farm itself. The precise division of surveyed farm's area is presented in Table 8.

**Table 8.**

*Farm area (in hectares)*

Terrain type	Land owned [ha]	Land leased [ha]	Total
Arable land	30	30	60
Pastures	0	0	0
Permanent meadows	5	0	5
Agriculturally usable land in total	35	30	65

Source: Author's own study based on data received from the farm.

The farm has precisely assigned areas of land for a specific vegetable. The size of land allocated for the potato cultivation is 30 ha. The onions grow on an area of 20 ha, the carrots cover 7 ha, and both the Hokkaido pumpkin and the common pumpkin cover 3 ha. The total area of land under cultivation is 60 ha.

The yield of the carrot has the highest ratio of productivity efficiency on the surveyed farm. The second average yield size per hectare is for the onions, the third for the potatoes, and the last for the pumpkins. As with almost every production, a certain amount of waste is generated on the farm. Having been collected, the waste is transported to the field or meadow. The volume of production waste is respectively: pumpkins approx. 15%, carrots approx. 6-7%, onions approx. 7-10%, potatoes approx. 7-10%. A detailed list of yields is presented in Table 9.

**Table 9.***Vegetable yield volume per hectare*

Vegetable	Yield size
Carrot	80-100 tons/ha
Onion	60 tons/ha
Potato	40-50 tons/ha
Pumpkin	28-45 tons/ha

Source: Author's own study based on data provided by the surveyed farm.

The farm is seasonal in its nature, which results in an increased demand for employees during periods of increased intensity of field work; during this period, 3 to 6 additional employees are hired on top of the 5 household residents who work full-time. Detailed data is presented in Table 10. The table calculates the average number of working hours of the household residents, depending on the average number of hours of total employees (data from 2019). Conversion factors and the sum of hours worked are presented in Table 10. The employment rates and man-hours were calculated on the surveyed farm.

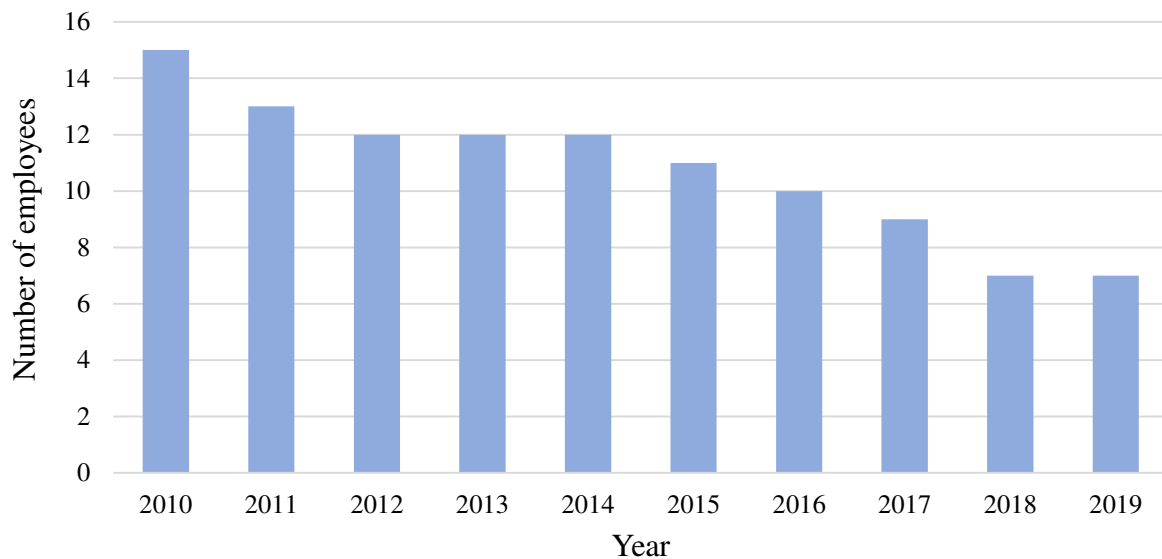
**Table 10.***Labour resources on the surveyed farm*

Household resident	Age (years)	Conversion factor for an able-bodied person	Number of hours worked on the farm (man hours/year)	Conversion factor for a full-time employee	Number of fully-employed and able-bodied people
1	2	3	4	$4/2200=5$	$5*3=6$
Owner	50	1.00	2940	1.34	1.34
Wife	50	1.00	1470	0.67	0.67
Father	70	1.00	1960	0.89	0.89
Mother	70	1.00	980	0.45	0.45
Cousin	60	1.00	2450	1.11	1.11
Total able-bodied people		5.00	-	-	-
Total number of hours worked on the farm			9800	-	-
Total number of full-time employees				4.45	-
Total number of full-time and able-bodied people					4.45

Source: Author's own study, data obtained from the farm.

Figure 1 shows the size of employment required on the surveyed farm in the years 2010-2019. The factor that determines and directly affects the described value is the purchase of new machines and equipment for vegetable processing. In 2010, a tractor was purchased for the farm, which largely replaced many human activities. In the following years, as part of its investment development, the farm also purchased machinery and equipment, e.g. a trailed field

sprayer, a conveyor belt, a vegetable washer, and a selection table. The implemented investments began to bring appropriate results. After a thorough analysis of the efficiency of machines and work efficiency of employees per man-hour, the farmer could reduce employment as human work was gradually being replaced by machines. The best investment of the farmer turned out to be the purchase of a tractor with high power and processing power, as well as a bagging machine – a machine that renders the preparation of the order faster and largely automated. This investment made it possible to reduce the previously required work of 5-6 employees on the conveyor belt and the washing machine by 2-3 people.



**Figure 1.** The impact on the size of employment through the purchase of machinery over 10 years  
Source: Author's own study based on data obtained from the farm.

### 3.1. Equipment on the surveyed farm

The surveyed farm has 2 cold chambers cooled by refrigeration units, which can accommodate 600 tons and 800 tons of vegetables respectively, in addition to regular 2 storage rooms with a total capacity of 1200 tons. The farm is also equipped with a shelter adapted for drying pumpkins and onions. In the storage halls, the temperature ranges from 1 to 10°C, depending on the ambient air temperature and sunlight at a given time of the year. The storage rooms are filled with box-pallets in which pumpkins, onions and potatoes are stored. Cold stores maintain a constant temperature of 2 to 5°C, depending on demand, and mainly carrots are stored there. The company also has a social room, a sorting room where vegetables are prepared for sale, and a large garage where most of the mechanical equipment is kept.

The farm features innovative machines that occupy a permanent place on the company's property and machines that mainly operate in the farming of arable fields and transport. This significantly improves the pace and efficiency of work. The farm also has at its disposal a semi-trailer for a truck, equipped with a cooling unit regulate the temperature during the transport of vegetables as well as 1 truck tractor. Additionally, the farm uses 1 delivery van to

fulfil small orders or to transport small items. The surveyed company also has 2 forklifts as well as 5 agricultural tractors used in daily work on the plant crops. The last breakthrough modernization introduced by the company in recent years was the purchase of a bagging machine – one person is required to operate the machine, while 3-4 people are needed at the selection table. All vehicles that belong to the company, along with their characteristics, are listed in Table 11.

**Table 11.**  
*Vehicles in stock of the surveyed company*

Vehicle name	Manufacturer	Model	Year of production	Power [HP]	Notes
Farming tractor	Deutzfahr	AgroPlus 87	2010	87	Wheelbase 1.5m
Forklift	LINDE	H45D	2001	-	Has tippers for box-pallets
Forklift	Toyota	6FGL18	1997	-	
Truck tractor	SCANIA	CF	2008	410	Trailer-compatible
Delivery van	Mercedes	Sprinter	2002	129	

Source: Author's own study based on data obtained from the farm.

The detailed range of the company's machines and devices, which are also a permanent asset of the company, is presented in table 12.

**Table 12.**  
*Machines and farming devices, including harvesting devices*

Machine/device name	Manufacturer	Notes
Seedbed cultivator	KONGSKILDE	4-metre Vibro master; 4-metre germinator
Plough	KUHN MASTER 4T+1	5 furrow; reversible
Disc harrow	KONGSKILDE	8 m
Cultivator-conditioner	ATTILA MASCHINO GASPARRDO	4 m with pin protection
Ridge former	BASELIER	Ridge spacing 4x75; used for carrot production
Potato planter	GRIMME G34T	4-row
Potato hiller	GRIMME	passive
Fertilizer spreader	KUHN RAUCH AXIS	none
Trailed field sprayer	TOSELLI	21 m with an air sleeve; 2000l
Rain shower	IRRILAND COMFORT	90x500
Vegetable seeder	Stanhay Singularie 870	Pneumatic, vacuum
Seedling planter	Lauwers	none
Stubble cultivator	KONGSKILDE Delta	working with a mechanical seeder used for aftercrops
Carrot harvester	DeWulf P3K	
Potato harvester	Grimme SE 15060	Includes an onion harvesting attachment
Storeloader		
Trailer		4,5 t for box-pallets
Transport trailer	Metaltech DB 8000	8 pcs
Onion digger	RUHENBERG ZVR 1350 TWIN	
Chives cutter		

Source: Author's own study based on data obtained from the farm.

The surveyed farm offers the sale of goods that are subject to the washing process: carrots, potatoes, onions and pumpkins. The ordered goods are sold loose, i.e. in packages, packed in raschel bags weighing from 10 to 15 kilograms, or in dedicated plastic boxes, depending on the

chain. The farm maintains the following temperatures during transport: carrots at 1-8°C, onions and potatoes at 5-15°C, pumpkins at 5-20°C, and combined transports at 3-10°C.

Considering the directions of production, farm owners must invest in and fully use the efficiency of machines and devices that enable efficient packaging of vegetables, in order to be able to sell to retail chains. A detailed share of the machinery on the farm is presented in Table 13.

**Table 13.**

*Machines and equipment for production without and with washing of plants*

Machines used for wet line			Machines used for dry production		
Equipment name	Brand	Notes	Equipment name	Brand	Notes
Receiving hopper	BIJSMA Hercules 2000L		Stockpile picker		
Belt conveyor	Remprodex		Belt conveyor		
Vegetable washer	PROVEGGA	2.5 m	Box-pallet tipper		
Water settling tank	HAITH		Sorter	PROVEGA	
Vegetable brusher		3 m	Multi-container scale	ALLROUND	
Selection table (roller), own production			Bagging machine	ALLROUND	
Belt feeder					
Filler					

Source: Author's own study based on data obtained from the farm.

### 3.2. Fertilizing vegetables

The surveyed farm applies appropriate soil fertilization, which is carried out before or during sowing, and adequately uses spraying with plant protection agents appropriate for cultivation, in compliance with all standards and recommended doses as well as original chemical compounds with an efficient (certified), modernized sprayer. Fertilizers are used preventively and as emergency.

The first step when using fertilizers in vegetable cultivation is to determine the area of cultivated land in order to calculate how much fertilizer and water should be used. This depends on many factors, including: plant variety, assessment of the seedling before planting, determining what was sprayed, planting spacing, weather conditions, cultivation of the preceding vegetable, method of applying fertilizer (manual or mechanical) as well as the operator who must know well the composition and appropriate doses of fertilizer assigned to appropriate vegetables in the regulations. To finalize the correctness of fertilization, the operator/contractor must complete the appropriate crop card and provide the complete fertilization record in the card. On the surveyed farm, spraying is used depending on the vegetables grown. The specification of fertilization characteristics is presented in Table 14.

**Table 14.**  
*Reason for fertilization on the surveyed farm*

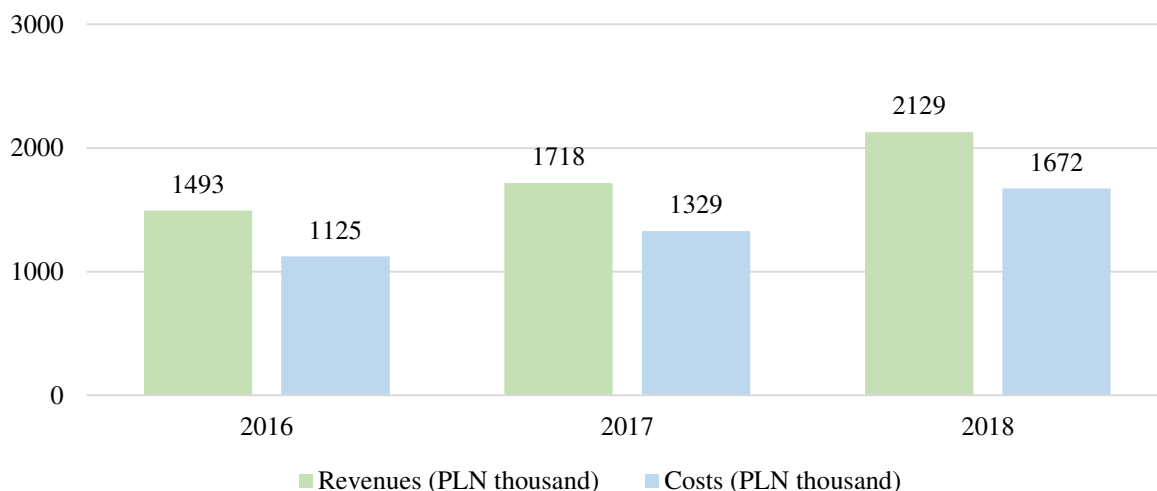
Vegetable name	Application for	Notes
Potato	weeds	Spraying done 3 times in the crop cycle; twice fertilized; 5 plant protection agents used
	potato blight	
	alternariosis	
Onion	herbicides	2 different fertilizers used; 8 different agents used; spraying done 6 times in the crop cycle
	grey mould	
	tobacco thrips	
	insects	
Carrot	herbicides	2 different fertilizers used; spraying done 4 times in the crop cycle; 4 different agents used
	alternariosis	
	mildew	
Hokkaido pumpkin	herbicides	spraying done with 2 different agents at the same time; spraying done once in the crop cycle

Source: Author's own study based on data obtained from the farm.

By regularly testing the concentrations of various chemical compounds in the soil as well as dosing fertilizers in accordance with specific standards, the farm contributes to the overall assessment of product quality. The selected family farm has had the GLOBALGAP certificate for its products since 2008. Additionally, the company has implemented the Hazard Analysis and Critical Control Points system (HACCP), a quality and food safety management system.

### 3.3. Sales volume and development prospects

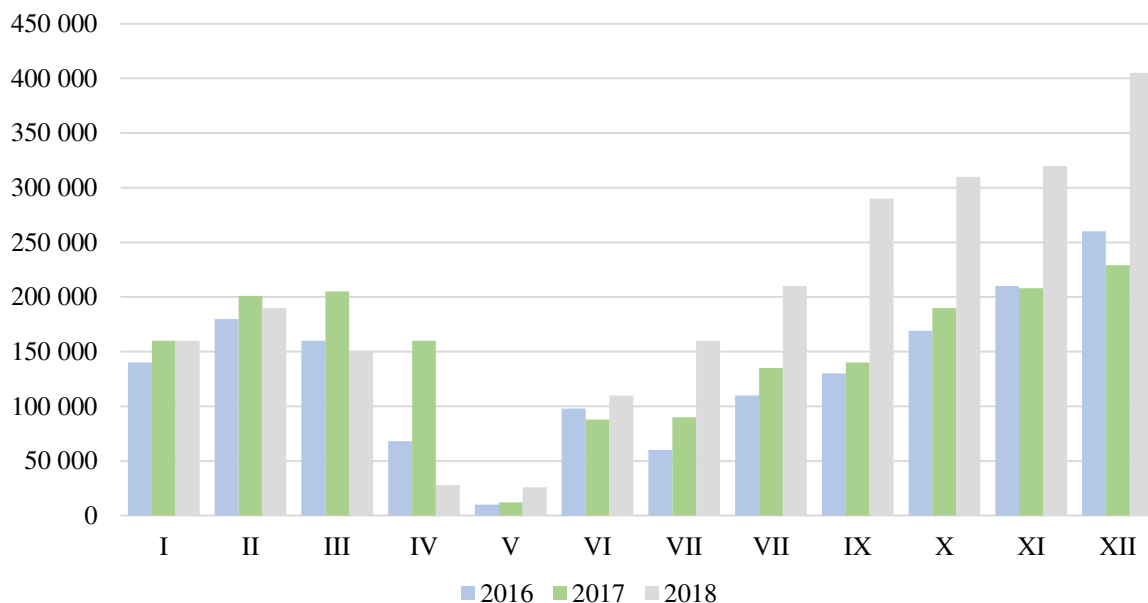
The costs of running the surveyed farm are mainly incurred for current expenses related to the purchase of seed material, fertilizers, plant protection agents, fuel, energy consumption as well as lease fees and staff employment costs. The company incurs costs related to improving the standard of the facility, renovation works, e.g. expansion and modernization of warehouses and cold stores. In order to meet the expectations of the production of good quality vegetables, it is necessary to constantly invest in modern, more efficient machines for harvesting and packaging vegetables as well as replacing the machinery, namely tractors. Over the course of 3 years, the company has increased its revenue by approximately 30%, and the level of costs and investments has also increased significantly. Comparing the farm's financial data from the past three years, it turns out that the situation on the farm is very good as the revenues significantly exceed the costs. The company purchased machines such as: a tractor unit with a refrigerated trailer, a potato harvester, a sprayer, 2 agricultural tractors as well as smaller soil cultivation machines. Moreover, cold stores for vegetables were modernized by replacing refrigeration units. The analyzed costs result from purchase invoices and declarations submitted to ZUS (Social Security Office). The company's revenues are presented together with the incurred costs in Figure 2.



**Figure 2.** Revenues and costs of a selected vegetable farm in 2016-2018.

Source: Author's own study based on data obtained from the farm.

When analyzing the revenues from each month of the year for 3 years, it can be easily observed that the largest revenues were generated in the autumn and winter months: October, November, December. The smallest amounts are recorded in April, May and June, when small amounts of vegetables are sold. During the analyzed years, the highest level of profit was achieved in 2018 (Fig. 3).



**Figure 3.** Revenues from the sale of vegetables by months and years 2016-2018 (in PLN).

Source: Author's own study based on data obtained from the farm.

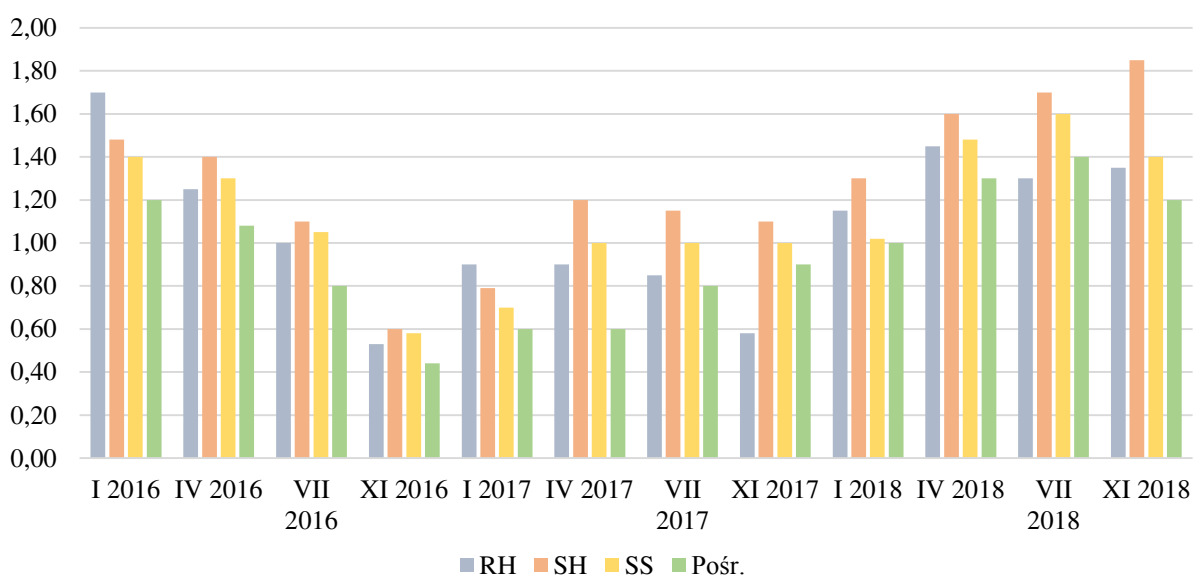
The farm has been cooperating with a foreign hypermarket chain for 20 years. For 10 years it has also been supplying its products to a Polish supermarket chain. Such long-term cooperation has allowed the farmer to: double the cultivation area, invest in innovative machines and production lines, expand cold stores and storage rooms, introduce the GLOBALGAP system, participate in numerous training courses on the quality of agricultural



and food products, rodent control, HACCP, disinfection and pest control, Health and safety. The structure of vegetable sales on the surveyed farm is as follows: the hypermarket chain orders 60% of all crops, supermarkets purchase from 30 to 35%, and an intermediary production and trade company orders 5-10% of the harvest.

The farm delivers to the distribution centres of cooperating retail chains 5-6 times a week. The location of the farm favours cooperation with other trading units, as the distance of the farm from distribution centres is approximately 25-30 km, while the wholesale market is only 5 km away, and the intermediary company approximately 10 km.

While checking market prices and analyzing the profitability of selling vegetables at the selected farm to the above-mentioned distribution channels, the VAT invoices of the surveyed company were analyzed as well as the price reports of the Bronisze Wholesale Market. The selling prices of carrots to various customers were analyzed, which showed that it is best to sell to supermarket and hypermarket chains. Over the course of three years and 12 periods considered, the sales price of 1 kg of carrots was recorded 10 times as the highest in the case of distribution to hypermarket chains and supermarkets. The average sales prices of carrots to hypermarket chains were 14% higher, and to supermarkets by 6%, compared to the Bronisze Wholesale Market. The selling price of carrots to intermediaries was many times lower than the price quoted on the Bronisze Wholesale Market. A detailed breakdown of carrot sales prices and their prices in PLN per kilogram in 2016-2018 is shown in Figure 4.



**Figure 4.** Sales prices to individual recipients (RH - wholesale market, SH - hypermarket chain, SS - supermarkets, Pośr. - intermediary) (in PLN).

Source: Author's own study based on data provided by the farm and data from the Warsaw-based agricultural and food company RH S.A. "Bronisze".

Potato sales also looked similar when analyzing sales offered to different recipients. In the same 12 analyzed periods as in the case of carrots, the price for 1 kilogram of potatoes was recorded as many as 9 times as the highest in the sale to supermarkets and hypermarket

chains. The average prices at these recipients were 8% higher than those at the Bronisze Wholesale Market.

Corresponding to the analyzed sales prices of carrots and potatoes, the sales price of 1 kilogram of onions was also the highest for supermarkets and hypermarkets, in 8 out of 12 examined periods. Prices were higher in the given chains than in the examined RH Bronisze by approximately 13%. Onion sales prices to intermediaries were on average 9% lower than in the examined Bronisze Wholesale Market.

Sales prices for various recipients were calculated by analyzing data provided by the farm and the Warsaw agricultural and food wholesale market RH S.A. "Bronisze". By examining the sales prices of selected vegetables listed earlier by individual recipients, it can be determined that, on average, the prices of retail chains are much higher compared to those at RH Bronisze, as well as those of the intermediaries. However, when market prices are very high, chains cannot pay such prices to the manufacturer. The middleman had the worst position because he bought vegetables at the lowest prices. The study did not take into account the costs of fuel, packaging or production of the goods.

On the farm under study, an annual increase in investment opportunities can be observed, and the company has ensured the high quality of the manufactured product over the years. The farm takes care of recycling and returns all plastic packaging. However, the farmer did not decide to introduce water reuse using a private sewage treatment plant on the farm, due to unprofitability.

#### **4. Summary and discussion**

The subject of the analysis was the technological and market aspects of vegetable production on the example of a selected farm. The article analyzed data on the condition of vegetable and agricultural farms in Poland. The production potential was presented as well as some differences in the volume of vegetable production. The paper presents changes taking place in the country over the years in the volume of vegetable yield. Lastly, the volumes of vegetable sales abroad and their purchase from other countries are presented.

The case study farm produces goods for over 10 months a year, which significantly affects the continuity of supplying the customer with fresh vegetables. The main recipients of its products are supermarket chains. Producing large quantities of goods requires adequate supply of warehouse space and vegetable processing halls. The surveyed farm is highly automated, innovative machines are a necessary annual investment of the farm in order to maintain its competitiveness and increase the value of the business. The farmer's activities were usually more intense in summer and autumn. An important factor in achieving success was the appropriate dosage and fertilization of the plants. One of the most important indirect factors in

the production of vegetables in the analyzed case is ensuring the appropriate quality of the product. The quality measured in the guidelines obtained by the farm for certificates as well as compliance with EU standards. The surveyed farm records a steady increase in investment opportunities as well as the improvement and introduction of recycling and ecological activities.

Managing a vegetable farm in an innovative way, considering the constant development of the business, is very demanding, labour-intensive and requires adequate capital. It is necessary to invest in new technologies, machines and devices that improve production and packaging, as well as to introduce possible changes that may bring an advantage over the competition in the long run. With a significant supply of vegetables on the market in the country, efforts should be made to improve efficiency, to conduct intensive production to reduce unit costs as well as to improve the yield per hectare. Nowadays, customers of vegetable farms pay particularly close attention to all aspects of plant production. Among other things, the type and quality of storage, compliance with many safety rules and the certificates held, which are necessary to be able to sell vegetables and fruits to retail chains.

Currently, the production market is extremely competitive. The number of regulations and the necessity to introduce system and management innovations are constantly growing. Thanks to the maximum use of technological resources available on farms that produce vegetables, producers are able to obtain yields many times higher than before. An important aspect of European farms in the coming years is the introduction of organic and safe food.

The sale of vegetables, with particular emphasis on the domestic market, depends mainly on supply. However, the supply is determined by weather conditions in the country, which affect the growing season and the quality of products. A high supply rate means that vegetable prices will be relatively low in comparison to the years in which supply was low. Farmers who cultivate large farms cooperate most profitably with retail chains. However, small producers should choose the wholesale market as their main supply channel if it is territorially convenient to supply the product to trade.

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## THE ROLE OF TECHNOLOGY PARKS IN ECONOMIC GROWTH – THE PERSPECTIVE OF STUDENTS OF ECONOMICS

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**Purpose:** The article aims to assess the knowledge and interest in the offer of technology parks by students of faculties offering theoretical and practical knowledge about starting and running a business.

**Design/methodology/approach:** A questionnaire plus the Pearson correlation coefficient and the T-Czuprow dependence coefficient were used to examine the relationship between the study variables.

**Findings:** Students are well acquainted with the offer of technology parks, while not sufficiently aware that these entities can provide them with support at the stage of setting up or developing their business activity.

**Practical implications:** Intensifying activities promoting the activities of the surveyed institutions at universities could activate entrepreneurial thinking and the involvement of academic youth.

**Originality/value:** The article highlights the important role of technology parks in supporting young entrepreneurs, which makes it a valuable source of information for those interested in starting their own businesses.

**Keywords:** technology parks, entrepreneurship, business, students, academic entrepreneurship.

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

## 1. Introduction

The main objective of technology parks is to offer a good location for technological and innovative companies in a particular area. Moreover, they provide businesses with the opportunity to make use of their infrastructure and take part in the unique and competitive environment that the park fosters. Due to the commercial nature of their business, the parks' offer is primarily aimed at long-established companies that are able to accept market rental rates, which are often very high. In view of the above, it would be necessary to verify how popular the services of such institutions are among young people who are about to start their own business. The study includes the opinions expressed by students of academic fields where the topic of starting and running a business is covered both in theory and practice. The aim of the research was to assess their familiarity with technology parks and their interest in the offer of such complexes. A survey questionnaire was used to verify this information. Meanwhile, in order to examine the relationship between the variables included in the study Pearson's contingency coefficient and Tschuprow's T correlation coefficient were applied.

## 2. Literature review

The prevailing dynamics of the market indirectly forces enterprises to embrace innovation as a means to ensure their long-term viability (Bańka et al., 2023). One of innovation-oriented institutions is technology park.

Technology parks are classified as innovation centres that fall into the category of business environment institutions. According to Polish law, a technology park is a cluster of separate real estate units with technical infrastructure, created in order to facilitate the flow of knowledge and technology between research units and entrepreneurs, where business owners using modern technologies are offered services in the scope of counselling in the creation and development of enterprises, technology transfer and conversion of research findings and development efforts into technological innovations, as well as to create opportunities for these entrepreneurs to conduct business activity through the use of real estate and technical infrastructure on a contractual basis (Ustawa z dnia 20 marca 2002 r. o finansowym wspieraniu inwestycji, Dz.U. Nr 41, poz. 363 z późn. zm. art. 2). These complexes strengthen their position in society and the economy by cooperating with institutions representing the science and business sectors (Skowron-Grabowska, 2020).

Other definitions relating to the business environment institution in question are given below.



**Table 1.**  
*Definitions of the technology park*

Author	Definitions of the technology park
Petree et al., 2000	Institutions intended to facilitate the production and commercialisation of advanced technologies by creating synergy between research centres, educational institutions and technology companies.
Brezdeń et al., 2010	A separate scientific and industrial team formed with the participation of local government authorities, offering enterprises modern technologies and services in the field of consulting in the creation and development of enterprises, technology transfer and commercialisation of scientific research results, as well as providing real estate and infrastructure to these entrepreneurs.
Matusiak, 2010	Institutions that aim to optimise the conditions for the creation and development of innovative companies and technology transfer.
Nauwelaers et al., 2014	Instruments used in the process of technology transfer, actively supporting the process of commercialisation of knowledge and technology, serving as a link between innovative solutions developed in academic centres and their recipients – entrepreneurs (narrower approach). Institutions that promote the development of an innovative environment and have an important role of focusing on the multifaceted connections between the various actors that make up this environment.
Waligóra, 2015	One of the basic instruments of public authorities' innovation policies, whose primary goal is to increase a region's competitiveness by creating business environments that encourage investors to start and grow their businesses.
Kwieciński, 2018	The most extensive form of so-called business environment institutions, whose work is related to renting space for laboratory equipment, financial services, as well as modern business development services (construction of pro-innovation networks, company formation, patent and legal support).
Hunjet et al., 2018	A place where technology, entrepreneurship, knowledge, innovation and creativity come together to support the creation of visions, ideas and new values.
International Association of Science Parks and Areas of Innovation, 2023	An organisation managed by qualified professionals whose goal is to increase the prosperity of the community in which it operates by promoting a culture of innovation and competitiveness among entrepreneurs and knowledge-based institutions.
Mondal et al., 2023	Selected locations where new technology-based companies and other SMEs can connect and promote a culture of innovation.

Source: Own elaboration based on the subject literature.

Taking into account the definitions listed above, it can be pointed out that a technology park is an institution whose aim is to integrate the scientific community with the business environment, enabling cooperation between both parties, as well as helping them develop and strengthen their position. In particular, technology parks aim to support the optimisation of the conditions for technology transfer processes for young, innovative companies offering products that require high technological commitment, as well as for scientific institutions that intend to commercialise the results of their research. Such a complex generates a synergy effect as enterprises with high growth potential and scientific institutions are concentrated in a strictly defined area. Also, the park offers a wide range of business-related services.

Technology parks are considered to be among the most developed centres of innovation and entrepreneurship, both from an organisational and conceptual point of view. They are also often referred to as 'science parks', 'research parks', 'science and research parks', 'science and technology parks', 'industrial and technology parks', 'technopoli' or 'technoparks'. It is quite common for these institutions to perform the functions of other innovation and entrepreneurship

centres within a single structure (technology parks may house technology incubators, training and advisory centres, technology transfer centres and academic business incubators) (Płoszaj, 2013). Technology parks are usually located close to one or more universities and research institutions or are well connected to them. Thanks to this, enterprises intending to take advantage of the park's support services are at the same time drawn by the proximity of universities and scientific institutions, as well as the attractive location.

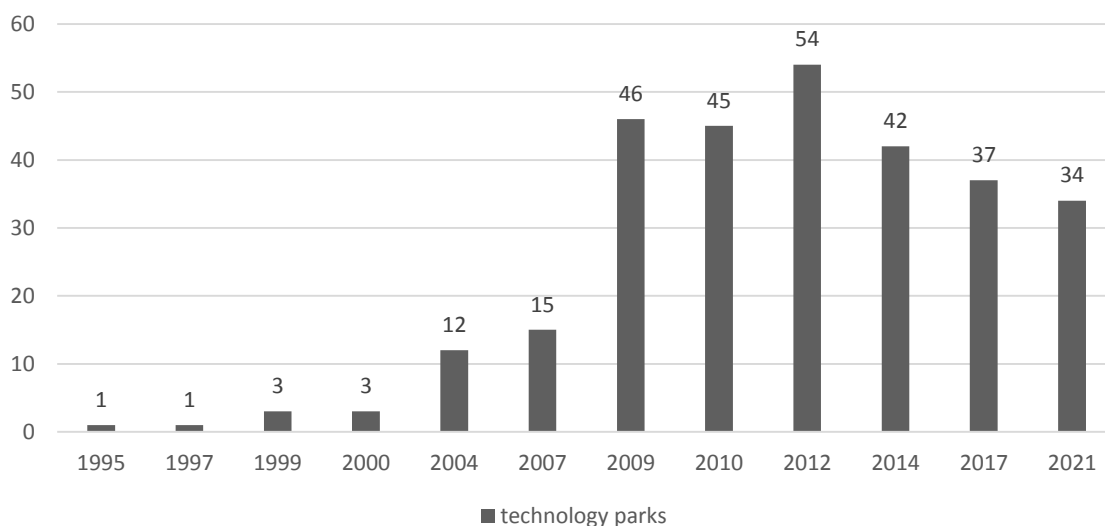
The present-day scope of the institutions in question harks back to the concept of industrial districts pioneered by British economist Alfred Marshall. It is believed that the first technology park established in the world was the Bohanson Research Park in Menlo Park, founded in the United States in 1948. The most famous one, however, is the Stanford Research Park, established three years later, located in Silicon Valley by Stanford University. Silicon Valley itself is the area where most of the world's technology companies are concentrated. The companies that were set up there benefited primarily from their close proximity to the university and the technology park, which allowed them to tap into the results of research carried out at these institutions, among other benefits. The pioneering role of the United States in the creation of technology parks is also reflected in their numbers, as half of them are located in the USA (Bartusik, Sołtysik, 2012). In Europe, the first technology parks did not begin to emerge until the 1980s.

The first European institution to operate in line with the principles of technology parks was the Technology Centre Ruhr in Bochum, Germany, established in 1981. However, many believe that Berlin's Centre for Entrepreneurship should be considered the first European technology park (Waniak-Michalak, 2015). The increased pressure on the participation of universities in industrial clusters has significantly accelerated the proliferation of the idea of technology parks (Protasiewicz, Trzaska, 2020). The increasing number of these institutions in European countries also stems from the fact that under its policy, the European Union holds and allocates a significant part of its budget to supporting and developing the innovation environment, including the development of intermediary institutions between scientific and industrial sectors. In 1984, the European Business & Innovation Centre Network (EBN) was established. At present, it comprises around 140 Business and Innovation Centres (BICs). The aim of this organisation is to support the development of innovative entrepreneurs, start-ups and SMEs (Protasiewicz, Trzaska, 2020). In the last two decades, the development of business environment institutions (including technology parks) has been dictated by European strategies: the Lisbon Strategy (e.g. strengthening support policies for businesses, especially for SMEs, support for innovative projects, reduction of administrative barriers, access to infrastructure for new companies, access to new technologies, promotion of the idea of innovation and research as well as access to funding) and the Europe 2020 Strategy (e.g. improvement of administrative conditions for conducting innovative activities by companies, innovative partnership at the EU level, strengthening the role of structural funds, development of rural areas, increasing investment in R&D and creation of mechanisms and

infrastructure enabling the transfer of theoretical knowledge to businesses, creation of national and regional innovation systems) (Protasiewicz, Trzaska, 2020).

It should be stressed that different terms for the institutions in question are used in various parts of the world. In the United States and Canada, the term 'research park' is commonly used, in Asia (e.g. Japan, China, Singapore, South Korea, the Philippines and Taiwan) call such a complex 'a technology park'. Meanwhile, in Europe science parks coexist with technology parks. While science parks are characterised by a smaller scale of operations, very strong links to academic centres and less frequent cooperation with industry, technology parks, which are much larger, are mainly focused on production (Marszałek, 2019).

The first technology park set up in Poland is Wielkopolskie Centrum Innowacji i Przedsiębiorczości S.A. [Greater Poland Center for Innovation and Entrepreneurship S.A.], established in Poznań in 1990 (Waniak-Michalak, 2015; Bąkowski, Mażewska, 2012). However, the development of these institutions in the country's economic conditions was initially very limited. Their focus was mainly on the problems of structural unemployment and initiatives aimed at supporting entrepreneurship rather than on taking innovative measures and commercialising research findings. With the stabilisation of the support system, parks became subjected to the rules of the market. As a result, the service offer was heavily commercialised (e.g. office rental) and also the functions of promoting innovation, marketing and supporting internationalisation were put in place. At present, in its policy, the EU places more emphasis on the effectiveness of business environment institutions rather than their quantity. This also applies to technology parks. Perhaps this is why a gradual decline in the number of these institutions has been observed since 2014. The figure below shows the number of technology parks operating in Poland between 1995 and 2021.



**Figure 1.** Number of technology parks operating in Poland between 1995 and 2021.

Source: Bąkowski, Mażewska, 2018.

Technology parks perform a number of different functions. These include as follows (Steruska et al., 2019; Błaszczuk et al., 2017; Mażewska, Tórz, 2019; Petree et al., 2020; Matusiak, 2008; Poznańska, 2001):

- start-up incubation – offering extensive assistance (including administrative support) to young enterprises (start-ups), mainly in the SME sector,
- enabling entrepreneurs to carry out R&D activities,
- cooperation with scientific entities and linking them with business,
- stimulating and managing the flow of knowledge and technology between scientific, research and development units and enterprises, e.g. through activities such as: assistance in establishing contacts between technology providers and recipients, preparation of an offer or request for technology, consulting regarding the process of implementing technology and assistance in advising enterprises on intellectual property rights,
- consultancy services (e.g. high-tech consultancy),
- adapting buildings (laboratories, workshops), land along with technical infrastructure (e.g. computer network, broadband internet) for the creation of new technologies and research,
- integrating companies with other entities – the creation of a business environment where companies support each other and exchange knowledge,
- contractual use of the university's scientific, engineering and IT resources,
- assistance in obtaining financing (e.g. cooperation with business angels or benefiting from venture capital),
- determining the scale of innovation of the companies located there,
- increasing the level of innovation in the region – encouraging innovative activities, the flow of information between the science and business sectors (e.g. the creation of spin-off and spin-out companies),
- promoting regions – the park can be viewed as a showcase for a given area, attracting investors, customers and future contractors.

The development of technology parks goes hand in hand with the growth of technopoly-oriented agglomerations and progressive specialisation of companies. The establishment of parks can be initiated by both public and private entities. Increasingly, EU countries are using public-private partnership institutions to set up such parks. Only a handful of technology parks operate without public support (Protasiewicz, Trzaska, 2020).

### 3. Methods

The survey was conducted in spring 2022 among students of the Faculty of Economics, Finance and Management at the University of Szczecin. 335 students from two fields of study took part in the survey, i.e. management (285) and entrepreneurship and investments (50 students), of which as many as 62.4% of respondents are considering starting their own business. These fields of study were selected for the study because of their profile partly related to setting up and running a business.

Entrepreneurship and investments are a practical field of study. The content of education in the field of study includes issues in the field of management and quality science, economics and finance as well as related disciplines. The students have an opportunity to learn practical skills with regard to starting and running their own business, developing a family business or pursuing the career of a local leader - a creator of economic ventures and initiatives undertaken within the local community. The practical profile enables education in line with the expectations of employers and with the participation of practitioners - entrepreneurs, managers and specialists. Graduates of the field of study are prepared to: establish and develop their own enterprise, take over a family business, work in managerial and specialist positions in small and medium-sized enterprises, in consulting companies and other organisations such as institutions supporting entrepreneurship, acting as a leader of local entrepreneurship, e.g. in the countryside, in a small village. The field of study is implemented in cooperation with entrepreneurs and local business support institutions. Students have the opportunity to become acquainted with the functioning of business in practice, including thanks to numerous visits by students to small and medium-sized companies, innovative forms of teaching are also implemented: theory combined with practice, meetings with entrepreneurs, decision-making games, case studies, work in small teams, creating original projects and many others.

The aim of study in the field of management is to acquire specialist knowledge in the field of management sciences, economics and related disciplines; shaping a critical understanding of phenomena as well as economic and organizational processes, as well as developing the ability to use methods and techniques necessary to solve problems and make decisions within the organisation. In addition, the studies are aimed at preparing graduates for the implementation of their own entrepreneurship, career development of specialists and managers in management structures. In the area of social competences, the studies are aimed at shaping ethical and social sensitivity, commitment and a sense of responsibility in the work environment and beyond, awareness of the need and development of personal development and lifelong learning skills. The studies programme includes both general managerial education (useful for running your own business and managing teams of people), as well as specialist management education. The knowledge acquired in the management field of study is of an applied nature and includes mainly theories and concepts describing and explaining the formation, functioning,

transformation, development and interaction of organisations, economic entities, but also organisations in the public and non-governmental sector. The graduate is prepared to work as an analyst and specialist, and to manage a small team of people in business and other organisations, as well as to run their own business.

The degree of studies is the criterion that divided the research group into two groups, which are almost equal in terms of quantity - 52.5% were first-cycle students and 47.5% were second-cycle students. In addition, 72.5% of the respondents are full-time students, and the remaining 27.5% are part-time students. 69.3% of respondents were female, while 30.7% were male. The aim of the study was to assess the familiarity with and interest in the offer of technology parks. It was also verified which areas of activity of business support institutions were indicated by students who are interested in using the services of the surveyed institutions. Students could choose from the areas of support most often offered by business environment institutions, namely: training and workshops, consultancy and individual consultations, promotion and advertising, obtaining grants for starting a business, assistance in applying for EU funds, access to current economic information, as well as various meetings and business and integration trips.

The survey questionnaire was directed to students electronically (students received a link that took them to the survey form). In addition to the key substantive part, the questionnaire contained important additional elements, such as: the title of the study, the name of the person or institution conducting the study, the purpose of the study and other explanations for the respondents. In the questionnaire form, mainly closed and semi-closed questions were used, as it limited the percentage of people resigned from answering the question. In addition, these types of questions made it easier to classify and analyse the data. A part of the survey form was also a metric, thanks to which it was possible to obtain the necessary information about the individual characteristics of the respondent, such as: gender, field of study, year of study. Collecting this data made it possible to analyse them in terms of selected characteristics of the surveyed students.

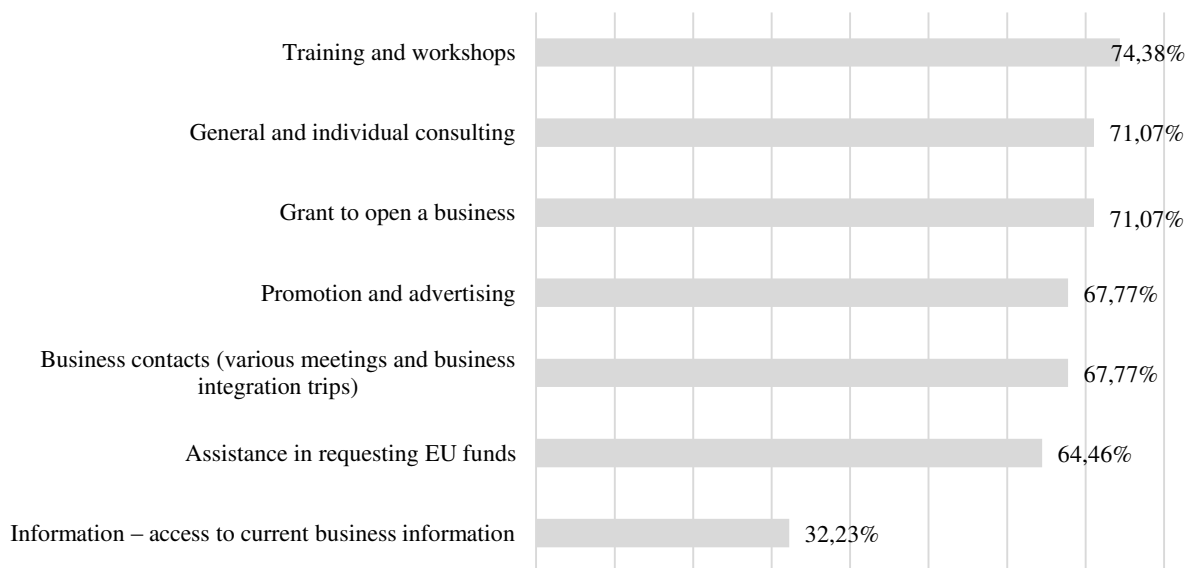
Pearson's correlation coefficient and T-Czuprow dependence coefficient were used to examine the relationships between the data being processed. The Pearson coefficient ( $r_{xy}$ ) is a linear correlation coefficient that indicates the level of linear relationship between random variables. Its value falls within the closed interval  $[-1, 1]$ . The greater the absolute value of this coefficient, the stronger the linear relationship between the variables. 1 indicates a positive relationship, - 1 in turn indicates a negative relationship between the characteristics. 0 indicates the absence of a linear relationship (Zeliaś, 2002). The T-Czuprow coefficient ( $T_{xy}$ ), on the other hand, is a dependency ratio that is used to measure the strength of the relationship between two nominal variables. It assumes values from the closed range  $[0, 1]$ . The closer the value of this coefficient is to one, the stronger the relationship between the examined characteristics (Domański, 2001).

The analysis contained in this article is part of a more extensive study on business environment institutions (Leoński, Tylżanowski, 2022; Tylżanowski, 2023).

## 4. Results

The surveyed group of students was asked to answer the question whether they would like to make use of the offer of technology parks if they were planning to set up a business or running one. Students had the opportunity to express interest (or disinterest). As many as 72.84% of students were familiar with the offer of technology parks, but only 36.12% of respondents were interested in benefiting from it. Students (in particular those pursuing studies in economics) should be familiar with the offer of entities that at some point may become one of their strategic partners facilitating the start or continuation of their own business.

The survey also asked which areas of operation pursued by business environment institutions the students would most like to benefit from when planning to run a business. The figure below details the percentage of these institutions' areas of support indicated by students who expressed an interest in using the services of technology parks.



**Figure 1.** Areas of activity of business support institutions in the opinion of students who are interested in using the services of technology parks.

Source: Own study based on own research.

The area of activity that was considered key by students interested in using technology parks was training and workshops, indicated by 74.38% of respondents. Training and workshops should be an intrinsic part of the operation of any company that wants to grow and continuously raise its profile on the market. The next most important area for respondents is consultancy and individual consultations, as well as obtaining funding including, but not limited to, grants (71.07% of responses). Receiving non-repayable funds at the start of a business, i.e. at the time of its greatest capital intensity, is a great form of support for young entrepreneurs. Further areas of business environment institutions indicated as important are assistance in obtaining business contacts as well as promotion and advertising, indicated by 67.77% of students. It is worth noting that every company starting its activity should engage in adequate promotion in order to gain visibility on the market. Providing assistance in applying for EU funding was important to 64.46% of students. Access to information turned out to be the least significant area of business environment institutions' operations for the surveyed group of students (32.23% of responses).

The study carried out on a group of students from the Faculty of Economics, Finance and Management also examined whether the independent variables (gender, field of study, degree of study and mode of study) had an impact on the dependent variable (desired areas of support among those interested in using the services of technology parks). The table below shows the percentage of students' answers to the question concerning the dependent variable. Four criteria were taken into account: gender, field of study, degree of study and mode of study. In addition, the following table presents the values of correlation coefficients between the independent variables as well as between the independent and dependent variables.

**Table 3.**

*Percentage of students who answered the question regarding the desired areas of support by gender, field of study, degree of study and mode of study*

Criterion		Desirable areas of activity of business support institutions by students who are interested in using the services of technology parks [in %]						
		Training and workshops	General and individual consulting	Grant to open a business	Promotion and advertising	Various meetings and business integration trips	Assistance in requesting EU funds	Information - access to current business information
Gender	Female	80,25	75,31	75,31	70,37	69,14	70,37	33,33
	Male	62,50	62,50	62,50	65,00	65,00	52,50	30,00
Field of study	Management	72,90	69,16	70,09	68,22	66,36	64,49	31,78
	Entrepreneurship and investments	85,71	85,71	78,57	64,29	78,57	64,29	35,71
Degree of study	I	75,41	63,93	67,21	75,41	68,85	59,02	34,43
	II	73,33	78,33	75,00	60,00	66,67	70,00	30,00
Mode of study	Full-time	79,52	68,67	75,90	78,31	69,88	68,67	33,73
	Part-time studies	63,16	76,32	60,53	44,74	63,16	55,26	28,95

Source: Own study based on own research.



**Table 4.**

*Values of Pearson's correlation coefficients between independent variables and values of T-Czuprow dependence coefficients between independent variables and the dependent variable*

Criterion		The value of the Pearson correlation coefficient $r_{xy}$ between the individual variants of the criteria (independent variables) when answering the question regarding the indication of the desired areas of business environment institutions by students who are interested in using the services of technology parks	The value of the T-Czuprow $T_{xy}$ relationship between the criteria (independent variable) and the indications of desired areas of activity of business environment institutions by students who are interested in using the services of technology parks (dependent variable)
Gender	Female	0,9232	0,0259
	Male		
Field of study	Management	0,9138	0,0296
	Entrepreneurship and investments		
Degree of study	I	0,7709	0,0470
	II		
Mode of study	Full-time	0,6652	0,0595
	Part-time studies		

Source: Own study based on own research.

## 5. Discussion

The above summary indicates that there is a very strong linear relationship in the case of criteria such as 'gender' and 'field of study', whereas in the case of criteria such as 'degree of study' and 'mode of study' a strong relationship exists between the independent variables in response to questions regarding the indication of the desired areas of activity of business environment institutions by students interested in using the services of technology parks. This means that women responded very similarly to men. Students of general academic and practical programme profiles also gave largely comparable answers. Also, no significant differences were noted between the responses of undergraduate and graduate students or between the responses of full-time and part-time students. At the same time, very low values of Tschuprow's T correlation coefficient indicate that gender as well as field, degree and mode of study did not affect the answers provided by students.

The results of the study indicate that students are well acquainted with the range of services offered by technology parks, yet at the same time they are not sufficiently aware that these entities can provide them with support, both at the stage of establishing and developing their business. Intensifying efforts to promote the activities of the surveyed institutions at universities could encourage academic youth to think entrepreneurially and get involved. Regardless of their field of studies, programme profile or degree of study, students should be provided with the

opportunity to acquire knowledge and skills necessary to run a business on their own. They may be given practical information in this regard, for instance, during training courses run by representatives of entities such as technology parks, especially since training and workshops are the most preferred area of support by students interested in using the services of these institutions. Academic staff should also step up their efforts to increase students' interest in the offer of technology parks. The institutions under study can increase the likelihood that the businesses run by graduates in the future will be more technologically advanced and will expand their efforts towards innovation.

## 6. Summary

It bears strong emphasis that the role of technology parks in the innovation system is crucial, which stems from the fact that, for example, as non-state public sector entities they perform public utility functions and play a major part in linking the science sector with the business sector, increasing the efficiency of both parties. All entities potentially interested in innovative processes should participate in the creation and development of technology parks, namely: universities and other scientific institutions (fostering entrepreneurial and creative attitudes, providing innovative ideas, initiating commercialisation processes), public authorities (contribution in the form of buildings, roads, land, funds and ensuring favourable political and legal conditions), financial institutions and enterprises (supply of innovative ideas and capital).

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## COMMERCIAL ATTRACTIVENESS OF INDUSTRY 4.0 TECHNOLOGY IN THE OPINION OF CUSTOMERS OF THE YOUNG GENERATION

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**Purpose:** The main objective of the article is to present the results of a study on the attitude of young generation customers to Industry 4.0 technologies used in manufacturing companies and the resulting conclusions.

**Design/Methodology/Approach:** The CAWI methodology was used in the study. The respondents were mainly students of the University of Gdańsk and the Pomeranian University in Słupsk (320) aged 18-35, as full-fledged clients of the young generation. As part of the survey, respondents explained what Industry 4.0 technology is all about.

**Conclusions:** As the basic results of the study turned out to be consistent with the hypotheses (younger generation customers are mostly ambivalent about the technologies used in manufacturing companies), an additional study was conducted on what is important to them. This part of the study yielded very interesting results from a marketing point of view.

**Research limitations/implications:** The main limitation is that the study was conducted on students majoring in management. Currently, the research is being continued, consisting in polling the opinions of students of humanities and engineering.

**Practical implications:** The results of the study can be used in the practice of marketing management of enterprises.

**Societal implications:** The results of the study will have no impact on society at large.

**Originality/value:** The publication is addressed to academics at management and marketing faculties and practitioners of the management of manufacturing enterprises. The main value of the article is the innovative (so far unprecedented) context of deliberations on technologies included in the Industry 4.0 concept.

**Keywords:** customers of the young generation, Industry 4.0 technologies, Industry 4.0, preferences, quality features of products.

**Thesis category:** research paper.

## 1. Introduction

After a short break, focused on dealing with the causes and effects of the COVID-19 pandemic (Walentynowicz, Szanter, 2021), the topic of transformation of economies towards a digital economy, with particular emphasis on the concept of Industry 4.0, has become attractive in the science and practice of business management. That concept has been known since 2011 (Klingenberg, until Vale Antunes, 2017), however, before 2020, in practice, the implementation of technological solutions included in the concept of Industry 4.0 was not as dynamic as science postulated (Wilkesmann, Wilkesmann, 2018; Friday, 2019; Pirug et al., 2021).

The concept of Industry 4.0 is currently promoted for various reasons (economic, ecological, social, political; increasing the competitiveness of enterprises, industries, economies; improving the efficiency of cities, regions, countries and on a global scale; solving environmental, social and demographic problems) and shown in various perspectives (business, technology, innovation, quality of ecology, client, industry and non-business). But all the time the main emphasis on the application of this concept is applied to enterprises. According to research by various authors (Mychlewicz, Piątek, 2017; PriceWaterhouseCoupers, 2017; Soldaty, 2017; Czupryna-Nowak, 2020; Michna, Kazmierczak, 2020; Babu et al., 2023), the comprehensive application of industry 4.0 solutions in enterprises is to lead to benefits such as:

- 1) increase in revenues,
- 2) reduction of operating costs (as a result of elimination of various types of losses, material savings or the number of employees),
- 3) increase in productivity,
- 4) increase in the efficiency of the use of machinery and equipment,
- 5) increase in the efficiency of management of various types of areas of the company as a result of greater access to data,
- 6) increase in the flexibility of the company,
- 7) increasing the level of innovation of the company,
- 8) increasing the speed of response to customer expectations and shortening their service times,
- 9) closer relationships with customers,
- 10) shortening the time of designing and placing the product on the market,
- 11) increase in the level of satisfying customer needs,
- 12) increase in profitability and return on investment,
- 13) increasing the competitiveness of the company,
- 14) increasing the attractiveness of the company as a business partner,
- 15) increase in the market value of the enterprise.

However, in order for the situation not to look potentially so colorful (so attractive), individual authors also raise the issues of threats related to the development of this concept (limitations in the supply of various types of IT specialists; increase in investment outlays and capital needed for this, increase in operating costs of this type of enterprises; threats to the security of key data; stress of employees in connection with the implementation of new technologies; qualification exclusion of some employees; polarization of society's earnings; AI threats) (Ersoy, 2022; Walentynowicz, 2020). In this way, after balancing the various costs and benefits of implementing Industry 4.0 solutions in organizations, we get a true picture of this concept, but it is unquestionable that progress cannot be escaped and in the future new technologies will dominate our lives and the functioning of organizations (Kelly, 2017).

However, how are the customers looking at the implementation and application of technology of Industry 4.0? So far, this research thread has been poorly explored in emerging publications (e.g. Alexander, 2020). However, since the company's activity is strictly dependent on how customers perceive it (Cohen, 1994), it seems important to know what value for customers has the use of various types of Industry 4.0 technologies by modern enterprises. Potentially, it seems small, because customers are primarily interested in the results of the company's activities that directly affect them (quality of products and services, their price, brand or level of service) and do not care too much about how companies achieve it, but the author decided to check this assumption empirically. The following research hypotheses were formulated:

1. Customers of manufacturing companies have very little interest in what modern technologies that are included in the concept of Industry 4.0 the company uses.
2. First of all, they are interested in the parameters of the product they buy on the market (quality, price, brand, warranty conditions, etc.).
3. If customers of manufacturing companies are interested in any modern technologies used by the company, it is primarily those that have a direct impact on the final effects of the products they purchase.

Therefore, in 2022, he conducted a research on students of the University of Gdańsk and the University of Pomerania in Słupsk as full-fledged participants in the commercial products market. The focus was on the customers of the young generation (18-35 years old), because for most companies they are the main target group of customers today and will continue to be so in the future.

The results of this study may be some hints for marketing managers about whether it is worth and how to promote the use of a given technology by the company among customers. Therefore, the main purpose of this article is to present the results of the study and the main conclusions resulting from it.

## 2. The essence of Industry 4.0

The emergence of the concept of Industry 4.0 is associated with the development and large-scale introduction of new information technologies (IT), mobile technologies (MT), machine learning (ML), artificial intelligence (AI) and the development of technology and data transfer speed (Internet 4G, 5G) (Sehlin et al., 2019). These technologies have led to the development and large-scale industrial application of solutions such as (Alcacer, Cruz-Machado, 2019; Iwański, Gracel, 2016; Mychlewicz, Friday, 2017; PriceWaterhouseCoupers, 2017; Pirug et al., 2021):

- 1) collection, storage, processing and use of a huge amount of internal and external data of the company (Big Data, cloud computing) for production management, for demand analysis and adaptation of the assortment offer to the market, for monitoring the state of wear and tear of machinery and equipment, in quality management and logistics,
- 2) large-scale use of e-communication and online information in the integration of supply chains (value creation chains) between business partners,
- 3) use of new technologies in manufacturing – additive technologies (3D printing), new materials and new technologies of their processing, automation and robotization of new generation manufacturing (cobots), cyberphysical (mechatronic) elements of production systems,
- 4) use of new technologies in logistics – digitally controlled warehouses, manipulators and autonomous transport devices (AGV), mobile, voice and visual systems supporting the completion of parts, geolocation, RFID (Radio-Frequency Identification), autonomous vehicles and drones,
- 5) direct communication of machines within the enterprise (M2M - Machine to Machine) and between enterprises (IoT - Internet of Things),
- 6) customization of production – more personalized, custom-made products and services, intelligent products,
- 7) use of mobile technologies in production systems management and logistics,
- 8) use of virtual reality and digital simulations in product design (Digital twin), production system design, production management, human resources management and logistics,
- 9) large-scale use of artificial intelligence in the activities and management of enterprises (e.g. bots in customer service or expert systems in decision-making),
- 10) extensive use of the Internet in communication between people and machines,
- 11) wide use of IT systems – practically for every field of functioning and management of enterprises,
- 12) new business models (virtual and networked),
- 13) cybersecurity,
- 14) new systems of settlements between enterprises in Blockchain technology.



The comprehensive goal of introducing the above solutions is to obtain Smart Factories – smart factories with minimal use of physical labor of people and maximum automation and autonomy of their functioning based on digital technologies (Stadnicka et al., 2017). The area of using human work in these systems is to change from physical and managerial work into conceptual, supervisory, development and maintenance work (Santarek, 2017). However, unlike the concept of Computer Integrated Manufacturing (CIM), which aimed to create fully automated factories without people, Industry 4.0 aims to effectively apply technology to help and collaborate with workers (Rauch et al., 2019).

In addition, the generation and logistics systems in the individual Smart Factories are to cooperate automatically (along the value chain), including internal and external transport systems (Aysenur, 2023). The essence of industry 4.0 is therefore the comprehensive use of the above-mentioned technologies to build a sustainable competitive advantage of enterprises (industrial and hard services) and economies (Balasingham, 2016).

Additional areas of use of new technologies (included in the concept of Industry 4.0) will be: soft services (Smart Services), buildings (Smart Buildings), cities (Smart Cities), trade (Smart Commerce), entertainment (Smart Entertainment) and health care (Smart Helthcare). These technologies, as already mentioned, have a chance to strongly contribute to the sustainable development and ecology of the above-mentioned areas of their application. It is estimated that this is an opportunity to create new markets, develop classic products towards "smart" and customized products, meet customer needs higher and solve the problem of employees of "ageing" societies (Dmowski et al., 2016; Babu et al., 2023). It is forecasted that such systems will be the basis for the functioning of economies in highly developed countries in the twenty-first century (Gerbert et al., 2015; Kagermann et al., 2013).

### **3. Methodology of the study**

In order to verify the research hypotheses and obtain answers to the formulated research problems, in the first half of 2022 a CAWI study was conducted on 320 students of the University of Gdańsk and the University of Pomerania in Słupsk, who are clients of the young generation of various types of manufacturing companies. The study was conducted on full-time and part-time students of management, because in the opinion of the authors of the study, as students understanding the issues of marketing, business management and the role of modern digital technologies for modern enterprises, as well as as active participants of the commercial market, often already working and maintaining themselves, in a more conscious and thoughtful way, they could answer often difficult questions. In order to make the answers more reliable, in the first part of each question, the essence of a given technology or issue was first explained, and only then it was asked about the importance of a given issue for the respondent within the

Likert scale. Responses were given by 242 women and 78 men, aged 18 to 25 (297 people) and 26 to 35 years (23 people).

The first part of the study concerned the importance of various types of marketing and quality properties of products offered by enterprises for customers of the young generation. In connection with this research problem, respondents were asked the following questions (Table 1):

**Table 1.**

*A list of questions asked to respondents in relation to the importance for them of various types of marketing and quality properties of products offered by enterprises*

Question number	Content of the question (regardless of whether we buy in a stationary or online store)
1.	How important is the product/company brand for you when choosing a product in the purchase process?
2.	How important is the overall quality of the product to you when choosing a product in the purchase process?
3.	How important is the reliability/durability of the product for you when choosing a product in the purchase process?
4.	How important are the materials used in production when choosing a product in the purchase process?
5.	How important is product design for you when choosing a product in the purchase process?
6.	How important is the modernity of the product (innovative solutions contained in it) for you when choosing a product in the purchase process?
7.	How important is the price to you when choosing a product in the purchase process?
8.	How important are the delivery terms for you when choosing a product in the purchase process?
9.	How important is the level of customer service for you when choosing a product in the purchase process?
10.	How important are the warranty conditions for you when choosing a product in the purchase process?
11.	How important is the quality and availability of after-sales service for you when choosing a product in the purchasing process?
12.	How important are the opinions of other customers when choosing a product in the purchase process?
13.	How important are professional reviews (in the press or on the Internet) for you when choosing a product in the purchase process?
14.	How important is the physical purchasing environment for you when choosing a product in the purchase process (aesthetics and good organization of the stationary store space; attractiveness and ease of use of the website)?

Source: Own elaboration.

The second part of the study probed the attitude of these customers to various types of modern solutions used by manufacturing companies. In connection with this research problem, respondents were asked the following questions (Table 2):

**Table 2.**

*List of questions asked to respondents in relation to the importance for them of various types of Industry 4.0 technologies used by manufacturing companies*

<b>Question number</b>	<b>Content of the question</b> (regardless of whether we buy in a stationary or online store)
15.	How important is it to you whether the company whose product you buy uses cloud computing (CC) in its business?
16.	How important is it to you whether the company whose product you buy uses Big Data analysis in its business?
17.	How important is it to you whether the company whose product you buy uses virtual reality (VR) and digital simulations in its activities?
18.	How important is it for you whether the company whose product you buy uses digital solutions supporting vertical integration (VI - Vertical Integration) (on the supplier-company-customer line) and horizontal integration (HI - Horizontal Integration) (within individual cells of the company)?
19.	How important is it to you whether the company whose product you buy uses Augmented Reality (AR) in its business?
20.	How important to you is whether the company whose product you are buying uses the Industrial Internet of Things in its activities?
21.	How important is it to you whether the company whose product you buy uses additive technologies (e.g. 3D printing, rapid prototyping) in its operations?
22.	How important is it for you whether the company whose product you buy uses autonomous robots (e.g. co-bots, AVG, robots supported by artificial intelligence)?
23.	How important is it to you whether the company whose product you buy uses a high level of cybersecurity in its operations?
24.	How important is it for you whether the company whose product you buy uses identification and sensor technologies (e.g. RFID, QR codes) in its activities?
25.	How important is it for you whether the company whose product you buy uses mobile technologies (e.g. smartphones, tablets) in its business?
26.	How important is it to you whether the company whose product you buy uses direct communication between machines and industrial devices (M2M) and machine learning in its activities?
27.	How important is it to you whether the company whose product you buy uses artificial intelligence (AI - Artificial Intelligence) in its activities?
28.	How important is it for you whether the company whose product you buy uses modern technologies in the company's internal logistics (automatic warehouses, self-propelled transport trolleys - AGV, robots and logistics manipulators)?
29.	How important is it for you whether the company whose product you buy uses modern technologies in external logistics (parcel lockers, drones, autonomous vehicles, GPS geolocation systems, electric cars)?
30.	How important is it to you whether the company whose product you are buying uses Blockchain in its activities?
31.	How important is it for you whether the company whose product you buy uses modern technologies in its activities that facilitate the customization of products?
32.	How important is it to you whether the company whose product you buy is widely present on the web (on the Internet)?

Source: Own elaboration.

On the basis of answers to the above questions, the respondents' preferences were evaluated using statistical methods and final conclusions were drawn regarding the research hypotheses.

In the third part of the survey, respondents were asked about the importance for them of the issue of applying various new management concepts in manufacturing companies, but in this article the answers to these questions will not be presented.

#### 4. The attitude of customers of the young generation to the Industries 4.0 technologies used by manufacturing companies

Table 3 presents the respondents' responses. It is clear how whether companies use different types of technologies included in the concept of Industry 4.0 is of little value to respondents (technologies 15, 16, 17, 18, 19, 20, 21, 22, 23, 26, 27, 28, 30). Technologies 25 and 31 (mobile and customization technologies) enjoy a medium level of interest. Of all 18 types of technology, the most important for respondents is whether the company is widely present on the Internet (i.e. information about products, communication with the company via the Internet, promotion of the company on the Internet or, for example, the possibility of buying products online). In the opinion of customers of the young generation, this conclusion seems very logical. Next, they value various types of innovations in the area of external logistics (e.g. parcel lockers, drones or e.g. ecological vehicles). So they also appreciate the mobile way of communication or settling accounts with the company (mobile technology – position 4 in the study). And in third place, of course, cybersecurity. In their opinion, this is a very important issue, but it seems that from the point of view of protecting customer data, not internal company data. Only those aspects included in the concept of Industry 4.0 turned out to be important for customers of the young generation (according to the results of the survey), so if a company focuses on these technologies in its activities, it can successfully use information on this subject in its market promotion. Thus, research hypothesis No. 1 was fully confirmed.

**Table 3.**

*Distribution of respondents' answers to questions related to the importance for them of individual technologies included in Industry 4.0*

Question number	Question about:	Never mind at all (N)	Unimportant (U)	Medium important	Important (I)	Very important (VI)	Sum of I and VI	% I and VI	The importance of technology for customers
15.	Cloud Computing	76	87	94	55	8	<b>63</b>	19,7	-
16.	Big Data	78	107	81	49	5	<b>54</b>	16,9	-
17.	Virtual Reality	76	111	72	56	5	<b>61</b>	19,1	-
18.	Vertical and Horizontal Integration	89	110	80	38	3	<b>41</b>	12,8	-
19.	Augmented Reality	83	107	84	44	2	<b>46</b>	14,4	-
20.	Industrial Internet of Things	76	100	84	52	8	<b>60</b>	18,8	-
21.	3D printing	76	113	94	29	8	<b>37</b>	11,6	-
22.	Robots	99	103	76	35	7	<b>42</b>	13,1	-
23.	Cybersecurity	21	49	59	112	79	<b>191</b>	59,7	<b>3</b>
24.	RFID	49	96	93	69	13	<b>82</b>	25,6	-
25.	Mobile Technology	31	55	93	93	48	<b>141</b>	44,1	<b>5</b>
26.	M2M and Machine Learning	69	107	95	44	5	<b>49</b>	15,3	-

Cont. table 3.

27.	Artificial Intelligence	50	99	101	59	11	<b>70</b>	21,9	-
28.	New technologies in internal logistics	67	114	77	53	9	<b>62</b>	19,4	-
29.	New technologies in external logistics	14	32	67	135	72	<b>207</b>	64,7	<b>2</b>
30.	Blockchain	59	90	98	56	17	<b>73</b>	22,8	-
31.	Customization	16	51	83	126	44	<b>170</b>	53,1	<b>4</b>
32.	Internet presence	4	15	56	124	121	<b>245</b>	76,6	<b>1</b>

Source: Own elaboration based on the results of the study.

In the study, it may be important to determine whether the gender of young customers significantly differentiates their attitude to the Industry 4.0 technologies used by enterprises. Do women and men have a similar attitude to these technologies? For this purpose, the statistical significance of differences in the responses of respondents of both sexes was examined. For this purpose, the Pearson chi-square independence test was used. A null hypothesis about the absence of gender influence on respondents' responses (lack of dependence) and an alternative hypothesis about the occurrence of such an influence (the occurrence of dependencies) were put forward. Due to the changing number of neutral answers ("I have no opinion"), the existence of such a relationship for the group of answers "unimportant and less important" and "important and very important" was examined separately. The critical value with the assumed significance of inference at the level of 0.05 and 17 degrees of freedom is the value of 27.584. Based on the answers obtained by respondents in the items "unimportant and less important", the value of the test statistic is  $\chi^2 = 17,815$  and is less than the critical value, which does not allow to reject the null hypothesis. Gender does not differentiate the answers in the "unimportant and less important" group. Similarly for respondents' answers in the items "important and very important". The value of the test statistic is  $\chi^2 = 19,072$  and is less than the critical value. There is therefore no basis for rejecting the null hypothesis. Gender does not differentiate the answers in the "important and very important" group. On the basis of the above, it can be concluded that the attitude of customers of the young generation to Industry 4.0 technologies used by manufacturing companies is similar in women and men, and the observed differences in respondents' suggestions should be considered accidental.

The distribution of respondents' answers by gender is presented in Table 4.

**Table 4.**

*Distribution of respondents' answers to questions related to the importance for them of individual technologies included in Industry 4.0 divided into men and women*

Question	Women's responses (n = 241)					Men's responses (n = 79)				
	Sum of N and U	% of sum of N and U	Sum of I and VI	% of sum I and VI	Rank Women	Sum of N and U	% of sum of N and U	Sum of I and VI	% of sum I and VI	Men's rank
15.	115	47,7	51	21,2	-	48	60,8	12	15,2	-
16.	130	53,9	46	19,1	-	55	69,6	8	10,1	-
17.	134	55,6	54	22,4	-	53	67,1	7	8,9	-
18.	140	58,1	33	13,7	-	59	74,7	8	10,1	-
19.	132	54,8	36	14,9	-	58	73,4	10	12,7	-
20.	127	52,7	49	20,3	-	49	62,0	11	13,9	-
21.	143	59,3	27	11,2	-	46	58,2	10	12,7	-
22.	151	62,7	28	11,6	-	51	64,6	14	17,7	-
23.	53	22,0	140	58,1	<b>3</b>	17	21,5	51	64,6	<b>1</b>
24.	103	42,7	64	26,6	-	42	53,2	18	22,8	-
25.	59	24,5	111	46,1	<b>5</b>	27	34,2	30	38,0	<b>5</b>
26.	128	53,1	34	14,1	-	48	60,8	15	19,0	-
27.	111	46,1	51	21,2	-	38	48,1	19	24,1	-
28.	132	54,8	46	19,1	-	49	62,0	16	20,3	-
29.	30	12,4	161	66,8	<b>2</b>	16	20,3	46	58,2	<b>2</b>
30.	108	44,8	59	24,5	-	41	51,9	14	17,7	-
31.	46	19,1	133	55,2	<b>4</b>	21	26,6	37	46,8	<b>4</b>
32.	7	2,9	200	83,0	<b>1</b>	12	15,6	44	57,1	<b>3</b>

Source: Own elaboration based on the results of the study.

At the same time, the results of this fragment of the study clearly confirm hypothesis No. 3.

Since such answers to questions related to the main research problem were expected, respondents were asked additional questions about the market effects of enterprises that are important to them. The answers to these questions were again not a disappointment for the researcher, which confirms hypothesis No. 2, but as part of their result, information very important for marketing promotion or market activity of the company was identified, namely about the strength and importance of these preferences for respondents. A detailed distribution of answers to questions about the preferred characteristics of the effects of market activity of manufacturing companies is presented in Table 5.

**Table 5.**

*Preferences of customers of the young generation regarding the quality characteristics of products and the conditions of their sale*

Question number	Feature	Never mind at all	Unimportant	Medium important	Important	Very important	Sum of I and VI	% I and VI	Validity for customers
2.	Quality	0	1	6	115	198	<b>313</b>	97,8	<b>1</b>
3.	Robust/Durable	1	5	15	161	138	<b>299</b>	93,4	<b>2</b>
7.	Price	1	9	37	116	157	<b>273</b>	85,3	<b>3</b>
12.	Reviews	3	9	71	149	88	<b>237</b>	74,1	<b>4</b>

Cont. table 5.

5.	Design	1	16	78	150	75	<b>225</b>	70,3	<b>5</b>
9.	Level of customer service	5	23	95	122	75	<b>197</b>	61,6	<b>6</b>
4.	Material	1	29	96	141	53	<b>194</b>	60,6	<b>6</b>
13.	Reviews	5	35	87	147	46	<b>193</b>	60,3	<b>6</b>
8.	Terms of delivery	6	32	94	127	61	<b>188</b>	58,8	<b>7</b>
1.	Brand	0	12	121	162	25	<b>187</b>	58,4	<b>7</b>
6.	Innovativeness	2	27	123	135	33	<b>168</b>	52,5	<b>8</b>
14.	Purchasing environment	6	39	111	131	33	<b>164</b>	51,3	<b>8</b>
10.	Warranty conditions	2	46	109	112	51	<b>163</b>	50,9	<b>9</b>
11.	Service availability	13	58	104	107	38	<b>145</b>	45,3	<b>10</b>

Source: Own elaboration based on the results of the study.

A similar analysis as above (broken down by gender) was carried out for respondents' preferences regarding the value of products and conditions of their sale. The critical value with the assumed significance of inference at the level of 0.05 and 13 degrees of freedom is the value of 22.362. Based on the answers obtained by respondents in the items "unimportant and less important", the value of the test statistic  $\chi^2 = 18,338$  is and is less than the critical value, which does not allow to reject the null hypothesis. Gender does not differentiate the answers in the "unimportant and less important" group. Similarly for respondents' answers in the items "important and very important". The value of the test statistic is  $\chi^2 = 10,025$  and is less than the critical value. Therefore, there are no grounds for rejecting the null hypothesis either. Gender does not differentiate the answers in the "important and very important" group. Based on the above, it can be concluded that the value of product attributes and the conditions of their sale is similarly perceived by both women and men.

The distribution of respondents' answers to questions about the value for them of individual effects of commercial activity of production companies broken down into women and men is presented in Table 6.

**Table 6.**

*Distribution of respondents' responses about their preferences regarding the quality characteristics of products and the conditions of their sale broken down by gender*

Question	Women's responses (n = 241)					Men's responses (n = 79)				
	Sum of N and U	% of sum of N and U	Sum of I and VI	% of sum I and VI	Rank Women	Sum of N and U	% of sum of N and U	Sum of I and VI	% of sum I and VI	Rank Men
1.	9	3,7	138	57,3	<b>8</b>	3	2,4	49	62,0	<b>5</b>
2.	0	0,0	236	97,9	<b>1</b>	1	0,8	77	97,5	<b>1</b>
3.	5	2,1	225	93,4	<b>2</b>	1	0,8	74	93,7	<b>2</b>
4.	20	8,3	141	58,5	<b>7</b>	10	7,9	52	65,8	<b>4</b>
5.	14	5,8	172	71,4	<b>5</b>	3	2,4	53	67,1	<b>4</b>
6.	21	8,7	130	53,9	<b>9</b>	8	6,3	38	48,1	<b>8</b>
7.	5	2,1	212	88,0	<b>3</b>	5	4,0	61	77,2	<b>3</b>
8.	22	9,1	154	63,9	<b>6</b>	16	12,6	34	43,0	<b>10</b>
9.	18	7,5	153	63,5	<b>6</b>	10	7,9	44	55,7	<b>7</b>
10.	32	13,3	127	52,7	<b>9</b>	16	12,6	36	45,6	<b>9</b>

Cont. table 6.

11.	51	21,2	111	46,1	<b>10</b>	20	15,8	34	43,0	<b>10</b>
12.	6	2,5	191	79,3	<b>4</b>	6	4,7	46	58,2	<b>6</b>
13.	33	13,7	144	59,8	<b>7</b>	6	4,7	49	62,0	<b>5</b>
14.	36	14,9	132	54,8	<b>9</b>	9	7,1	32	40,5	<b>11</b>

Source: Own elaboration based on the results of the study.

The effects of this part of the study are not very revealing, but they lead to very important conclusions from the point of view of the possibility of their use in the marketing activities of enterprises. Namely, customers of the young generation most as the effects of market activity of manufacturing companies appreciate: the general quality of products, and especially their solidity/durability, understood as low susceptibility to damage or loss of usability of products over time. (This gives food for thought about the problem of planned obsolescence, so popular recently among manufacturers in the automotive industry!). However, the fact that for customers of the young generation a very important factor in the market competitiveness of the company is the price of its products is not a big discovery. What turns out to be revealing, however, is the fact that opinions about the company or its products of other customers are a very valuable factor for the respondents. First of all, in the network, it is worth for manufacturers to pay strong attention to this aspect (which, unfortunately, in practice does not always happen). Important for customers of the young generation is the design of products and the materials from which the product is made. However, the level of customer service and professional reviews about products (e.g. on YT) are more important to them than the brand (company/product) (!). Similarly, the terms of delivery. Customers of the young generation have probably become accustomed to the high level of innovation of the products offered to them, because in the conducted research this factor was ranked 11th (out of 14), but despite everything, the author of the study on the place of managers in practice would not underestimate this factor. The results of various types of marketing research or case studies from practice confirm that it is still a very important factor in the market competitiveness of the company. The least important for the customers of the young generation (according to the results of the study) turned out to be: the purchase environment, warranty conditions or availability of the service, while according to the conclusions presented above in practice, the author of the study would also not underestimate these factors, trying to build the most attractive and competitive bundle of market effects of the production company's operations. At the same time, the results of the study clearly show what modern enterprises should devote their strength and resources to in the first place in order to obtain a high level of market attractiveness of the effects of their activities for the main group of customers, and thus their market competitiveness.

If companies target a group of men or women in their jobs, they can use the information presented in Table 6. For the overall results of the study, individual differences in their preferences turned out to be statistically insignificant.



## 5. Summary

This article addresses the issue of the importance for customers of the young generation ("Y"+"Z") of the use of technologies included in the concept of Industry 4.0 by manufacturing companies. After a brief explanation of what characterizes this concept, the results of research conducted on a sample of 320 respondents were presented. Based on the results of the study, the research hypotheses put forward at the beginning were verified:

Hypothesis 1 – fully verified.

Hypothesis 2 – fully confirmed.

Hypothesis 3 – positively verified.

At the same time, as a result of the research, additional and very interesting information was obtained, namely about the detailed preferences of customers of the young generation in terms of new manufacturing technologies used by enterprises and in terms of the features of the products they offer and the methods of their marketing promotion. The differences in the responses of men and women to the questions turned out to be statistically insignificant.

On the occasion of the study, it was identified that currently there are not many scientific publications on this subject in the literature (e.g. Velvet et al., 2022), and the presented results may bring important information useful for use in the practice of modern manufacturing enterprises.

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## THE USE OF SOCIAL MEDIA IN THE PROCESS OF EMERGENCY REMOTE TEACHING DURING THE COVID-19 PANDEMIC

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**Purpose:** The study aims to analyze determinants that influence the attitude of students who use social media for emergency remote teaching.

**Design/methodology/approach:** The research was carried out on a sample of 465 students from various universities in Poland. The confirmatory factor analysis and then the regression method were used for the purpose of conducting the study.

**Findings:** The results pointed to the ease of social media use and their clear impact on improving emergency remote teaching. The vast majority of respondents also indicated an increased use of social media in relation to the pre-COVID period, which confirmed the thesis that the use of social media for emergency remote teaching during the pandemic was helpful.

**Research limitations/implications:** The limitations of the research carried out were the low diversity in the fields of study. Most of the respondents were students of economic, sociological, and technical departments. Students of medical and artistic faculties participated in the study to a small extent only, which is also an important premise and direction to be taken into account while organizing further research on a wider group of students.

**Originality/value:** The study brings new conclusions regarding the educational use of social media. The results provide important conclusions for universities.

**Keywords:** Social Media, Emergency Remote Teaching, Higher Education, COVID-19.

### 1. Introduction

2019 was a rather calm year in Europe, whereas in China, the first case of the coronavirus was identified as early as on 17 November according to epidemiologists. The first case of the coronavirus outside of China was spotted on 13 January 2020 in Thailand. Then, on 21 January, the first case of Covid-19 appeared in the United States, and on 24 January, the first case was identified in Europe (in France). In March 2021, a year passed since the first case of SARS-CoV-2 infection had been diagnosed in Poland. On 11 March 2020, educational units were closed and emergency remote teaching (ERT) began. Before the outbreak of the pandemic,

information technology was used as a support to the learning process, as well as was utilized as a source of new knowledge, skills, self-education, and improvement. It has been noticed that education supported by new methods of learning has been influencing qualitative changes in knowledge transfer, developing motivation to learn, and increasing interest in specific fields. E-learning has replaced traditional courses and the use of the Internet as an educational tool has been promoted by many scholars (Arulogun et al., 2020; Balakrishnan, Gan, 2016; Greenhow, Robelia, 2009; Hartley, Bendixen, 2001).

The literature on the subject defines terms related to learning with the use of information technology, i.e., online learning, distance learning, mobile learning, remote learning and others (Moore et al., 2011; Hodges et al., 2020; Martin et al., 2022). Many of these terms indicate that the learner is at the distance from the teacher or lecturer, and both of them use some type of information technology that offers the possibility to learn from anywhere, anytime, in any rhythm, with any means (Anderson, 2008; Cojocariu et al., 2014; Dhawan, 2020). However, it should be emphasized that online learning, as well as all the terms mentioned above, is a complex process with specific standards. Online learning requires the development of courses and programs, their implementation, and evaluation (Bawa, 2020). In our research, we focused on emergency remote teaching, which means a sudden transition to online teaching in a crisis (Bawa, 2020; Hodges et al., 2020; Nussli, Oh, Davis, 2022). ERT does not allow for a thorough course preparation process, and lecturers, despite providing them with training and support, are not able to take full advantage of online teaching opportunities. Such a transition to ERT was not an easy task, neither for teachers who suddenly needed to acquire new teaching skills with the use of information and communication technologies (ICT) (Bozkurt et al., 2020; Procentese et al., 2022) nor for students, who despite the ability to better cope with ICT, were not always able to adapt to the new teaching system. It is also worth noting that computer servers and online education platforms were often overloaded (Bao, 2020). The outbreak of the COVID-19 pandemic pushed the world to implement online teaching using varying technology applications including social media as an essential tool in the learning process (Eid, Al-Jabri, 2016; Makki, Bali, 2021; Salloum et al., 2021).

Nowadays, social media are being adopted by millions of users, most of whom are students of different levels of education. Using social media in an educational context can be seen as a potentially powerful idea. Students spend a lot of time online using various social media. These sites can support new ways of learning. Social media can be used as tools that engage individuals in critical thinking and enhance communication, as well as collaboration between people. Many lecturers use social media to achieve active and discovery-based learning environments (Paliszkievicz, Koohang, 2016).

Due to the pandemic, universities around the world have implemented alternative learning methods using information technologies. ERT introduced as a result of the COVID-19 pandemic calls for the search for new solutions with respect to sharing and acquisition of knowledge. One of such ways of integrating the student community, among others for learning

purposes, is to opt for social media. It is therefore sensible to examine changes caused by the COVID-19 pandemic with regard to the use of social media in ERT. Moreover, as mentioned above, in the normal mode of learning, the online learning process is meticulously prepared well in advance, which cannot be said for ERT.

The study aims to analyse determinants that influence the attitude of students using social media as a result of switching to ERT during the COVID-19 pandemic. The study highlights, among others, the communication functionality, commitment, and skills of students using social media. The frequency of using social media, the solution of scientific problems, and the availability of university-specific pieces of information made public thanks to social media have all been examined.

The rest of this paper has the following organization. First, we discuss the theoretical background about social media and its use in the learning process and then develop related research questions. Next, we outline the methodology and data samples of the research. In the following section, we present the results of the conducted study. Then, we discuss the presented results and finally, we conclude with the limitations of the study and directions for future research.

## **2. Social media in the learning process**

Social media are defined as “a group of web-based applications that are ideological and technological underpinnings of Web 2.0 that enable the creation and exchange of user-generated content” (Kaplan, Haenlein, 2010). Social media can be considered to be a huge, active and engaged community that uses Internet-oriented technologies to engage in an interactive dialogue. Social media create a new space of communication distinguished by the free flow of information made public by the participants of the communication process. They use not only the principle of active and conscious participation but also the principle of teaching process subjectivity, in which conscious participants of the educational process decide about its course (Spivakovsky et al., 2013). There is no one-way communication – open and free discussion is also possible.

A popular theory being an immediate result of the widespread utilization of social media and mobile technologies in the learning process is the so-called social learning theory (SLT). It assumes that learning is more effective when learners have the opportunity to observe other learners, interact with them, take part in research groups, as well as actively participate in the widely understood learning process (Gong et al., 2014). The social learning theory developed by Bandura (1977) is a desired synergy between traditional learning theory and the cognitive approach. “The majority of human behavioral patterns is acquired observationally through modeling: by observing others, an idea is formed of how a given behavior should be performed.

Later on, said encoded piece of information serves as a guide to action” (Bandura, 1977). It is a process of constant and mutual interaction. Traditional one-way communication has changed into a two-way, three-way, or even multidirectional one, which in turn has increased the frequency of cognitive processes related to learning and obtaining valuable knowledge (Deaton, 2015).

Social media platforms offer a number of functions, such as creating online courses and assignments, monitoring the activities of students and teachers and, above all, the ability to share knowledge and communicate with others (Liao et al., 2015; Rahman et al., 2020). In the case of the interactive world of social media, the application of social learning theory serves as an opportunity to promote significant student achievements. Furthermore, cognitive concepts, attentiveness, memorization, and motivation are promoted by social media (Deaton, 2015; Van Dem Beemt et al., 2020).

Studies carried out on the use of social media as seen through the prism of academic performance turn out to be inconclusive. On the one hand, new technologies may support students in their scientific development and help them develop psychosocial patterns of behavior, but on the other hand, they may hinder the said processes (Lau, 2017). A negative impact of the use of social media on academic achievements has been observed by, among others, Kirschner, Karpinski (2010) and Lau (2017). The simultaneous processing of various streams of information may have a negative impact on the effectiveness of task completion. Social media have a distracting character, which may, in turn, adversely affect the concentration process, thus requiring a person to be more involved and devote more time to performing certain tasks (Bou-Hamad, 2020). A positive aspect of the learning process is based on social media cooperation-oriented principles, which in turn encourages the development of social skills, critical thinking, memorization, knowledge consolidation, as well as competitiveness (Minocha, 2009; Miyazoe, Anderson, 2010; Yang, Chang, 2012). Students are stimulated and encouraged to solve certain problems as a group, as well as to realize certain projects. Research has shown that the use of Twitter for learning purposes improved student engagement during classes (Junco et al., 2011).

## **2.1. Intention of use**

Previous research indicates that social media are mainly used to build social networking (Duffy, 2011), as they bring people closer, facilitate cooperation, and communication (Obar, Wildman, 2015). Initially, their role focused on providing entertainment and information (Bou-Hamad 2020; Mingle, Adams, 2015) evolving into an effective marketing, educational and communication mechanism. Nowadays, social media and the set of tools they contain have become an integral part of the daily life of students (Dumford et al., 2023). Thanks to social media, students and teachers have unlimited access to remarkable sources of information, including tools that allow rapid access to specific data (Liao et al., 2015; Putra et al., 2021; Van Den Beemt et al., 2020). The multimedia-oriented character of the media facilitates



systematic and constant control over the level of the acquired knowledge, as well as stimulates and activates students. The user independently searches for necessary information and creates his or her own knowledge system (Greenhow et al., 2009). Due to the amount of data, students are forced, through analysis and criticism, to select the information they consider to be the most relevant. The materials are located on different servers, which favors a multifaceted, multidimensional approach to a given issue and the selection of an optimal solution. The user can actively participate in activities on the website, share content, share opinions, and create various groups to serve scientific purposes. It is reasonable to investigate whether students have been more likely to use social media for learning in the ERT situation than before the pandemic.

## **2.2. Communication functionality**

Social media offer new opportunities for sharing, creating and interacting between students and teachers. Researchers have found that the use of social media makes students more independent and effective by improving the quality of communication with their teachers and classmates. The students in the research group preferred to gather information through social media (Deandrea et al., 2012; Hamilton et al., 2016). Popular social media platforms (Facebook, YouTube) allow students to interact directly with their peers and lecturers, as well as to receive quick feedback (Salloum et al., 2018). Facebook and Google+ enable multimedia content hosting. In shared media spaces, students can learn together and benefit from the knowledge of others (Wankel, 2009). According to Top (2012), teachers promote cooperation among students and create a sense of community, so they are moderately enthusiastic when it comes to using blogs while learning. They favor live broadcasting media. Teachers use social media specifically to motivate students and improve teaching. However, research indicates that teachers experience problems using social media in a situation where there has been a sudden shift to ERT (Bozkurt et al., 2020; Procentese et al., 2022). Not all teachers were well prepared for such an extensive use of social media. Therefore, we pose a question regarding the functionality of communicating with students and lecturers in the ERT situation through social media.

## **2.3. Way of proceeding**

Social media are also a way to supplement knowledge and make educational activities more comprehensive. Platforms such as Google Meet and MS Teams allow for a free remote discussion, in the case of which each participant is at home, whereas the Periscope and ClickMeeting applications were created for people conducting webinars and videoconferences. They allow users to record a file with their own presentation and share their screen with other recipients, just like in the case of Google Meet and MS Teams (Brady et al., 2010). Facebook, Twitter, YouTube, and blogging platforms are used to send educational materials, and videos and explain information that seems to be unclear at first (Moran et al., 2011).

Concerning social mediapractices, the results pointed out that knowledge sharing has a significant positive impact on the perceived usefulness and perceived ease of use of e-learning systems (Salloum et al., 2021). Displaying didactic video clips has become effective in terms of education. Students can develop decision-making skills, higher-order thinking, problem-solving, communication, collaboration, and information sharing (Greenhow, Robelia, 2009). Studies have shown that social media (Instagram, WhatsApp, Facebook) can activate interactive, collaborative and cooperative learning which can control students while learning and provide reflection so that there is a reciprocal exchange between lecturers and students that facilitates closer learning (Putra et al., 2021; Roro et al., 2021).

We wonder if, in the ERT situation, students have taken advantage of the opportunities described above regarding social media to improve their chances of better academic performance.

#### **2.4. Involvement**

Social media may be useful in the case of “independent” students with predispositions to work individually because using social media allows such students to study the material provided beforehand at any place and time. It allows them to independently set challenges and initiatives for themselves while obtaining knowledge, mainly by browsing for key pieces of information (Hsieh et al., 2011). Students who prefer to study independently require special projects based on their interests. They are proficient when it comes to using social media in order to set their study schedule. They especially value social media ensuring their anonymity. A website that is similar to Facebook is Yammer, which allows students and lecturers to collaborate, organize projects, and interact, while at the same time granting them much greater privacy. Students also opt for such social tools as blogs and posts (Blogger, WordPress) (Ryan, Xenos, 2011).

Independent and temporarily unlimited access to information and knowledge is certainly valuable. We want to check how factors related to the convenience of access to information affect students’ academic performance.

#### **2.5. Students’ performance in using social media**

Even though social media are considered by students to be a social technology and not a formal learning or teaching tool, they can have an impact on educational outcomes (Mazman, Usluel, 2010). Nevertheless, the pandemic situation forced a greater use of these tools in learning than before.

In the literature on the subject, there are also numerous examples of the positive impact of social media on academic performance (Hamilton et al., 2016; Salloum et al., 2018). One of the key determinants of the learning process is the interaction between the student and the teacher. Students who are determined to understand the material actively derive satisfaction from their educational endeavors and take responsibility for their own learning. They also

perform well when it comes to remote learning, even if it requires them to be more involved than in the case of traditional (classroom-oriented) learning processes (Van Dem Beemt et al., 2020). An interesting study on the use of social media and its impact on student performance was conducted by (Alshuaibi et al., 2018). The authors of the study found that cognitive engagement, defined as the level of self-initiative in studying, allows students to improve their academic performance. Active participation of the student in mastering and understanding the topic can be developed with the help of social media. Furthermore, research by Lemay, Bazalais & Doleck (2021) indicated that students reported an increased workload with less understanding of course objectives and less interaction with peers. In our research, we focused on assessing the degree of complication of lectures, exercises and laboratories conducted with the use of social media tools.

The global situation caused by the COVID-19 pandemic forces the use of modern information technologies for distance learning. At the same time, the new reality has created a research gap. Therefore, it is vital to study the use of social media with regard to ERT. In addition, we also wanted to investigate whether factors such as the form and type of studies, gender and place of residence were important in the use of social media by students in the ERT process. This analysis aims to answer the following research questions:

- RQ1. Which groups of factors (i.e. Intention to use, Communication functionality, Way of proceeding, Involvement) significantly influence the performance of students that use social media for learning purposes?
- RQ2. Has the study mode, type of studies, place of residence, or the male/female sex been important when it comes to the use of social media by students for learning purposes?

### **3. Methodology**

#### **3.1. Sample and data collection**

The research was carried out in March 2021 on a sample of 465 students studying in Poland at universities, taking part in first-cycle (engineering and bachelor) and second-cycle (master) courses. The sample consisted of 465 participants, 325 females (69.9%), and 140 males (30.1%). A survey questionnaire was used for the study, which was divided into five blocks: Intention to use (1), Communication functionality (2), Way of proceeding (3), Performance (4), Involvement (5). In the intention to use group, three variables were distinguished, indicating the intention to use for personal or professional purposes and the overall frequency of social media use. In the communication functionality group, four variables were distinguished, indicating the frequency, ease of communication among students, and information flow between students and lecturers. In the way of proceeding group, four variables were

distinguished regarding own skills with regard to using social media, ease of ERT through social media, scientific activity in the media, and said media assistance in solving problems related to ERT during the COVID-19 pandemic. In the performance group, four variables were also identified, regarding assistance in passing remote exams and access to information through said media (such as rector's and deans' announcements for students). In the last group of questions relating to involvement, attention was on improving the quality of learning thanks to the possibility of learning anywhere and anytime, the impact of the pandemic on the creation of new accounts on social networks, the ease of information exchange, and interactions through social media. Table 1 summarizes demographic characteristics of the sample in the current study.

**Table 1.**

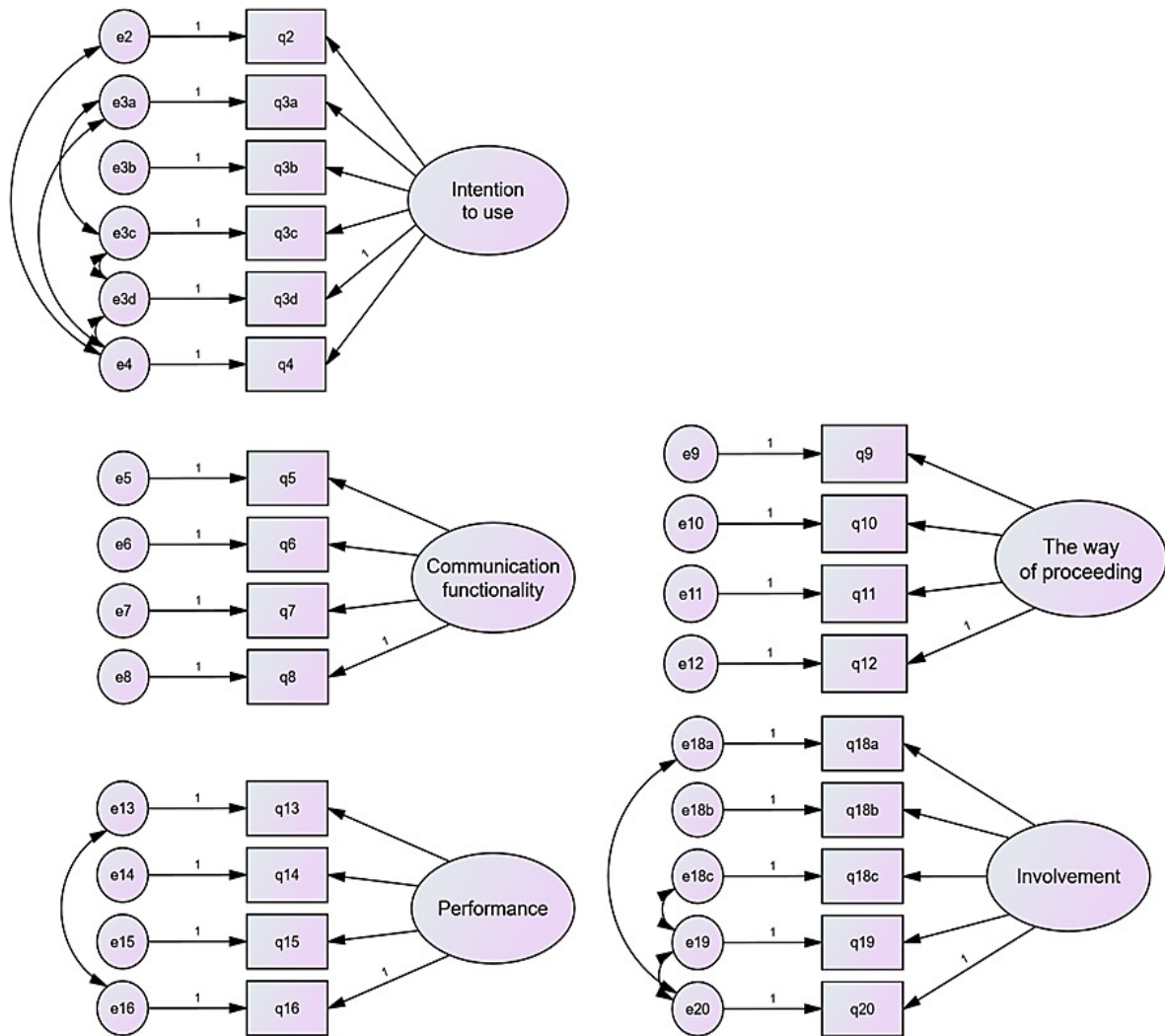
*Demographic characteristics of the sample in the current study*

Characteristic	Value	n	%
Sex	Females	325	69.9
	Males	140	30.1
Study Mode	Part-time study	92	19.8
	Full-time study	373	80.2
Place of residence	City	287	61.7
	Village	178	38.3
Speed of the Internet available	Low	33	7.1
	Average	213	45.8
	High	219	47.1
Type of studies	Engineering	172	37.0
	Bachelor	184	39.6
	Masters	109	23.4

*n* – number of participants; % – sample percentage.

### 3.2. Confirmatory factor analysis

To verify the factorial structure of the questionnaire used for the discussed study, a confirmatory factor analysis was performed based on the likelihood. The preliminary assumption that was verified was that each block measured a separate and homogeneous variable. Each block of the questionnaire was analyzed by opting for a separate model. The only modifications that were applied in order to achieve the adequateness of the analyzed factor structure were based on adding inter-correlations between specific items. They were based on the values of modification indexes with a threshold value equal to 4. Figure 1 presents final structures that were developed in the course of the analysis.



**Figure 1.** Factor structures of separate blocks of the questionnaire used in the current study.

Table 2 presents the values of fit indexes for each block of the questionnaire used for the current study.

**Table 2.**  
*Values of fit indexes for blocks of the questionnaire*

Model	$\chi^2/df$	RMSEA	CFI	NFI	
Block1	Intention to use	3.19	0.07	0.99	0.98
Block2	Communication functionality	1.87	0.04	0.98	0.97
Block3	Way of proceeding	2.19	0.06	0.99	0.98
Block4	Performance	4.57	0.09	0.99	0.99
Block5	Involvement	3.26	0.07	0.99	0.99

RMSEA – root mean square error of approximation, CFI – comparative fit index, NFI – normed-fit index.

The values of the fit indexes for the final models showed that the fit was adequate.

Table 3 presents acquired factor loadings and correlation values between items.

**Table 3.**  
*Factor loadings acquired using confirmatory factor analysis*

Factor loadings			<i>f</i>	<i>p</i>
q3d	<---	Intention to use	0.56	0.001
q3c	<---	Intention to use	0.48	0.001
q3b	<---	Intention to use	0.83	0.001
q3a	<---	Intention to use	0.70	0.001
q2	<---	Intention to use	0.36	0.001
q4	<---	Intention to use	0.32	0.001
q8	<---	Communication functionality	0.56	0.001
q7	<---	Communication functionality	0.47	0.001
q6	<---	Communication functionality	0.31	0.001
q5	<---	Communication functionality	0.47	0.001
q12	<---	Way of proceeding	0.66	0.001
q11	<---	Way of proceeding	0.48	0.001
q10	<---	Way of proceeding	0.87	0.001
q9	<---	Way of proceeding	0.41	0.001
q16	<---	Performance	0.58	0.001
q15	<---	Performance	0.62	0.001
q14	<---	Performance	0.69	0.001
q13	<---	Performance	0.55	0.001
q20	<---	Involvement	0.38	0.001
q19	<---	Involvement	0.32	0.001
q18c	<---	Involvement	0.76	0.001
q18b	<---	Involvement	0.96	0.001
q18a	<---	Involvement	0.64	0.001
Correlations between items			<i>r</i>	<i>p</i>
e3d	<-->	e4	0.30	0.001
e2	<-->	e4	0.20	0.001
e3d	<-->	e3c	0.18	0.002
e3a	<-->	e4	-0.17	0.001
e3c	<-->	e3a	-0.21	0.001
e16	<-->	e13	-0.25	0.001
e20	<-->	e19	0.31	0.001
e19	<-->	e18c	0.19	0.001
e20	<-->	e18a	0.13	0.006

*f* – factor loadings; *r* – correlation coefficients; *p* – statistical significance.

## 4. Results

### 4.1. Descriptive statistics

Table 4 presents descriptive statistics of interval variables in the current study, i.e. mean values, standard deviations, minimum and maximum values, skewness and kurtosis values, values of Kolomogorov-Smirnow test for normality and Cronbach alpha reliability coefficients.

**Table 4.***Descriptive statistics of interval variables in the current study*

	<i>M</i>	<i>SD</i>	<i>min</i>	<i>Max</i>	<i>S</i>	<i>K</i>	<i>Z</i>	<i>p</i>	<i>α</i>
Intention to use	4.09	0.90	1.83	5.83	-0.24	-0.62	0.082	0.001	0.73
Communication functionality	3.58	0.84	1.25	6.00	-0.05	0.15	0.077	0.001	0.50
The way of proceeding	4.35	0.97	1.25	6.00	-0.56	0.03	0.095	0.001	0.68
Performance	3.81	1.07	1.00	6.00	-0.16	-0.41	0.078	0.001	0.67
Involvement	3.87	1.02	1.00	6.00	-0.10	-0.13	0.050	0.007	0.78

*M* – mean value; *SD* – standard deviation; *min* – minimum value; *max* – maximum value; *S* – skewness; *K* – kurtosis; *Z* – value of the Kolmogorov-Smirnow test; *p* – statistical significance; *α* – Cronbach reliability coefficient.

The distributions of all the analyzed variables significantly differed from the normal distribution. Therefore, the bootstrap method was applied in the subsequent analysis.

#### 4.2. Intention to use, communication functionality, way of proceeding, and involvement as predictors of performance

Regression analysis was used to assess the relationships between intention to use, communication functionality, way of proceeding, involvement, and performance. The bootstrap-based entry method was chosen. Table 5 shows the acquired values of the regression coefficients.

**Table 5.***Analysis of intention to use, communication functionality, way of proceeding, and involvement as predictors of performance*

<b>Predictors</b>	<b><i>B</i></b>	<b><i>p</i></b>
Intention to use	0.04; 0.24	0.004
Communication functionality	0.07; 0.27	0.001
Way of proceeding	0.43; 0.63	0.001
Involvement	0.13; 0.29	0.001

*B* – 95% confidence intervals for standardized regression coefficients; *p* – statistical significance.

The model was statistically significant,  $F(4,460) = 119.83$ ,  $p < .001$ . Intention to use, communication functionality, way of proceeding, and involvement were positively related to performance. The whole model explained 51.0% of the performance variance.

In addition, an analysis was carried out between different groups by gender, type of studies, and place of residence. It allowed to check whether there were significant differences between them in the approach to learning through social media.

#### 4.3. Comparisons between groups

Table 6 presents the mean values of the variables analyzed acquired in the male and in the female group with the values of independent *t* samples test which were used to assess the statistical significance of the differences between the two groups. Statistical significance was based on the bootstrap procedure.

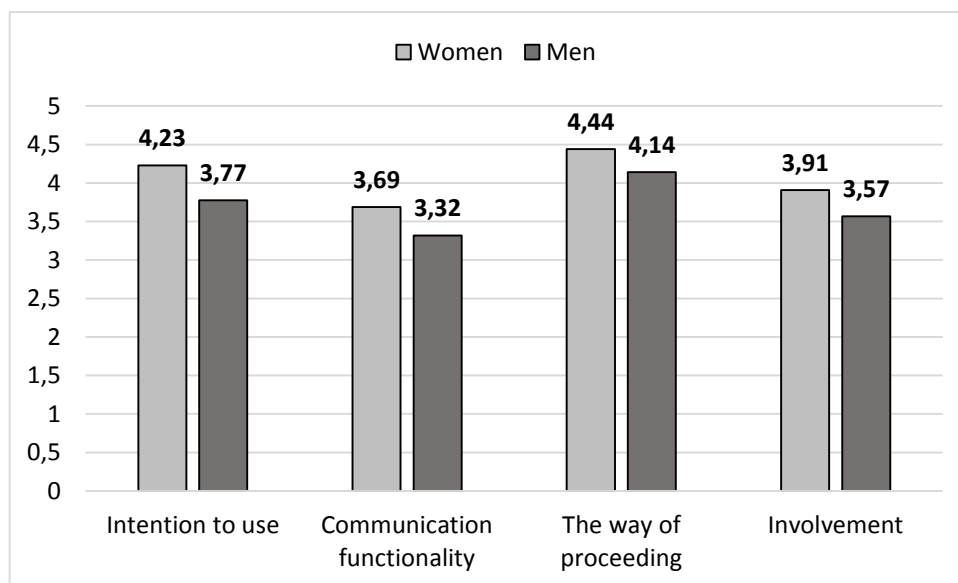
**Table 6.**

Mean values of variables analyzed acquired in the male and female groups

	Women (n = 325)		Men (n = 140)		t	df	p
	M	SD	M	SD			
Intention to use	4.23	0.86	3.77	0.91	5.15	463	0.001
Communication functionality	3.69	0.78	3.32	0.94	4.09	224.99	0.001
Way of proceeding	4.44	0.93	4.14	1.02	3.06	463	0.002
Performance	3.89	0.98	3.83	1.11	0.57	463	0.566
Involvement	3.91	1.02	3.57	1.16	3.16	463	0.002

M – mean, SD – standard deviation, t – value of independent samples t-test; df – degrees of freedom; p – statistical significance.

The mean values of intention to use, communication functionality, way of proceeding, and involvement were significantly higher in the group of women than in the group of men (see Figure 2).



**Figure 2.** Statistically significant differences between the female and male groups.

Table 7 presents the mean values of variables analyzed acquired in the group of part-time students and in the group of full-time students with the values of independent t samples test which was used to assess the statistical significance of differences between the two groups. Statistical significance was based on the bootstrap procedure.

**Table 7.**

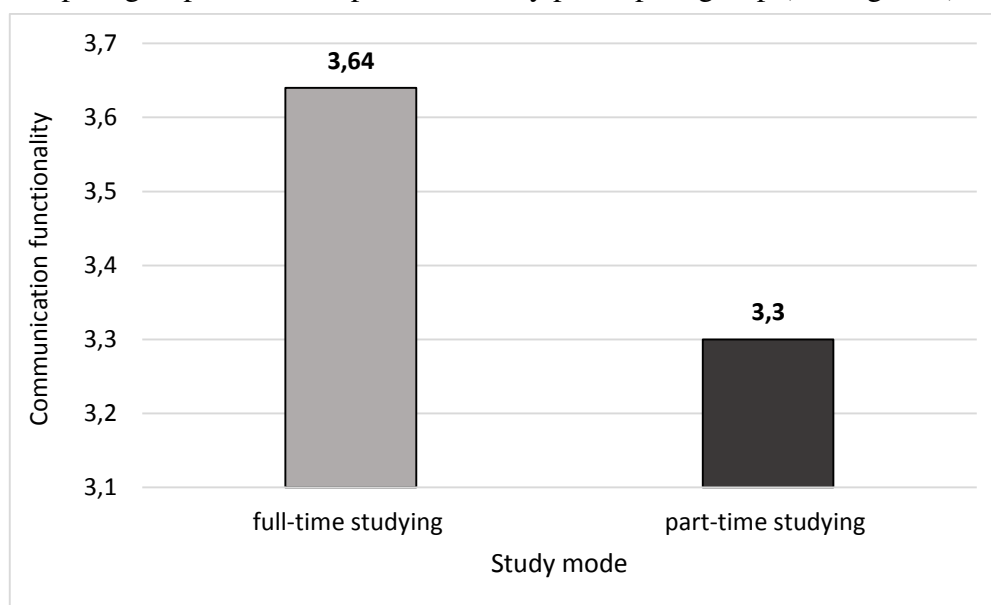
Mean values of variables analyzed acquired in the group of part-time and full-time students

	Study mode				t	df	p
	full-time (n = 373)		part-time (n = 92)				
	M	SD	M	SD			
Intention to use	4.10	.89	4.06	.91	0.38	463	0.702
Communication functionality	3.64	.82	3.30	.88	3.59	463	0.001
Way of proceeding	4.35	.98	4.33	.93	0.25	463	0.801
Performance	3.89	1.02	3.80	1.00	0.81	463	0.418
Involvement	3.78	1.06	3.89	1.12	-0.86	463	0.392

M – mean, SD – standard deviation, t – value of independent samples t-test; df – degrees of freedom; p – statistical significance.



The mean value of communication functionality was significantly higher in the full-time study participant group than in the part-time study participant group (see Figure 3).



**Figure 3.** Mean values of communication functionality in part-time and full-time study groups.

Table 8 presents the mean values of the variables analyzed acquired in the group of participants living in cities and in the group of participants living in villages with the values of the independent  $t$  samples test that was used to assess the statistical significance of the differences between those two groups. Statistical significance was based on the bootstrap procedure.

**Table 8.**

*Mean values of variables analyzed acquired in the group of participants living in cities and villages*

	Place of residence				$t$	$df$	$p$
	city ( $n = 287$ )		village ( $n = 178$ )				
	$M$	$SD$	$M$	$SD$			
Intention to use	4.08	0.89	4.10	0.91	-0.25	463	0.805
Communication functionality	3.55	0.89	3.62	0.76	-0.91	42.23	0.363
Way of proceeding	4.28	0.99	4.45	0.93	-1.84	463	0.066
Performance	3.88	1.02	3.87	1.01	0.11	463	0.915
Involvement	3.74	1.09	3.92	1.05	-1.77	463	0.077

$M$  – mean,  $SD$  – standard deviation,  $t$  – value of independent samples t-test;  $df$  – degrees of freedom;  $p$  – statistical significance.

There were no statistically significant differences between participants living in cities and living in villages.

Table 9 presents the mean values of analyzed variables according to the type of studies with the values of one-way analysis of variance which was used to assess the statistical significance of the differences between the three groups.

**Table 9.***Mean values of analyzed variables depending on the type of studies*

	Type of studies						<i>F</i>	<i>df</i>	<i>p</i>
	Bachelor ( <i>n</i> = 184)		Engineering ( <i>n</i> = 172)		Masters ( <i>n</i> = 109)				
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>			
Intention to use	4.14	0.87	3.97	0.95	4.19	0.83	2.61	2,462	0.075
Communication functionality	3.66	0.77	3.58	0.91	3.43	0.84	2.59	2,462	0.076
Way of proceeding	4.39	0.92	4.32	1.05	4.32	0.93	0.27	2,462	0.762
Performance	3.93	0.91	3.83	1.09	3.84	1.07	0.48	2,462	0.621
Involvement	3.81	1.02	3.74	1.10	3.90	1.11	0.72	2,462	0.488

*M* – mean, *SD* – standard deviation, *t* – value of independent samples t-test; *df* – degrees of freedom; *p* – statistical significance.

There were no statistically significant differences between participants with respect to different types of studies.

## 5. Discussion

The study was based on a functional approach to university-based emergency remote teaching opportunities through social media in the context of the COVID-19 pandemic. The motivation for the research was the desire to learn about the attitudes to ERT based on the social media of students studying at various universities in Poland, especially in comparison to the traditional way of learning. In the case of RQ1, the statistical analysis carried out allowed us to conclude that all four groups of factors (i.e. Intention to use, Communication functionality, Way of proceeding, Involvement) positively influenced the performance of students that use social media for learning purposes.

The first block of factors studied was the intention to use. It is common for companies to use social media to promote and advertise their own products and/or services, as well as for ordinary people - to utilize the medium for private purposes. In our research, we focused on checking how the frequency of social media use increased in comparison to the pre-pandemic period and for what purpose students used them. While it should not be a surprise that among students social media are used to contact friends and acquaintances, they are used almost as often for purposes related to both studies and searching for information on topics of interest to the users. However, the opposite is the case when it comes to using social media for work-related purposes. The percentage of students using social media for professional purposes was 32%, which does not necessarily translate into no intention, but rather indicates that the examined group included a limited number of working individuals. It is worth noting that 72% of the students surveyed indicated a greater frequency of use social media than before the pandemic and over 84% of them found it helpful in learning.

The second factor block examined was communication functionality. Students eagerly used social media as a channel allowing them to contact each other. 36% of the respondents indicated they used for several hours a day and 30% several times a week. However, in relation to contact with lecturers, social media were not the main contact channel. Students declared such contact with lecturers several times a month (64%). This approach to contact with lecturers might have resulted from the fact that universities use specific platforms for organizing remote classes, thus specifying the form of contact between students and teachers. Another reason may be the lower involvement of academics in modern technologies, described in the literature on the subject.

The third of the blocks studied, way of proceeding, explored the factors related to the student's skills and activities. Almost 80% of the surveyed students indicated that social media made ERT easier. In addition, the pandemic forced them to be more scientifically active in social media than they had been so far. At the same time, the respondents indicated that they had remarkable skills in terms of using social media, as they had been using podcasts or educational fanpages, which also translated into solving problems related to remote studies easier.

The fifth block, involvement, assessed the availability of scientific information (library resources) and the difficulty of learning in relation to various types of classes. Due to the epidemic situation and ERT, students set up new accounts on social media, most often on Google Meet or Zoom. Usually it was one (71%), two (15.3%), or three (6.5%) accounts. It is crucial to evaluate learning through social media compared to three traditional groups of classes: lectures, workshops, and laboratories. The fewest problems were indicated by the students with regard to the lectures, as they were considered to be easy. Difficulties began when comparing remote and traditional workshops, while laboratories turned out to be disadvantageous. More and more often it is emphasized that a return to the traditional form of education is needed, but distance learning will remain the new norm. The functioning of the education system in the post-pandemic reality will certainly force the use of information technologies, including social media, to a greater extent than it was before 2019. The results of the examination of ERT suggest that lecture is a type of educational activity that can be conducted in a different way than in the traditional form without sacrificing its quality. The access to scientific information was assessed by students at either average or good level.

The discussed factor blocks (1, 2, 3, 5) were used to evaluate the dependence on block 4 - performance. This block focused on factors related to the intensity and convenience of learning, as well as access to university-specific pieces of information. More than half of the students surveyed concluded that social media did not make it easier for them to pass an exam and that the intensity of their learning did not increase in their case. It means that social media complements learning and knowledge acquisition processes. Importantly, nearly 85% of respondents believed that the use of social media for learning was helpful. The efficiency of social media is also reflected in the high assessment of access to current, relevant academic information. Almost 70% of students positively evaluated learning at any time and place.

However, these results should be correlated with the difficulty of understanding the educational activities conducted and should not be treated in an overly optimistic manner. An in-depth research should be carried out to capture the relationship between ERT at any time and place and both the quality and difficulty of the material presented in a remote form.

For RQ2, it should be noted that there were no obvious discrepancies in the responses. The respondents, regardless of sex, type of studies, and place of residence, answered the questions almost identically. Slight differences in the results confirmed the reliability and credibility of the research carried out. It should also be taken into account that the respondents almost unanimously stated that the analyzed media had a positive impact on solving problems related to remote studies. The same pattern was observed while analyzing the contribution of the above-mentioned media to the facilitation of ERT.

## **6. Conclusion**

The study on ERT based on the use of social media during the COVID-19 pandemic allows us to draw many interesting conclusions. By using the confirmatory factor analysis and then the regression method, one of the leading statistical data analysis methods, it was found that during the pandemic, students used social media more than in the previous period and that many of them were forced to create new social media accounts. The profiles most frequently created were the ones on platforms for audiovisual communication, videoconferencing, and online conversations, such as Zoom, Google Meet, and WhatsApp. Particular attention should be paid to the increased use of social media since the spread of the pandemic compared to the pre-COVID situation and the fact that more than half of the respondents communicated with other students at least one hour a day, as well as that the vast majority of them did it for a minimum of several hours a day, which proves the importance of social media in communication and ERT, as well as points to the potential development of education through social media in the years to come.

The analysis of the regression method used in this study showed that the covid pandemic had a huge impact on the development of ERT through social media, as well as on ERT through social media in terms of the development of educational initiatives based on the possibility of studying from anywhere in the world.

The study shows extremely important conclusions for universities. There is a very high probability that most of the solutions used during the pandemic will be used and developed in the post-COVID period. The positive perception of conducting online lectures (anytime, anywhere) has shown that universities should implement a hybrid teaching model. Laboratories and workshops that require face-to-face contact with the lecturer should still be conducted in a stationary manner. Nevertheless, lectures may be conducted online. The examinations carried

have broadened the knowledge on the use of social media for ERT and determining what factors favor the intention to use, communication functionality, way of proceeding, performance, and involvement.

The research inspired the authors to continue research on the impact of COVID-19 on ERT through social media. It seems interesting to focus on the quality of the results of ERT using social media compared to knowledge acquired in a traditional way and the attitudes of students to return to full-time learning. The limitations of the research carried out were the low diversity in the fields of study. Most of the respondents were students of economic, sociological, and technical departments. Students of medical and artistic faculties participated in the study to a small extent only, which is also an important premise and direction to be taken into account while organizing further research on a wider group of students.

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## DISSIMILAR METAL WELDING OF S690 QL WITH DOCOL 1400 M STEEL FOR THE STRUCTURES OF VARIOUS MEANS OF TRANSPORT

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**Purpose:** The novelty and the aim of the article is to check the possibility of dissimilar welding of two grades of steel with significantly different properties.

**Design/methodology/approach:** Two various materials have been checked in welding in order to obtain a high-quality joint of various means of transport. The properties of the joint were checked by NDT (Non Destructive Test) and also bending and tensile strength were tested.

**Findings:** Relations between process parameters and the quality of welds.

**Research limitations/implications:** In the future, it can be suggested to investigate the effect of micro addition of nitrogen and oxygen in gas shielding mixtures of the MIG/MAG welding process.

**Practical implications:** The proposed innovation will not cause problems in the production process provided that the technological regime will be respected.

**Social implications:** Modifying the welding method will not affect the environment and production management methods. Producing dissimilar welds (although it is very difficult) translates into large savings.

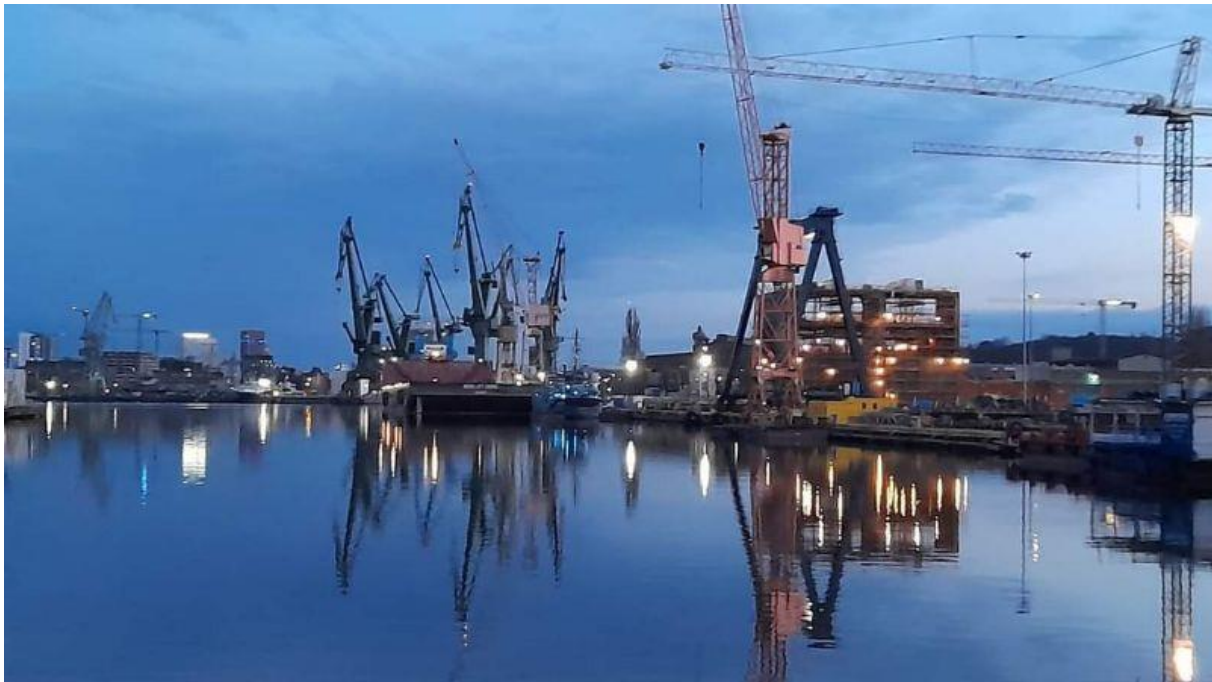
**Originality/value:** It is to propose a new solution with its scientific justification. The article is addressed to manufacturers of high-strength steel and advanced high-strength steel for automotive industry and other means of transport.

**Keywords:** dissimilar welding, S690 QL, DOCOL 1400 M, transport, shielding gas mixture, production savings.

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

## 1. Introduction

The article presents the results of tests leading to the choice of the correct MAG dissimilar welding parameters of of S690 QL high-strength steel (HSS) with DOCOL 1400 M advanced high-strength steel (HSS). These steels are taken into account as a new materials in the construction of various means of transport. The HSS and AHSS (advanced high-strength steel) steels can be used in automotive and shipbuilding industry and for elements of mobile platforms and tower cranes (Fig. 1). Other applications in the transport and other industrial sectors are also possible. The use of dissimilar welds is strongly recommended because of economic reasons.



**Figure1.** Tower cranes with elements made from HHS and AHSS steels.

Source: own study.

HSS and AHSS steels are very often used for antenna towers due to their very high strength (Jaewson et al., 2011; Darabi et al., 2016; Hadryś, 2015). The weldability of this steel is still not well easy because of the martensite structure (Golański et al., 2018, pp. 53-63; Skowrońska et al., 2017, pp. 104-111).

A major difficulty of 690 QL and DOCOL 1400 M welding steel is the tendency to welding cracks. Dissimilar joints made of this two steel grades could crack even more often. Therefore it is very important to determine welding parameters separately for each structure made of a dissimilar joint (Silva et al., 2019; Krupicz et al., 2020):

- welding current,
- arc voltage,
- welding speed,

- beveling method,
- type of electrode wires,
- composition of gas mixtures,
- pre-heating temperature.

Dissimilar welding of HSS with AHSS steel is complicated because of the high titanium content (Fydrych, Łabanowski et al., 2013; Shwachko et al., 2000). Preheating is very often recommended for proper welding of HSS and AHSS steels, but there is no mention in literature of preheating during dissimilar welding of HSS with AHSS (Szymczak, 2020).

## 2. Materials

For dissimilar MAG welding of S690 QL with DOCOL 1400 M the UNION X90 wire (EN ISO 16834-AG 89 6 M21 Mn4Ni2CrMo) was proposed. There were used and a gas mixture of argon and nitrogen. In the welding process, it was decided to check the need for drying preheating to a temperature of 100°C. A thickness of both elements was 1.8 mm. Table 1 shows the mechanical properties of the S690 QL and DOCOL 1400 M.

**Table 1.**

*Tensile strength of tested materials*

Steel	YS MPa	UTS, MPa	A5, %
S690 QL	690	970	14
DOCOL 1400 M	1150	140	5

The table data shows that both materials have different mechanical properties. DOCOL 1400 M steel has high strength, and S 690 QL has good plastic properties. These differences result from the chemical composition of both materials (Table 2).

**Table 2.**

*Chemical composition of S690 QL [6]*

Steel	C	Si	Mn	P	S	Al	Cr	Cu	Mo	Nb	Ni	Ti	V	B
S690 QL	0.21	0.8	1.7	0.025	0.015	0.01	1.55	0.5	0.7	0.06	2.1	0.05	0.12	0.005
DOCOL 1400 M	0.17	0.2	0.24	0.01	0.02	0.04	0.02	-	-	0.15	-	0.25	-	-

Chemical composition of electrode wire is given in Table 3.

**Table 3.**

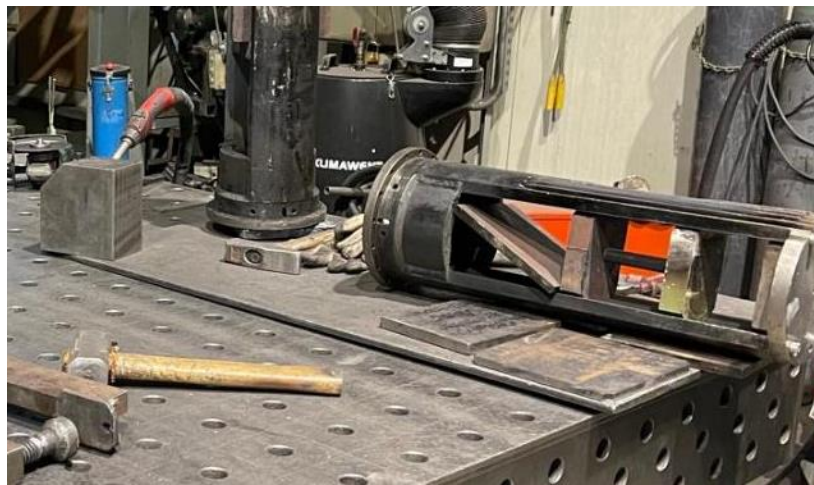
*Electrode wire UNION-X90 –composition [10]*

UNION	C%	Si%	Mn%	P%	Cr%	Mo%	Ni%	Ti%
X90	0.11	0.8	1.8	0.010	0.35	0.6	2.3	0.005

Before starting to make dissimilar joints no chamfering was performed. The welding parameters were as follows:

- diameter of the electrode wire: 1 mm,
- arc voltage: 20.5 V,
- welding current: 115.5 A,
- welding speed: was 320 mm/min,
- shielding gas flow: 14.5 l/min
- the nature of the weld: single-pass.

The workshop is presented in Fig. 2.



**Figure 2.** View on the MAG welding workshop.

Source: own study.

The joints were made with a drying pre-heating to the temperature of 105°C and without pre-heating. The shielding gas was changed twice in the MAG dissimilar welding process.

### 3. Methods

After dissimilar MAG welding, some non-destructive tests (NDT) and further destructive tests were carried out.

NDT examination generally based on:

- VT - visual test with a magnifying glass at  $3 \times$  magnification; the observation was carried out in accordance with PN-EN ISO:17638 standard with criteria of evaluation based on EN ISO 5817,
- MT- magnetic particle test in accordance with the PN-EN ISO:17638 standard, the observation was assessed in accordance with EN ISO 5817 using a magnetic flaw detector REM - 230.

The dissimilar welds were also structurally examined using a light microscope (LM). The observation was carried out in accordance with the PN-EN ISO 9016 2021 standard. Amount of nitrogen content in the weld metal was performed on the LECO ONH836 analyzer. A bending test was performed in accordance with PN-EN ISO 7438 standard.

#### 4. Results and discussion

The dissimilar joints were made using three different variants of shielding gases with various chemical composition:

- Argon,
- gas mixture containing argon and 0.8% N<sub>2</sub>,
- gas mixture containing argon and 1.6% N<sub>2</sub>.

The joints were additionally made in two ways:

- without preheating (samples A2, A4, A6),
- with preheating to the temperature of 105°C (samples A1, A2, A3).

The effect of visual tests is presented in Table 4.

**Table 4.**

*NDT results for tested dissimilar welds*

Sample	Type of shielding gas (mixture)	Welding without pre-heating	Welding with pre-heating up to 105° C
A2, A1	Ar	Cracks in weld	No cracks
A4, A3	Ar + 0.8 N <sub>2</sub>	Cracs in weld	No cracks
A6, A5	Ar + 1.6 N <sub>2</sub>	Cracs in weld	Cracs in weld

It was discovered that preheating before dissimilar steel welding S690 QL with DOCOL 1400 M is strongly recommended. The preheating temperature at the level of 105°C was accepted to be correct, because neither welding defects nor incompatibilities were observed in joints. It was easily noted that only in two teste cases it was possible to obtain correct dissimilar joints:

- argon,
- gas mixture containing argon and 0.8% N<sub>2</sub>.

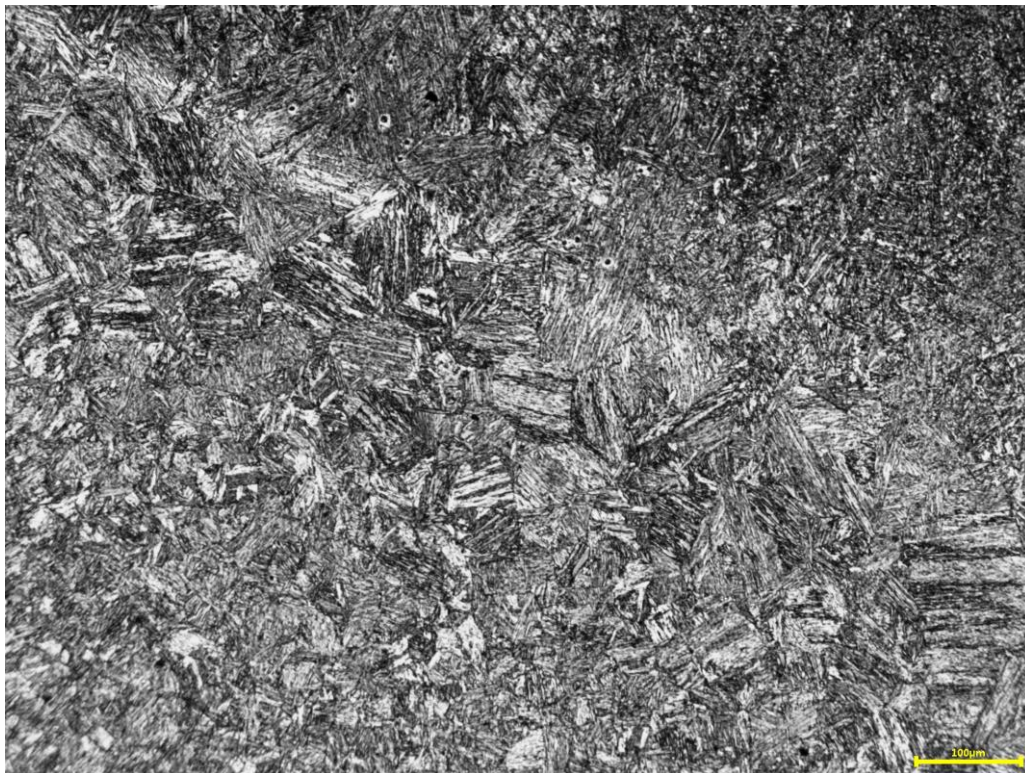
The next part of the research was to determine and compare the nitrogen content in the weld metal deposit, which was done on the LECO ONH836 analyzer. The test results are shown in Table 5.

**Table 5.**  
*Nitrogen in weld metal deposit (WMD)*

Sample	Shielding gas mixture	Nitrogen in WMD, ppm
A1	Ar	50
A3	Ar + 0.8 N <sub>2</sub>	55
A5	Ar + 1.6 N <sub>2</sub>	65

It is easy to observe that after dissimilar welding only in argon shield, the weld metal was obtained with the lowest nitrogen amount: 50 ppm. The use of a shielding gas containing 0.8% N<sub>2</sub> ppm allows only for a slight increase in the nitrogen content in the metal deposit to the amount of 55 ppm. The use of a shielding gas containing 1.6% N<sub>2</sub> translates into a significant increase in nitrogen content in weld metal deposit on the level of 65 ppm%. This is clearly too high a nitrogen concentration in the weld metal and this may correspond to the cracks observed during NDT tests.

For main destructive tests i.e. microstructure and tensile strength, only dissimilar joints made with preheating of 105° C were analyzed (samples A1, A3). The dominant structure was martensite, bainite, small amount of ferrite and non-metallic inclusions (Figure 3).



**Figure 3.** Structure of dissimilar weld (above S690 QL, below DOCOL 1400 M). The area around the main diagonal of the rectangle corresponds to a dissimilar weld; sample A3, Nital etch.

Additional observations using a scanning microscope allowed for a more complete identification of the structure due to the nature of the inclusions in the dissimilar weld.



Mainly identified such as inclusions as:

- carbides; mainly TiC, NbC),
- carbonitrides; mainly Ti(N, C),
- nitrides; mainly TiN).

In a dissimilar weld A3 containing 55 ppm nitrogen (table 5), more amount of TiN nitrides were observed than in the dissimilar weld A1 containing 50 ppm nitrogen. It is very important observation, because nitrogen in weld metal deposit strongly strengthens steel welds. The last part of the research was to check the tensile strength. Table 6 shows the mechanical properties of dissimilar welds (tensile strength UTS).

**Table 6.**

*Tensile strength of joints*

Sample	Type of shielding gas (mixture)	UTS [MPa]
A1	Ar	575
A3	Ar + 0.8 N <sub>2</sub>	615

The table data indicate that it is possible to get higher tensile strength of the dissimilar joint (over the 600 MPa level). This result was achieved when 0.8 N<sub>2</sub> was added to Ar. The tensile strength of the dissimilar weld made only in the argon shield is much lower. The gas mixture containing 0.8 N<sub>2</sub> nitrogen was found to be a preferable choice. This fact might be explained by the relationship that nitrogen has a high affinity for titanium and niobium. The presents of inclusions such as TiN, NbN, TiC, Ti (N, C), their size and distribution determine the dissimilar weld strengthening.

The last stage of the research was the performance of bending tests of the dissimilar welds, which were made from the face and ridge side of the weld. The test result of bending test is presented in Table 7

**Table 7.**

*Bending test of dissimilar weld*

Sample	Face side	Ridge side
A1	No cracks	No cracks
A3	No cracks	No cracks

The bending test result was positive. No welding defects or nonconformities were found. Bending tests were carried out only for joints A1 and A3, because they had the best properties in previous tests. In assessing good weldability, it is important to check both good joint strength and plastic properties. All completed weldability tests of the dissimilar joint S690 QL with DOCOL 1400 M can be treated as very positive.

## 5. Summary

In the paper, it was decided to find a way to weld together two types of steel with different mechanical properties, of which S 690 QL steel has good plastic properties and average strength value, and DOCOL 1400 M steel has high strength but poor plastic properties. Dissimilar joints are difficult to weld, but they are often made to save money, because one of the welded materials is always cheaper. In this case, the focus was on two different high-strength steels that are used in the construction of various types of means of transport. To assess the good weldability of dissimilar joints, it was decided to check the influence of the various nitrogen content added to the argon shielding gas mixture. Simultaneously, the influence of the application of the preheating before welding at the level of 105°C was checked. Several non-destructive and destructive tests were performed. The nitrogen content in the weld was tested, tensile strength and bending tests were performed. Destructive tests were selected due to the diverse nature of two dissimilar materials that were joined together. One steel was more durable, but had worse plastic properties. The second steel, on the contrary, had lower strength, but much better plastic properties. It has been shown that the gas mixture containing the small nitrogen content (0.85 N<sub>2</sub>) allows to noticeable increase the tensile strength of the joint with good plastic properties. Making recommended gas mixtures might improve knowledge of dissimilar welding, which can be used in the construction of many means of transport.

The following conclusions were made:

1. Preheat (105°C) is strongly recommended in dissimilar S690 QL/DOCOL 1400 M welding.
2. It is possible to obtain the tensile strength of the dissimilar joint of S690 QL/DOCOL 1400 M at the level over 600 MPa.
3. In the tested welds, it was observed that the dominant phase is martensite, bainite, ferrite and various nonmetallic inclusions.
4. On the basis of the research it can be concluded that the Ar + 0.8% N<sub>2</sub> gas mixture is more appropriate for the dissimilar welding of S690 QL/DOCOL 1400 M.

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## ASSESSMENT OF USEFULNESS OF CMMS CLASS SYSTEM FOR INDUSTRY 4.0 ENTERPRISE

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**Purpose:** The purpose of the article is recognition of the possibility of using CMMS class systems in supporting maintenance in the conditions of the implementation of the Industry 4.0 concept.

**Design/methodology/approach:** The above-mentioned purpose was achieved as well by examining the opinions of employees of the selected company as the mathematical formula for CMMS social assessment.

**Findings:** During the conducted research, it was found that there is a need to use CMMS class systems as a tool in the area of maintenance in an Industry 4.0 enterprise. It can be deduced from the ratings given by the employees of the researched company to these systems. There is also a need for further research and development of this topic as well as for providing appropriate training and support for employees for effective using CMMS class systems.

**Research limitations/implications:** The article shows the method of social evaluation of a technical solution which is a CMMS class system. Such a system may be implemented if the results of such an assessment are verified on the basis of data on maintenance activities of a technical, economic, organizational or environmental nature. Therefore, it is justified to continue research in the mentioned area using indicators and measures of the maintenance effectiveness (KPI, OEE, measures/indicators of reliability of machines, devices and systems), as well as methods and techniques of their simulation and forecasting in the discussed area.

**Practical implications:** The indicator for social evaluation can be used at the stage of selection, purchase of a CMMS class system of a production or service company or when carrying out comprehensive or partial changes in its information structure, ending with the implementation of a selected system of this class.

**Social implications:** Conducting a research using the method proposed in the article among the company's employees may convince them that the introduced changes are justified and beneficial for themselves, the company and its environment.

**Originality/value:** The article has a cognitive and application value, because it proposes the use of the original set of questions contained in the survey, as well as the original evaluation indicator of the CMMS class system.

**Keywords:** exploitation, maintenance, management, CMMS, Industry 4.0.

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

## 1. Introduction

The need for enterprises to compete in the conditions of a market economy forces them to take actions that allow them to achieve their intended goals. One of them is the implementation of the Industry 4.0 concept, which assumes the use of the Internet of Things and intelligent systems used in the acquisition, transmission and processing of large amounts of data, in particular for the purposes of controlling machines, including robots. One of the areas of the company's activity requiring the use of such data is the operation and maintenance of technical means. The occurrence of complex algorithms that require the collection and processing of such data requires the possession of an appropriate computer-aided tool, which in the discussed area can be a CMMS class system (Computer Maintenance Management system) (Walczak, 2012; Palka, Ciukaj, 2019).

James Harrington, an English writer, publicist and philosopher once said that "no company has the time or resources necessary to learn only from its mistakes". Therefore an implementation of such systems must be making thoughtful decisions, including conducting their analyses, that will make it possible to determine their usefulness for a company functioning, among others, in the conditions of industry 4.0. Such analyzes should include technical, economic and environmental aspects, as well as social aspects of maintenance, which are a novelty described in the literature.

Therefore, the article reviews the literature on the means and ways to support the implementation of the concept of industry 4.0, including CMMS class systems. Particular attention was paid to the social evaluation of technology (Technology Assessment) as a way to support decision-making on the implementation of tools of the discussed class. An original method of social evaluation of technology was proposed, which is the CMMS class system, and then it was verified on the example of a selected enterprise (Każmierczak et al., 2015; Kaźmierczak, 2013).

## 2. Means and methods supporting the implementation of the concept of Industry 4.0

The improvement of the company's competitiveness becomes possible thanks to the increase in productivity, which can be achieved through the use of the digital revolution in enterprises. It will be carried out through the implementation and operation of measures and methods supporting the implementation of the concept of industry 4.0 (Palka, Rizaoglu, 2019). Some of the currently used means and methods of the Industry 4.0 concept in enterprises are described below.

**The Internet of Things** (IoT) and/or the Industrial Internet of Things (IIoT) – according to (Fidali, Rybka, 2021), (Atzori et al., 2010) is a network information technology of physical objects (sensors, machines, cars, buildings and other technical means), which enables the interaction and cooperation of these objects to achieve common goals. The technologies that, according to (Mukhopadhyay, 2014), will control the Internet of Things in the future include sensor techniques, including RFID, SmartThings technology, nanotechnology and miniaturization. The Internet will help transform businesses and societies into sustainable and secure ones that enable efficient interaction between the physical world and its digital counterpart, what is commonly referred to as a cyber-physical system. The Industrial Internet of Things, on the other hand, covers the domains of machine-to-machine (M2M) technology and industrial communication technologies with automation techniques. According to this literature, IIoT paves the way to a better understanding of the manufacturing process, thus enabling efficient and sustainable production.

**Artificial Intelligence** can be defined as a sub-discipline of computer science dealing with the implementation of data processing systems that perform functions characteristic of human intelligence, such as reasoning, learning and self-improvement. The use of artificial intelligence by machines to complete complex tasks, reduce costs and improve the quality of products and services is the basic principle of intelligent enterprises and Industry 4.0 enterprises (Bahrin et al., 2016).

**Big data** should be understood as data sets that are characterized by a large volume, significant speed with which new data is generated (velocity) and a large variety of formats, dimensionality, and structure of the data itself (variety). In maintenance, according to (Jamrozik, 2018), large amounts of data are collected in SCADA or CMMS systems (Razali et al., 2020; Wiczorek, 2019).

**Modeling and simulation** - currently, there is an urgent need to develop simulation models, because an increasing amount of data is currently being processed in enterprises, which is the result of the increase in the level of automation and robotization and the need to ensure high flexibility of modern manufacturing systems, using streams from interconnected subsystems (Krenczyk, Pawlewski, Plinta, 2022). Contemporary simulation models use the concept of a "digital twin", which should be understood as a virtual representation of the product as an integrated data system, models and analytical tools imposed on the entire product life cycle (Fidali et al., 2021). Examples of the use of simulation methods and techniques in the operation and maintenance of technical systems in the conditions of Industry 4.0 are shown in (Palka, 2021a, 2021b, 2021c; Paszkowski, Loska, 2018).

**Machine learning**, in the context of Industry 4.0, is one of its key elements. Machine learning is a field of artificial intelligence that enables computers to automatically learn from available data and make decisions or perform tasks without having to program in an explicitly defined way. This technology is used in various industrial areas, such as production, logistics, data analysis and quality management. Thanks to its ability to analyze huge data sets, machine

learning allows you to extract hidden patterns, discover dependencies and predict future events. In the context of CMMS-class systems, machine learning can be used to create predictive models that make it possible to predict failures and necessary maintenance. By analyzing historical maintenance data, machines can "learn" to recognize patterns that indicate impending problems or failures. This allows you to schedule maintenance more efficiently, minimizing production downtime and emergency repair costs. Machine learning is also used in the optimization of production processes. By analyzing data on machine performance, production quality, consumption of raw materials or environmental parameters, CMMS class systems can provide recommendations for process optimization, identifying factors affecting problems or reducing losses.

**Cloud computing** is the storage and processing of data on remote servers that are accessible via the Internet. Cloud computing offers many benefits for enterprises, especially in the context of the large amounts of data generated as part of Industry 4.0. Cloud computing enables flexible scaling of resources, which is particularly important when processing large amounts of data. Enterprises can adapt their computing resources to current needs, which allows for efficient data processing without the need to invest in their own infrastructure. Cloud computing ensures the availability of data and applications from any place and device connected to the Internet. Employees can freely use data and applications, regardless of location, which promotes a flexible and mobile work environment. Cloud computing can provide a higher level of data security than traditional in-house solutions. Cloud services often offer advanced security mechanisms, such as data encryption, access controlled by authorization and authentication, as well as regular backups. The use of cloud computing allows enterprises to avoid high costs related to the purchase, maintenance and updating of their own infrastructure. Cloud service charges are typically flexible and scale based on actual resource usage. Cloud computing enables easy integration of various systems and applications. Enterprises can create integrated environments where data and applications are linked and exchange information. Cooperation between various departments of the company is facilitated, which promotes synergy and efficiency of activities (Palka, Ciukaj, 2019).

**The Integration of IT Systems** is another important aspect supporting the implementation of the Industry 4.0 concept. It consists in connecting various IT systems in the company in a way that enables a smooth flow of data and information between them. This technology allows for uniform data management in the enterprise. Information collected in various systems is synchronized and up-to-date, which enables informed decisions to be made based on complete and consistent knowledge. The integration of IT systems eliminates the need to manually transfer information between different areas of activity. Data is automatically transferred between systems, which shortens the response time and minimizes the risk of errors resulting from manual data entry. Consolidated collection of data from various areas of the company enables advanced data analysis, pattern detection, trend identification and strategic decision-making based on reliable information (Loska, 2012, 2015; Winkler et al., 2012).



**Virtual Reality (VR)** is one of the tools that can support and facilitate the implementation of CMMS class systems in an Industry 4.0 enterprise. Thanks to VR, it is possible to create realistic visualizations of production processes, simulations of machine operation and training for employees. By interacting in a virtual environment, employees can gain practical experience and improve their skills in the use of CMMS class systems. In addition, VR enables remote training and real-time collaboration, which is of great importance in the context of global employee teams. Employees can meet in a virtual environment using advanced VR features such as virtual tools and guidance. This contributes to the effective transfer of knowledge and increasing the effectiveness of the implementation of CMMS class systems in an Industry 4.0 enterprise. Virtual reality combined with CMMS class systems also allows for real-time data monitoring and analysis. Thanks to VR, it is possible to visualize performance indicators, the condition of machines or production processes, which makes it easier to identify areas that require improvement. This enables the company to make quick decisions and optimization activities based on real data collected by CMMS class systems.

### **3. Literature research on the application of computer aided maintenance in the mentioned area**

Conducting exploitation of technical means in the conditions of Industry 4.0 is possible if management in this area is carried out properly. One of the guarantors of the correct implementation of the function of managing the operation and maintenance of technical means (planning, organizing, motivating and controlling) is the collection, processing, transfer or sharing of data, information and/or knowledge using the CMMS class system. This knowledge may include data/information:

- on measures and technical systems,
- on operational events (intended and unintentional),
- on operational processes,
- about a person - users and technical means.

In many Research Centers, including the Department of Production Engineering of the Silesian University of Technology, research has been carried out for many years on the use of the CMMS class system in the operation and maintenance of technical means. Their results are books, articles, master's and doctoral theses, reports on research work carried out - internal (statutory) and work for the industry: (Każmierczak, 2000; Legutko, 2007; Orłowski, Lipski, Loska, 2012; Loska, 2012, 2015, 2016; Loska, Paszkowski, 2017; Palka, Ciukaj, 2019; Wieczorek, 2019; Wieczorek, Rozmus, 2017; Wieczorek, Szulc, Karwot, 2011). So far, they have focused on the following areas:

- application of the CMMS class system in the planning and implementation of maintenance and repair works,
- the use of CMMS class systems in the control of activities in the field of operation and maintenance of technical means,
- cooperation of CMMS class systems with systems of other classes (tools supporting decision making, simulation tools, tools supporting reliability analyses, systems supporting RCM analyses, geographic information systems, virtual reality systems),
- modeling of objects/locations in CMMS class systems,
- implementation of CMMS class systems.

These works are continued due to the need to implement the industry 4.0 philosophy in organizations and the need to use CMMS class systems in the conditions of its implementation. The subject of the relationship between the implementation of the Industry 4.0 concept and the subject of CMMS class systems has been presented in, among others, the following publications: (Azra, Dachyar, 2020; Cao et al., 2012; Razali et al., 2020; Nordal, El-Thalji, 2021; Dalzochio et al., 2020). Under the conditions of the implementation of the Industry 4.0 philosophy, by obtaining data/information from machines from the Internet of Things to CMMS class systems, transferring data from them to databases of other supporting systems (e.g. MRP, ERP, computer aided simulation system, etc.), or providing different users, it is possible to conduct a properly adopted policy of exploitation of technical means. Therefore, it becomes necessary to evaluate the CMMS class system at the stage of its implementation or to analyze the information system in order to carry out their modification. This assessment must take into account the needs arising from the operation of machines and devices in the conditions of industry 4.0. These needs include, among others (Jamrozik, 2018):

- detection of failures and faults by the machine in which they occur,
- planning tasks in the field of preventive and predictive maintenance, where the plans will be adapted to current data from various areas of the company's activity,
- automatic generation of reports containing data from various areas of the company's activity,
- conducting inspections of machines and devices based on solutions in the field of automation and robotics,
- implementation based on solutions in the field of automation and robotics of transactions in warehouses of material resources used in the implementation of tasks in the field of servicing technical means (spare parts, consumables and consumables, machines and service devices),
- optimization as an antidote to the failure to use data from CMMS class systems and systems derived from them.

One of the problems in the implementation of CMMS class systems, as well as other solutions in the field of the Industry 4.0 concept, is their evaluation. In connection with the subject of research on the use of CMMS class systems in the enterprise, in the opinion of the author of the article, it is important to carry them out in the following research areas:

- development of a method of comprehensive assessment of maintenance solutions supporting the implementation of the Industry 4.0 concept in the enterprise. This assessment should cover the technical, economic, environmental and social aspects of these solutions,
- development of methods and techniques for obtaining, collecting and processing data, information and knowledge for the purpose of conducting the above-mentioned assessment. The use of not only CMMS class systems, but also expert systems should be considered in this area.

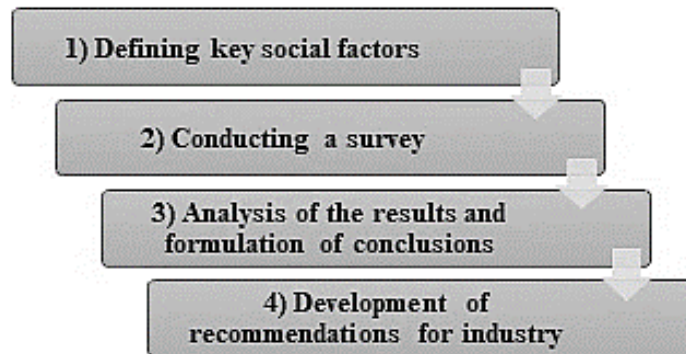
An element of a comprehensive assessment of the solutions described in the article should be a social assessment. This assessment allows you to receive subjective information, which is the opinions of users about the technical means they use. The reason for their implementation should be the risk of side effects and consequences that are difficult to predict (Stankiewicz, 2010), which also applies to CMMS class systems used in the implementation of the Industry 4.0 concept. In the literature, this way of approaching a technical measure is referred to as Technology Assessment. This area of research is constantly evolving. Examples of publications on Technology Assessment include: (Kaźmierczak, 2013; Kaźmierczak et al., 2015; Grunwald, 2019).

One of the significant problems of the social evaluation of technology are the gaps in the availability of methods and/or their use for the purposes of implementing selected types of technologies. Examples of such solutions are CMMS systems. Their application for the purpose of Industry 4.0 conception require an assessment of the influence of exploited technical object, operation and maintenance events, processes and systems to the company and its environment. Many attempts to deal with this problem have been made, whose example is (Michalski, 2011). Therefore, the task of developing a method to support the assessment of CMMS class systems as tools for implementing the concept of industry 4.0 was undertaken in the article.

#### **4. The concept of a method for social assessment of the suitability of CMMS class systems in an Industry 4.0 enterprise**

The concept of the method of social assessment of the suitability of CMMS class systems in an Industry 4.0 enterprise is based on considering the social and human perspective in the process of evaluating these systems. This helps to understand what the social, organizational,

and psychological factors are affecting the effective implementation and use of CMMS systems in the context of Industry 4.0. The main concept methods are shown in Fig. 1.



**Figure 1.** The main concept methods.

Source: own study.

The method of social assessment of CMMS class systems in an Industry 4.0 enterprise consists in identifying key social factors that affect the effectiveness of the implementation and use of these systems. The survey focuses on company employees who are in contact with CMMS systems. The questions concern employees' perceptions, expectations, concerns, benefits and suggestions related to CMMS systems. The analysis of the results allows to identify dominant patterns and trends in the social assessment of CMMS systems, and the conclusions can help in understanding the key social factors for the effectiveness of the implementation and use of these systems. Based on the analysis, recommendations can be developed to improve the implementation of CMMS systems, such as employee training, information campaigns, emotional support, organizational changes or user interface customization. The implementation of these recommendations is aimed at increasing the acceptance, involvement and effectiveness of CMMS systems in the enterprise.

#### 4.1. Survey study

Implementation of a CMMS class system may be a chance to meet the needs of the company's management resulting from the implementation of the Industry 4.0 concept. It can be carried out using the assessment of their suitability in the enterprise for the purposes of implementing this concept. An element of this method is a survey in which the following questions appear:

1. To what extent, in your opinion, would a CMMS class system allow for the collection of a large amount of appropriate data (Big Data) and enable their processing in order to make rational decisions in the field of maintenance?
2. To what extent, in your opinion, would a CMMS class system with learning machines be able to improve the detection of failures and faults in the company where you work?

3. To what extent, in your opinion, would the CMMS class system with the Internet of Things (providing communication between machines and machines and the user) in the company where you work contribute to reducing the number and value of downtimes of machines and devices?
4. To what extent, in your opinion, would reporting using the CMMS class system as an element of an integrated automated system supporting the exchange of information between machines and between machines and people in the company where you work bring measurable economic benefits in the area of machine maintenance?
5. To what extent, in your opinion, would reporting using the CMMS class system as an element of an integrated automated system supporting the exchange of information between machines and between machines and people in the company where you work bring measurable economic benefits in the area of warehouse management (by implementing solutions in the field of the Industry 4.0 concept, including the concept of a smart warehouse)?
6. To what extent, in your opinion, a CMMS class system with a relational database (optionally together with other supporting systems) and methods and techniques of computer simulation and short-term forecasting and artificial intelligence could in the enterprise where you Do you work effectively to support decision-making in the conditions of the philosophy of preventive and predictive maintenance, as well as the implementation of the green maintenance concept ?
7. To what extent, in your opinion, would the CMMS class system in the conditions of industry 4.0 in the company where you work contribute to improving the efficiency of planning and scheduling maintenance work, which would affect the implementation of production/service tasks according to plan?

The research sample consisted of 75 respondents representing various departments of the company of clothing industry, such as production, logistics and maintenance (it was assumed that selected persons know the processes and systems (including information and computer systems) in a company). Respondents were randomly selected (simple random sampling) from different working teams. Different hierarchical levels and work experience were included in the sample to obtain a variety of perspectives. The survey was voluntary and respondents were guaranteed confidentiality. With the help of a diverse sample, it is possible to obtain representative and comprehensive results regarding the social assessment of the suitability of CMMS class systems in Industry 4.0.

Each question was rated on a scale from 1 to 5, where 1 was the lowest score and 5 was the highest score.

Data from the surveys were the basis for calculating the value of the social evaluation index, calculated according to the formula:

$$W_i = \sum_{j=0}^n (P_{ij} \cdot K_{ij}) \quad (1)$$

where:

- P – probability of occurrence of i – this answer (on i – this question in the survey) for j – this assessment,  
 K – this rating (from 1-5, where 1 - the lowest rating of i - this answer, 5 - the highest rating of i - this answer).

Probability of occurrence of i – this answer (on i – this question in the survey) for j – this assessment can be computed with the use of the following formula:

$$P_{ij} = \frac{n_{ij}}{N} \quad (2)$$

where:

- $n_{ij}$  – amount of persons filling the questionnaire, answering i – this question in the survey j – this assessment,  
 N – amount of all persons answering the questions in the all surveys.

The results of the survey were collected in a spreadsheet and analyzed. On this basis, the probability of a given answer and the social evaluation were calculated based on the formula (1). The conducted analysis is summarized in Table 1.

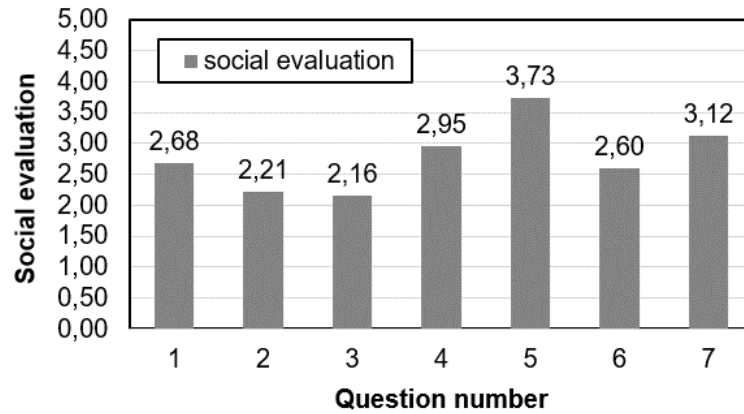
**Table 1.**  
*Results of the survey*

N	Response scale					Social evaluation
	1	2	3	4	5	
1	0	5	7	29	34	2,68
P	0,00	0,07	0,09	0,39	0,45	
2	5	7	14	28	21	2,21
P	0,07	0,09	0,19	0,37	0,28	
3	0	2	11	37	25	2,16
P	0,00	0,03	0,15	0,49	0,33	
4	0	1	8	27	39	2,95
P	0,00	0,01	0,11	0,36	0,52	
5	1	0	8	15	51	3,73
P	0,01	0,00	0,11	0,20	0,68	
6	2	9	20	21	23	2,60
P	0,03	0,12	0,27	0,28	0,31	
7	0	0	3	27	45	3,12
P	0,00	0,00	0,04	0,36	0,60	

N - question number, P – probability.

Source: own study

In order to illustrate the obtained results and to maintain the legibility of their visualization, a bar graph was prepared. The results of the social assessment of the suitability of CMMS class systems in an industry 4.0 enterprise are shown in Fig. 2.



**Figure 2.** The main concept methods. The results of the social assessment of the suitability of CMMS class systems in an Industry 4.0 enterprise.

Source: own study.

The analysis of the answers to the questions shows that the overall assessment of the CMMS class system by the respondents is moderate, with slightly higher assessments of the economic benefits in warehouse management and maintenance planning. It is worth noting the lower ratings related to the possibility of collecting data, improving the detection of failures and faults, and reducing the number and downtime of machines and devices. These results may suggest areas where the CMMS system may require further development and improvement to better meet the expectations of respondents.

## 5. Summary and conclusions

This article aims to present a method for social assessment of the suitability of CMMS (Computer Maintenance Management System) class systems in the context of an Industry 4.0 enterprise. As part of the literature research and the conducted survey, an attempt was made to examine the opinions of employees from various departments regarding the potential benefits and use of the CMMS class system in their daily work.

As part of the survey, respondents were asked a number of questions regarding various aspects related to the CMMS class system. Employees were to assess to what extent they believe that the CMMS class system allows for the collection and processing of large amounts of data, improves the detection of failures and faults, reduces the number and value of machine downtimes, generates economic benefits and affects the effectiveness of planning maintenance works.

The analysis of the obtained results allowed the formulation of the following conclusions:

**Question 1. Average rating: 2.68/5**

The answers indicate that the respondents, on average, think that the CMMS class system has a moderate capacity to collect and process large amounts of data in order to make rational decisions in the field of maintenance.

**Question 2. Average rating: 2.21/5**

The answers suggest that the respondents attribute little value to the CMMS system in improving the detection of failures and faults in cooperation with the learning machines in their enterprise.

**Question 3. Average rating: 2.16/5**

The answers indicate that the respondents attribute low value to the CMMS system in reducing the number and downtime of machines and devices through integration with the Internet of Things.

**Question 4. Average rating: 2.95**

The answers suggest that the respondents attribute moderate economic values for reporting using the CMMS system as an element of an automated information exchange system between machines and humans.

**Question 5. Average rating: 3.73/5**

The answers indicate that the respondents attribute relatively high economic values for reporting using the CMMS system in the area of warehouse management, especially in the context of the concept of Industry 4.0 and the intelligent warehouse.

**Question 6. Average rating: 2.60/5**

The answers indicate that the respondents attribute a moderate value to the CMMS system equipped with a relational database, computer simulation methods, short-term forecasting and artificial intelligence in the context of supporting decisions regarding preventive and predictive maintenance and the implementation of the green maintenance concept.

**Question 7. Average rating: 3.12/5**

The answers suggest that the respondents attribute a moderate value to the CMMS system in improving the efficiency of planning and scheduling maintenance works and the implementation of production/service tasks as planned in the conditions of Industry 4.0.

The conclusions of the study confirm the great potential of CMMS class systems in Industry 4.0 enterprises. However, there is a need for further research and development of this subject, taking into account the specificity of individual industries and adapting solutions to specific requirements. It is also essential to provide appropriate training and support for employees to make the most of the opportunities offered by CMMS systems. The introduction of CMMS class systems together with learning machines, the Internet of things and other Industry 4.0 solutions can contribute to improving the detection of failures, reducing the downtime of machines and devices, increasing the efficiency of planning maintenance works and generating economic benefits. Implementation of these solutions, however, requires careful planning,



tailoring to the needs of a specific organization and ensuring the involvement of all stakeholders.

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## WHISTLEBLOWING AS A TOOL FOR HR COMPLIANCE MANAGEMENT SYSTEM – SURVEY REPORT

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**Purpose:** To present an excerpt from author's own study conducted among HR professionals, managers and directors in December 2022 in Poland as part of the research project 'HR Compliance in HR Risk Management'. The aim of the article is to characterise whistleblowing as a tool of the HR Compliance Management System and to identify differences in the evaluation of the process of reporting wrongdoing and undesirable behaviour in organisations depending on the job position of the respondents, the size of employment in the company, the form of ownership and the industry.

**Design/methodology/approach:** A proprietary survey questionnaire was developed. The study was carried out using a diagnostic survey method. A computer-assisted web interview (CAWI) and a computer-assisted telephone interview (CATI) were used. Statistical methods were used to analyse the survey results, including chi-square test with Yates' correction, Kruskal-Wallis test.

**Findings:** Whistleblowing is an instrument for detecting wrongdoing in organisations, being one of the three pillars of HR Compliance and an important tool of the Compliance Management System. Differences in the evaluation of the various elements of the whistleblowing system have been diagnosed. One-third of the respondents do not have a clear opinion on the evaluation of a well-established whistleblowing system. In medium-sized companies, respondents' rating is higher than in other organisations in terms of evaluating internal channels for whistleblowing, as well as protecting whistleblowers from retaliation. The HR department is the entity empowered to receive and coordinate the handling of whistleblowing reports in the workplace in public organisations, which stand out with the highest average rating of providing anonymity to the whistleblower and granting protection to the whistleblower against potential retaliation. Differences in rating by job position relate to issues of organisational culture, employee confidence in the proper functioning of the company's whistleblowing system, the scope of reportable wrongdoing within the company, the preparation and provision of internal channels for whistleblowing. On average, professionals rate the whistleblowing system in organisations lower.

**Research limitations/implications:** The research sample was 205 units. The survey was not randomised and therefore the results developed are not representative and do not allow generalisation and drawing conclusions about the phenomenon on a national scale.

**Practical implications:** The results obtained from the research may be useful for business owners, managers, human resources and compliance professionals who are responsible in organisations for implementing systemic whistleblowing solutions in the workplace.

**Social implications:** Building awareness of whistleblowing and its key role in the HR Compliance management system in companies.

**Originality/value:** The article is of cognitive value for the development of management and quality science in the area of human resource management and organisational risk management. It contributes to the development of knowledge on whistleblowing in companies from a management perspective.

**Keywords:** whistleblowing, whistleblower, compliance risk, HR Compliance, personnel risk, compliance management system.

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

## 1. Introduction

This article deals with the important and topical issue of whistleblowing in the workplace, and it is written during the period of the planned coming into force of the EU Directive 2019/1937 on the protection of whistleblowers [Directive (EU) 2019/1937], which so far has not yet been implemented in Poland, although it should have been implemented as early as two years ago (Makowski, 2023).

It turns out that the transposition of the directive's provisions to the Polish legal system is not easy, whereas changing the mentality and building a positive image of whistleblowers is also a big challenge. Undoubtedly, whistleblowing should be treated both as a risk management tool, which allows to identify weaknesses, improve management processes and introduce innovations, and as a communication channel between the employees and the employer, which provides him with the necessary knowledge about the current state of the institution and the reservations of the team (Jarzęcka-Siwik, 2021, pp. 152-153).

Indeed, whistleblowing is a tool used to detect organisational irregularities that can assist management in companies (Bielińska-Dusza, Żak, 2018, p. 119). Whistleblowing involves reporting both illegal activities and activities that are immoral or unethical (Bielińska-Dusza, Żak, 2018, p. 119).

The article attempts to look at this topic from a management perspective, describing the current practices of the whistleblowing system in Polish organisations from the point of view of HR specialists, managers and directors, treating whistleblowing as an important tool of the HR Compliance Management System. It should be emphasised that the importance of the Compliance Management System (CMS) is growing in the management of modern organisations, which is mainly determined by key legislative changes and the resulting numerous new obligations imposed on companies (Barcik, 2019, p. 232).

Recently, the issue of whistleblowing has become one of the most important elements in the discussion on compliance management in the organisation, and an increasing number of organisations are conducting internal investigations (Tokarczyk, 2020, p. 9). Hence the interest

and urge to write an article on this topic. It presents an excerpt from the results of the author's own survey conducted as part of the research project entitled "HR Compliance in HR Risk Management". The article is written in the form of a survey report, and includes an extract selected from it, concerning whistleblowing only, supplemented by an analysis of the differences in the evaluation of the process of reporting wrongdoing and undesirable behaviour depending on the respondents' job position, the size of employment in the company, the form of ownership and the industry (see Winnicka-Wejs, 2023).

## 2. Literature Review

Whistleblowing is the subject of only a few Polish studies and academic publications. For example, in the BazEkon database for the query "whistleblowing" there were only 32 records (publications from 2006-2023) (BazEkon, 2023), and in the National Library database - 43 results, where 25 of them were assigned to the "law and the judiciary" entry (National Library, 2023).

In Poland, the topic of whistleblowing is still under-researched, especially in the context of management. The predominant works are in the field of legal sciences (Szewczyk, 2020b; Sieradzka, Wieczorek, 2021; Baran, 2019; Baran, Ożóg, 2021), as well as in the context of fraud in accounting and finance (see Knopp, Cemel, 2016, pp. 156-166; Niewiadoma, 2009, pp. 221-231; Miklaszewski, 2009, pp. 81-99). The publications of Wolters Kluwer from the so-called "Compliance Library" are also noteworthy (e.g. Makowicz, Jagura, 2020).

The Polish literature on the subject emphasises that whistleblowing aims to protect the public interest, protect the employer's interest and protect the interest of the whistleblowing employee (Hołda-Wydrzyńska, 2023, p. 140). This literature identifies significant factors determining the occurrence of internal whistleblowing, which have been attributed to the following areas: ethics, leadership, policies and procedures, retaliation and safeguarding, social climate, organisational justice, education and training, reporting channels, communication, additional motivation, organisational size and structure, and audit committee (more in Mrowiec, 2022, pp. 142-186). In contrast, based on McKinsey's 7S model, other factors influencing whistleblowing were identified in healthcare organisations: staff, style, shared value, system, structure, strategy, skills (more in: Wiśniewska, 2021, pp. 131-165).

Surveys conducted among municipal-level local government entities showed that almost half of the municipalities had no knowledge of the EU whistleblower directive (they learned about it from a survey), and the main rationale for implementing a whistleblower system is, or will be in the future, the legal obligation imposed on municipalities to introduce it, rather than the belief that the system is an effective tool for preventing the occurrence of irregularities (see Przybylska, Kańduła, 2022, pp. 60-73; Przybylska, 2020, pp. 1-16). It appears that the

implementation of a whistleblower protection system as a management control tool in the aforementioned entities can be a considerable challenge (see Tubek, Przybylska, 2022, pp. 65-77; Małecka-Lyszczek, 2021, pp. 54-61; cf. Wiatrak, 2021, pp. 129-145).

On the other hand, the results of a survey conducted among future professionals (students) also indicated a low level of familiarity and a vague attitude towards whistleblowing (see Świątek-Barylska, Opara, 2016, pp. 2-8), while those conducted among employees of Polish organisations proved that those who are pro-socially oriented have a more positive attitude towards whistleblowing than others (more in: Fornalczyk, Goderska, 2015, pp. 119-129). In contrast, a survey in the pharmaceutical industry showed that the whistleblowing tool evoked bad associations and negative emotions (more in: Stankiewicz-Mróz, 2015, pp. 158-169). Moreover, in Polish organisations, the social acceptance and interest of employees in disclosing irregularities occurring in the workplace that are important for social or public interest is conditioned by the degree of harmfulness of the act. As the degree of the threat increases, so does the declarative willingness to report irregularities (Świątek-Barylska, 2012, p. 410).

Existing cases of whistleblowing and censorship in workplaces in Poland (including those from the COVID-19 pandemic) indicate the need to redefine the issue of loyalty in labour law and the related freedom of expression of employees (see Kobroń-Gąsiorowska, 2021, pp. 131-142; cf. Bolesta, 2018, pp. 35-46), as well as the limits of acceptable criticism of the employer (see Bosak-Sojka, 2018, pp. 59-68).

The analysis of the Polish literature on the subject has identified a research gap regarding the analysis of whistleblowing from a management perspective, from the point of view of experts - practitioners in the field of HR (human resources management). Such a research perspective was also not observed when analysing English-language reviewed papers from the ProQuest database (from 2013 to 2023, with the search query: whistleblowing (abstract) & hr compliance) (ProQuest, 2023). The theme of whistleblowing appears in the context of law (e.g. Tschepik, 2020), business ethics (*Journal of Business Ethics*) and even criminology theory (Peltier-Rivest, 2018).

Their content analysis shows that whistleblowing is a process, rather than a single decision (Vandekerckhove, Phillips, 2019, pp. 201-219; Vandekerckhove, 2018, pp. 15-25). Whistleblowing intentions are higher when the reporting channel is administered externally than when it is administered internally (Gao, Greenberg, Wong-on-wing, 2015, pp. 85-99). Power distance, moral intensity, and professional commitment influence decisions to disclose irregularities (Pangestu, Dian, 2020, pp. 144-162). Whistleblowing both enhances the quality of life in that it sustains the democratic process, and may well be related to economic prosperity (Francis, Armstrong, Foxley, 2015, pp. 208-218).

The legislation should include corporate grievance mechanisms to match remedies with victims' expectations (Saloranta, 2021, pp. 753-780). Corporate wrongdoing continues to take a prominent place in business headlines, and with it the issue of how to manage whistleblowing



(Webster, 2015, pp. 65-75). Employee-perceived organizational politics partly mediates the relationship between ethical leadership and internal whistleblowing (Cheng, Bai, Yang, 2019, pp. 115-130). Employee whistleblowing via social media channels represents a very high risk to corporate reputation and can potentially lead to litigation and financial loss, especially when the message goes viral (Xiao, Wong-On-Wing, 2022, pp. 519-542). Companies can use dissenting voices to improve workplace safety, empower employees and strengthen organizational culture (Rebbitt, 2013, pp. 58-61).

When examining reporting mechanisms, it was found that effective whistleblowing mechanisms should actively encourage reporting wrongdoing, and all credible allegations should be independently investigated and whistleblowers should be given the opportunity to remain anonymous (Peltier-Rivest, 2018, pp. 784-794). Among US employees, the relationship between the frequency of unethical behaviour that employees observe in their organisation and their intention to whistleblow was studied. The results confirmed the expected curvilinear relationship based on the Focus Theory of Normative Conduct (Kaptein, 2022, pp. 857-8750).

However, specific cultural elements may make it difficult to report irregularities and limit the generalisation of the results of previous studies, which were almost always based on the context of Anglo-Saxon countries. For example, in Brazil, researchers have neglected this topic (Sampaio, Sobral, 2013, pp. 370-388), as is the case in Poland.

### **3. Research Methodology**

The literature study identified the state of research in the subject area addressed, defined the research gap in the literature and outlined the research area. The primary literature was identified, a selection of publications was made and a database of publications was compiled. This was followed by a content analysis and an assessment of the quality of the research to date (cf. Czakon, 2020, pp.119-139).

The empirical survey was conducted among HR professionals, managers and directors in December 2022 in Poland, as part of the research project 'HR Compliance in personnel risk management'. It covered the subject area pertaining to research fields concerning managers' attitudes towards risk; sources of personnel risk on the part of the employer (board members, executives) and the staff; assessment of the HR Compliance system in the organisation, including the whistleblowing system, prevailing behaviour towards personnel risk in the company, losses occurring as a result of risks related to the human factor, assessment of the issue of personnel risk management and HR Compliance.

A proprietary survey questionnaire was developed for the study in November 2022. The pilot study, which aimed, among other things, to improve the tool in terms of content and technical aspects, was conducted from 1.12.2022 to 8.12.2022. The survey proper took place

between 12.12.2022 and 19.12.2022. The nationwide survey was commissioned to the Centre for Research and Development at the University of Economics in Katowice, which has experience in conducting this type of market and marketing research and has a contact database of companies.

The study was carried out using a diagnostic survey method. A computer-assisted web interview (CAWI) and a computer-assisted telephone interview (CATI) were used. A total of two hundred and five fully completed questionnaires were obtained. Statistical methods were used to analyse the survey results, including chi-square tests with Yates' correction and the Kruskal-Wallis test.

A total of 205 people took part in the survey. The structure of respondents in terms of gender, age, position, size of employment in the company, form of ownership, PKD industry (as in Polish Classification of Activities), and voivodeship is presented in Table 1.

**Table 1.**

*The structure of respondents in terms of gender, age, position, size of employment in the company, form of ownership, PKD industry (as classified by PKD, i.e. Polish Classification of Activities), and voivodeship*

Group	Share (%)
<b>Gender</b>	
Female	57.56
Male	42.44
<b>Age group</b>	
Up to 29 years	1.95
30-39 years	51.71
40-49 years	30.73
50-59 years	15.12
60 years and more	0.49
<b>Position</b>	
HR Specialist	11.22
Recruitment Officer	26.83
Talent Management Specialist	1.46
Payroll Specialist	17.07
Compensation and Benefits Specialist	3.41
Training Officer	9.76
In-House Trainer	1.95
HR Business Partner / HR Consultant	4.39
HR Manager, Payroll Manager	16.10
Personnel Director	3.41
Other	4.39
<b>Employment size</b>	
Up to 9 employees	19.51
10-49 employees	38.54
50-249 employees	30.73
over 250 employees	11.22
<b>Form of ownership</b>	
Foreign	15.61
National private	58.05
State	16.10
Municipal	0.98
Mixed	9.27

Cont. table 1.

<b>PKD Industry (as classified by PKD, i.e. Polish Classification of Activities)</b>	
Agriculture, Forestry, Hunting and fishing	0.49
Mining and quarrying	0.49
Industrial processing	6.34
Electricity, gas, steam and air conditioning supply	0.98
Water supply; sewerage, waste management and remediation activities	0.49
Construction	15.12
Wholesale and retail trade; repair of motor vehicles, including motorbikes	15.61
Transport and storage	9.27
Accommodation and food service activities	2.93
Information and communication	2.93
Financial and insurance activities	6.34
Real estate activities	0.98
Professional, scientific and technical activities	2.93
Administrative and support service activities	0.49
Public administration and national defence; compulsory social security	0.98
Education	6.83
Healthcare and social welfare	1.46
Arts, entertainment and recreation activities	3.90
Other service activities	21.46
Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	0.00
Activities of extraterritorial organisations and bodies	0.00
<b>Voivodeship</b>	
Lower Silesian	3.41
Kuyavian-Pomeranian	8.29
Lublin	0.49
Lubush	1.46
Łódź	15.61
Lesser Poland	4.39
Mazovian	20.98
Opole	0.98
Subcarpathian	0.49
Podlaskie	1.95
Pomeranian	7.32
Silesian	21.46
Świętokrzyskie	2.44
Warmian-Masurian	2.93
Greater Poland	5.83
West Pomeranian	1.95

Source: (Winnicka-Wejs, 2023).

## 4. Results and Discussion

### 4.1. Definitions and etymology of the terms “whistleblowing”, “whistleblower”

There is no definite understanding of the terms whistleblowing or whistleblower in the literature. Whistleblowing has its roots in medieval England and the common law that operated there. In those days, as a result of poorly functioning law enforcement agencies, the *qui tam* law was introduced, whereby any person could file a lawsuit on behalf of the king, which

allowed for more effective enforcement of existing laws. *Qui tam* is an abbreviation of the Latin phrase: *Qui tam pro domino regequam pro se ipso in hac parte sequitur*, i.e. he who prosecutes on behalf of the king and himself in this case (Świątek-Barylska, 2012, p. 405).

It appears that the concept, although known since the Middle Ages, has only been associated with the disclosure of crime in organisations since the 1970s (Beściak, 2010, p. 31). Table 2 includes selected definitions of 'whistleblowing' and Table 3 of 'whistleblower'.

**Table 2.**  
*Definitions of 'whistleblowing'*

Definition	Author
"Whistleblowing is an increasingly common tool for detecting fraudulent activities. It involves informing the organization's management or external entities of any ethically, fraudulently or corruptly motivated irregularities."	(Skoczylas-Tworek, 2020, p. 96)
"The phenomenon of an employee's disclosure of any reprehensible and prohibited activities taking place in institutions or workplaces."	(Kobroń-Gąsiorowska, 2018, p. 131)
" An irregularity detection activity involving the reporting by specific individuals (usually employees of the organisation in question) of violations of the law, perceived fraud or ethical violations in a designated manner, generally ensuring the anonymity of the reporter (the so-called violations reporting system)."	(Eleryk, Piskorz-Szpytka, Szpytka, 2019, p. 179).
"Ethical disclosure of information on crime and abuse occurring in companies."	(Bąk, Witkoś, 2016, p. 116)
"Disclosure in the public interest, by a person inside an organisation, of information about irregularities within that organisation to those with an interest in the proper functioning of that organisation."	(Maciejewski, 2013, p. 341-358)
"The disclosure or transmission of information about irregularities that relate to corruption or other criminal activities, failure to fulfil obligations, unlawful decisions, situations of threat to public health and the environment, abuse of power, unauthorized use of public funds and property, gross waste public resources or mismanagement, conflicts of interest, and all activities aimed at concealing these pathologies."	Transparency International (Worth, 2013)
"Disclosure, in the public interest, of information about irregularities within an organisation by an individual inside that organisation to parties concerned with the proper functioning of that organisation."	(Banisar, 2011).
"The disclosure by organization members (former or current) of illegal, immoral and illegitimate practices under the control of their employers to persons and organizations that may be able to effect action."	(Near, Miceli, 1985, p. 1).
"A type of 'ethical signalling', reporting wrongdoing in the workplace in the name of the greater good. <i>Whistleblowing</i> involves disclosing irregularities, illegal, dishonest or prohibited activities that occur in the workplace."	(Klimczak et al., 2017, p. 3)
"Reporting - by current or former employees, co-workers or counterparties - of illegal, improper, hazardous, harmful or unethical practices by the entrepreneur concerned, a public body or their employees or co-workers."	(Bodziony et al., 2021, p. 15)

Source: own compilation based on sources included in the table.

**Table 3.**  
*Definitions of 'whistleblower'*

Definition	Author
"A person who reports to his or her employer (e.g. ethical advisor, internal auditor, supervisory board, through a hotline or other mechanisms) or outside his or her employer (e.g. to the competent control, supervisory, law enforcement or ownership body, also to the public) of irregularities occurring in the workplace, professional environment or one falling under the responsibility of the employer."	(Szewczyk, 2021, pp. 32-33)

Cont. table 3.

"In the most general sense - a whistleblower is a person who, having information about improper conduct of other entities, informs the relevant public authorities or the public about it."	(Pietruszka, 2020, p. 115)
"An individual (employee in the broad sense) who, for the sake of his or her workplace and/or the public good, communicates (first to his or her superiors, then - if this is ineffective - to other instances, law enforcement agencies or the media) information about irregularities related to the functioning of his or her organisation."	Batory Foundation (Makowski, 2023) (Markowski, Waszak, 2016, p. 9)

Source: own compilation based on sources included in the table.

An analysis of available publications reveals a problem with finding Polish equivalents of the words whistleblowing, whistleblower, which are not always accurate and adequate. There are both terms with a negative ethical connotation and axiologically neutral expressions. Unfortunately, some phrases do not capture the essence of whistleblowing and are burdened with historically bad connotation (cf. Table 4, 5).

**Table 4.***Whistleblowing and its synonymous terms*

<b>Whistleblowing</b> - "blowing the whistle", signalling, voice of conscience, informing in good faith, sounding the alarm, exposing, employee exposure, publicising unethical behaviour, disclosing in good faith, informing superiors, shouting in terror ("bellow in terror", "beat the drums in terror"), "hue and cry" - shouts of displeasure upon hearing of a crime, "catch thief!", early warning of wrongdoing, dirt laundering, signalling, signalling unethical behaviour, reporting irregularities, wrongdoing reporting system, raising the alarm about irregularities in one's company, system of informing about irregularities (SIN for short), irregularities signalling system.
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Source: own compilation based on (Hołda-Wydrzyńska, 2023, p. 137; Berry, 2004, p. 1; Bielińska-Dusza, Żak, 2018, p. 121; Rogowski, 2007a, p. 24; Arszułowicz, 2007, p. 97; Piwowarczyk, 2018, p. 103; Beściak, 2010, p. 32; Makowicz, 2020, p. 59; Jagura, Zdziarstek, 2020, p. 208).

**Table 5.***Whistleblower and its synonymous terms*

<b>Whistleblower</b> - "one who blows the whistle to expose wrongdoing", someone who blows the whistle, signalman, unmasker, employee who exposes wrongdoing, informant acting in good faith, informer, bona fide informer, informer reporting in the public interest, snitch, denunciator, sneaker, snooper, "discloser", herald, talebearer, stool pigeon, accuser, warner, betrayer, confidential informant, signaller of unethical behaviour, man who can't keep silent, blabber, squealer, gossip, agent, rat, mole, plant, spy, bootlicker, turncoat, traitor, canary, busybody, collaborator.
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Source: own compilation based on (Hołda-Wydrzyńska, 2023, p. 137; Świątek-Barylska, 2012, p. 403; Rogowski, 2007a, pp. 23-24; Brzeziński, 2022, p. 11; Kobylińska, Folta, 2015, p. 1; Beściak, 2010, p. 32; Lewicka-Strzałecka, 2014, pp. 77-98).

## 4.2. Whistleblowing as a tool of the HR Compliance Management System

The whistleblowing system is one of the essential structural elements of the compliance system in a particular enterprise and it means the disclosure by an employee or other whistleblower of irregularities in the functioning of the enterprise consisting of various acts of dishonesty or malpractice involving other employees, the employer or the employer's representatives, e.g. acts of embezzlement, mismanagement or corruption (Szewczyk, 2021, p. 34). In a well-managed organisation, information about reprehensible acts should be used as a signal to eliminate obstacles that slow down its development (Stawecki, 2010, p. 134).

Whistleblowing is an important tool for diagnosing irregularities in the work environment (see Laga, 2017, pp. 467-484). Whistleblowing systems are implemented by organisations as an integral part of their fraud risk management programme (Sroka, 2019, p. 120), helping to reduce the risk of harmful human behaviour within the company (Kobroń-Gąsiorowska, 2017, p. 74). In the management aspect, it is noted that they should be part of a larger overall effort to build an ethical culture and a comprehensive compliance system (e.g. according to ISO 37001, ISO 19600) (Sroka, 2019, p. 136). It is also pointed out that this is an important method of control in organisations, especially public ones (cf. Piwowarczyk, 2018, pp. 103-114).

The system for reporting wrongdoing and the procedure for conducting internal investigations are elements of a compliance management system. Such a system comprises all the actions taken by the organisation's management to minimise the risk of irregularities and to detect them at an early stage and manage irregularity-induced crises (Tokarczyk, 2020, p. 11). On the one hand, this system minimises the risk of irregularities (e.g. committing criminal offences, acts of unfair competition, violations of ethical principles) and, on the other hand, it constitutes a measure for managing crisis situations caused either by irregularities or other random events (accident at work, construction disaster). In the Compliance Management System, whistleblowing occupies a special position as the glue of all the regulations that make up compliance (Tokarczyk, 2020, pp. 20-21).

In the practice of organisations, a distinction is made between internal whistleblowing, i.e. 'internal reporting' - the communication of information about violations within a public or private legal entity, and external whistleblowing, i.e. 'external reporting' - the communication of information about violations to the competent authorities (outside the entity) or to the public (more in: Szewczyk, 2020, pp. 6-7). In addition to the aforementioned criterion of the addressee of the report, the following criteria are also distinguished in the classification of whistleblowing systems: the identity of the whistleblower (anonymous and non-anonymous whistleblowing), the structure (centralised and decentralised whistleblowing), the form (IT-based whistleblowing, traditional whistleblowing) (cf. Jagura, Zdziarstek, 2020, pp. 212-218). It should be emphasised that whistleblowing is one of the three pillars of HR Compliance (cf. Table 6).

**Table 6.**  
*Whistleblowing as the second pillar of HR Compliance*

<b>Pillar of HR Compliance</b>	<b>Features</b>
First	The provision by the employer of mechanisms to identify and prevent undesirable behaviour (mobbing, discrimination, sexual harassment) to which individual employees may be victims.
Second	Shaping the mechanisms introduced by the employer for receiving and dealing with employee whistleblowing (whistleblowing procedures).
Third	Ensuring that the employer respects the rights of employees regulated by labour law, internal policies, codes of ethics, separate rules.

Source: own compilation based on (Kibil, 2022, pp. 15-16).

A significant proportion of whistleblowers are employees who help protect not only the rights of employees but also contribute to improving their workplaces (Kobroń-Gąsiorowska, 2018, p. 133). It is not uncommon for them to reveal irregularities completely spontaneously, and this is when so-called autonomous (natural) whistleblowing takes place (Rogowski, 2007b, p. 1). When an organisation starts to act unethically or dangerously to its environment, it is the employees who are usually the first to find out (Dehn, Calland, 2004, p. 1). They are involved in control activities (Pauch, 2012, pp. 71-78) and it is on their involvement and initiative that an effective early warning system depends (Nartowski, 2006, pp. 19-21).

Typically, a whistleblower is an employee, former employee, self-employed person or member of an organisation (state, local government, social organisation) (Pietruszka, 2021, p. 116). The recognition of a given person as a whistleblower is determined by the fact that the following criteria are jointly fulfilled: the whistleblower discovers irregularities; reports them to the relevant entity motivated by 'noble motives' (the good of the employer, protection of other persons); and the whistleblower's situation is endangered as a result of the disclosure of irregularities (Pietruszka, 2021, p. 117).

Threats and irregularities reported by whistleblowers can be identified in two main areas: activities harming individual rights and freedoms (e.g. violations of labour rights by employers), activities related to widespread malpractice and financial fraud in the public and private sector (e.g. nepotism, waste) (more in: Koldys, 2016, pp. 31-38; cf. Kutera, 2016, pp. 116-123).

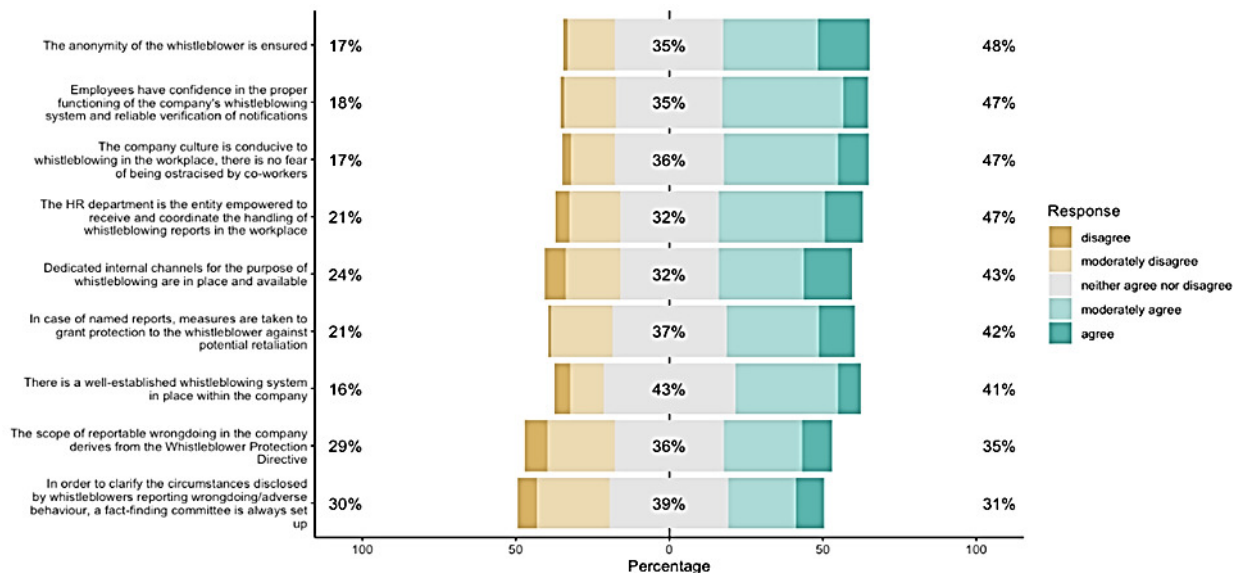
The results of one study show that employees most frequently report incidents related to abusive employee issues, such as discrimination, harassment, compensation, general HR issues. These types of cases account for up to 72% of reports (more in: NAVEX Global 2016). They can be described as mismanagement or categorised as ethical (moral) issues, which allows for a broader view of irregularities - not only non-compliance with (EU) law (cf. Szewczyk, 2020a, p. 6).

Well-known whistleblowers include: Karen Silkwood (Keer-McGee, 1974), Sherron Watkins (Enron, 2001), Bożena Łopacka (Biedronka, 2004), Thomas S. Inman (Fannie Mae, 2007) (see Rogowski, 2007a, pp. 38-39), Cynthia Cooper (WorldCom), Coleen Rowley (FBI) (Arszułowicz, 2007, p. 101), Edward Snowden (former CIA employee), Christopher Wylie (Cambridge Analytica) (DGTL Kibil Piecuch, 2021, p. 3), Rudolf Elmer (Bank Julius) (Kenny, Bushnell, 2020, pp. 643-656).

### 4.3. Whistleblowing - evaluation of the whistleblowing system in organisations - results of an author's own empirical study

#### 4.3.1. Evaluation of the whistleblowing system

During the survey, respondents rated the whistleblowing system in organisations on a five-point scale (1 - no, 2 - rather not, 3 - neither yes nor no, 4 - rather yes, 5 - yes). The structure of the responses to the question regarding the attitude to selected statements about the whistleblowing system in organisations is shown in Figure 1.



**Figure 1.** Structure of responses to the question "Please respond to the following statements regarding your organization's whistleblowing system".

Source: (Winnicka-Wejs, 2023).

Figure 1 shows that in the surveyed organisations, the whistleblowing system ensures the anonymity of the whistleblower (48% of responses), employees have confidence in the proper functioning of the company's whistleblowing system and reliable verification of notifications (47% of responses), the company culture is conducive to whistleblowing in the workplace, there is no fear of being ostracised by co-workers (47% of responses), the HR department ('personnel department') is the entity empowered to receive and coordinate the handling of whistleblowing reports in the workplace (47% of responses).

This is followed by dedicated internal channels for the purpose of whistleblowing being in place and available (43% of responses), and in the case of named reports, measures are taken to grant protection to the whistleblower against potential retaliation (42% of responses), there is a well-established whistleblowing system in place within the company (41% of responses).

The fewest positive indications referred to the statement that the scope of reportable wrongdoing in the company derives from the Whistleblower Protection Directive (35% of responses) and that a fact-finding committee is always set up to clarify the circumstances disclosed by whistleblowers reporting wrongdoing/adverse behaviour (31%).



It should be noted that with the question about *Whistleblowing*, higher values were recorded for 'neither agree or disagree' responses when compared to the other survey questions (cf. Winnicka-Wejs, 2023). For example, 43% of the respondents marked this response variant with the option "there is a well-established whistleblowing system in the company" and 39% with the statement regarding the establishment of a fact-finding committee.

#### 4.3.2. Differences in the evaluation of whistleblowing performance in organisations

Differences in the evaluation according to company employment size, ownership form and industry are included in Table 7.

**Table 7.**

*Differences in evaluation by company size, form of ownership and industry (p-values)*

	Size of employment <sup>1</sup>	Form of ownership <sup>1</sup>	Industry <sup>1</sup>
1. There is a well-established whistleblowing system in place within the company.	0.056.	0.252	0.156
2. In order to clarify the circumstances disclosed by whistleblowers reporting wrongdoing/adverse behaviour, a fact-finding committee is always set up.	0.034*	0.905	0.731
3. The company culture is conducive to whistleblowing in the workplace, there is no fear of being ostracised by co-workers.	0.258	0.208	0.189
4. Employees have confidence in the proper functioning of the company's whistleblowing system and reliable verification of notifications.	0.120	0.120	0.022*
5. The scope of reportable wrongdoing in the company derives from the Whistleblower Protection Directive.	0.100	0.374	0.319
6. The HR department is the entity empowered to receive and coordinate the handling of whistleblowing reports in the workplace.	0.148	0.050.	0.027*
7. Dedicated internal channels for the purpose of whistleblowing are in place and available.	0.010**	0.191	0.783
8. The anonymity of the whistleblower is ensured.	0.172	0.007**	0.042*
9. In case of named reports, measures are taken to grant protection to the whistleblower against potential retaliation.	0.021*	0.010**	0.071.

<sup>1</sup> Kruskal-Wallis test.

Statistical significance at a level less than: 0.001 '\*\*\*' 0.01 '\*\*' 0.05\*' 0.1 '.'

Source: Own study based on survey results.

A thorough analysis of the data showed that, with the option 'there is a well-established whistleblowing system in the company', large companies stood out from the other organisations - respondents marked the answer 'neither agree nor disagree'. The highest average rating (4) was obtained from medium-sized companies. At least 25 per cent of the respondents from medium-sized companies moderately agreed/agreed that a fact-finding committee is set up to clarify the circumstances disclosed by whistleblowers reporting wrongdoing/adverse behaviour. The worst situation is in micro and large companies. In medium-sized companies, respondents' rating is higher than in other organisations in terms of assessing internal channels for whistleblowing, as well as protecting whistleblowers from retaliation. The average rating for the statement 'The HR department is the entity empowered to receive and coordinate the handling of whistleblowing reports in the workplace' (4) is highest among respondents from

public organisations. The highest average ratings from these organisations also relate to ensuring anonymity to the whistleblower and granting protection to the whistleblower against potential retaliation.

There are also differences in the evaluation of different elements of the whistleblowing system depending on the industry. The analysis of the data shows that in the culture, entertainment and recreation industry, employees have confidence in the proper functioning of the company's whistleblowing system and the reliable verification of whistleblowing, while an average of "4-agree" also applies to other service activities, industrial processing, information and communication. Ensuring anonymity of the whistleblower was rated highest by respondents from the professional, scientific and technical industry. Respondents from construction as well as financial and insurance activities were similar in their ratings, with a median of '3'. In terms of taking measures to grant protection to the whistleblower against potential retaliation, respondents from the information and communications industry had the lowest median rating, while respondents from the cultural and entertainment, financial and insurance and other service activities had the highest (more in: Winnicka-Wejs, 2023).

Table 8 shows the differences in the evaluation of the whistleblowing system by the respondents' job position.

**Table 8.**

*Differences in the evaluations of the whistleblowing system by the respondents' job position*

	<b>Job position</b>
1. There is a well-established whistleblowing system in place within the company.	0,133
2. In order to clarify the circumstances disclosed by whistleblowers reporting wrongdoing/ adverse behaviour, a fact-finding committee is always set up.	0,169
3. The company culture is conducive to whistleblowing in the workplace, there is no fear of being ostracised by co-workers.	0,030*
4. Employees have confidence in the proper functioning of the company's whistleblowing system and reliable verification of notifications.	0,010*
5. The scope of reportable wrongdoing in the company derives from the Whistleblower Protection Directive.	0,038*
6. The HR department is the entity empowered to receive and coordinate the handling of whistleblowing reports in the workplace.	0,444
7. Dedicated internal channels for the purpose of whistleblowing are in place and available.	0,032*
8. The anonymity of the whistleblower is ensured.	0,160
9. In case of named reports, measures are taken to grant protection to the whistleblower against potential retaliation.	0,256

Source: Own study based on survey results.

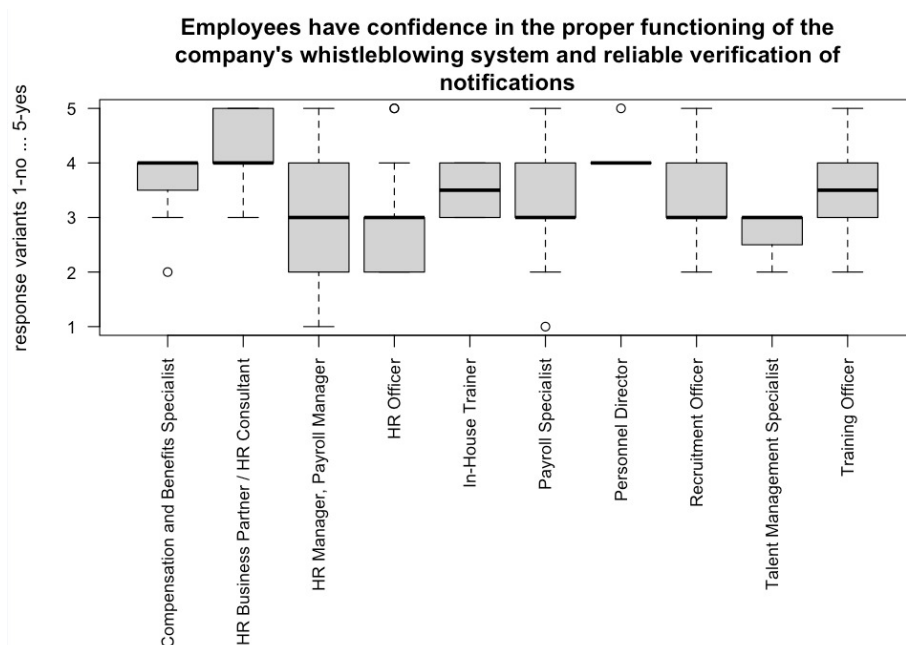
A thorough analysis of the data showed that professionals on average rate the whistleblowing system in organisations lower. The differences in evaluation by job position relate to the issue of company culture (cf. figure 2), employee confidence in the proper functioning of the company's whistleblowing system (cf. figure 3), the scope of reportable wrongdoing in the company (cf. figure 4), the preparation and availability of internal channels for whistleblowing (cf. figure 5).



**Figure 2.** Differences in respondents' attitudes to the statement "The company culture is conducive to whistleblowing in the workplace, there is no fear of being ostracised by co-workers" by job position.

Source: Own study based on survey results.

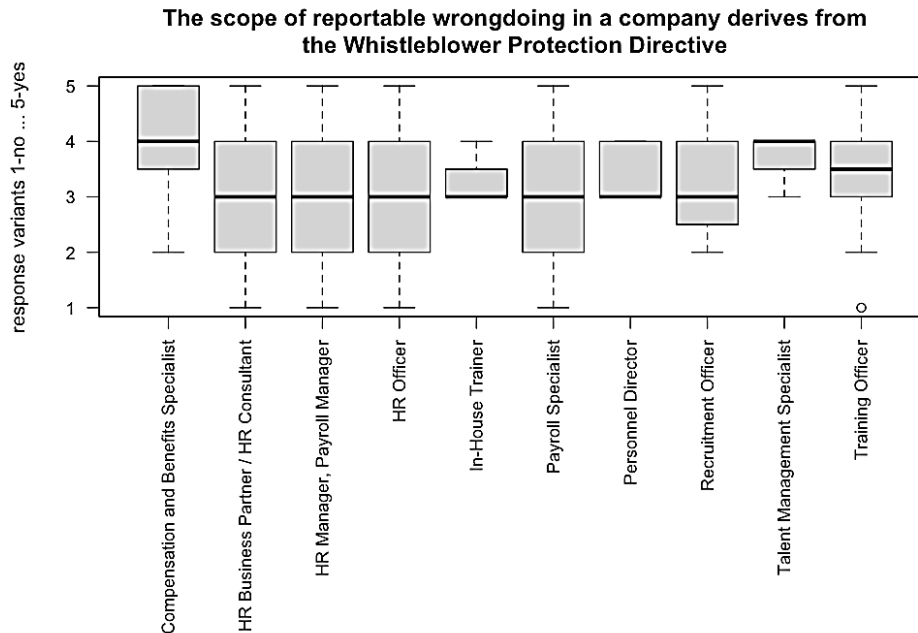
Figure 2 shows that personnel directors rate higher the statement regarding a company culture being conducive to whistleblowing in workplaces. Recruitment officers and human resources specialists are similar in their evaluations. The ratings of training officers clearly differ from the other ratings.



**Figure 3.** Differences in respondents' attitudes to the statement "Employees have confidence in the proper functioning of the company's whistleblowing system and reliable verification of notifications" by job position.

Source: Own study based on survey results.

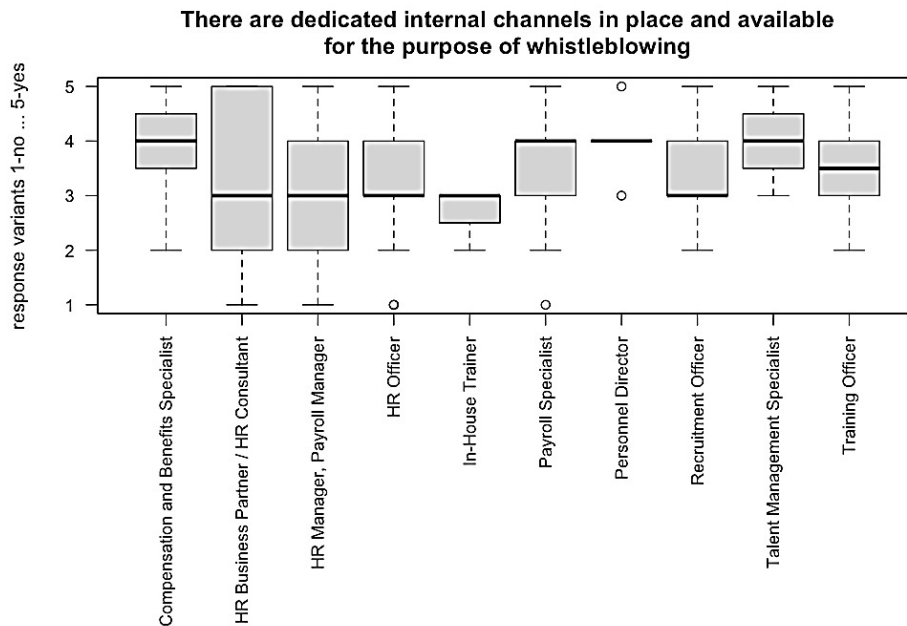
Figure 3 shows that HR and Payroll Specialists and Recruitment Officers gave similar ratings regarding employee confidence in the company's proper whistleblowing system. The highest ratings in this respect are represented by Personnel Directors and HR Business Partners/HR Consultants, the lowest by Human Resources Managers/HR and Payroll Managers/Managers (at least 25% of them marked disagree/moderately disagree).



**Figure 4.** Differences in respondents' attitudes to the statement "The scope of reportable wrongdoing in a company derives from the Whistleblower Protection Directive" by job position.

Source: Own study based on survey results.

Figure 4, on the other hand, shows that the median rating of compensation and benefits professionals is '4' (moderately agree). They were the only ones who gave the highest rating to the statement on the scope of reportable wrongdoing in the company deriving from the whistleblower protection directive.



**Figure 5.** Differences in respondents' attitudes to the statement "There are dedicated internal channels in place and available for the purpose of whistleblowing" by job position.

Source: Own study based on survey results.

Figure 5 shows that personnel directors stand out in their responses, as they confirmed that their companies have dedicated internal channels in place and available for the purpose of whistleblowing.

## 5. Conclusions

The results of the survey indicate that there is a need to work on the whistleblowing systems currently operating in Polish organisations. No statements describing whistleblowing in the surveyed organisations received more than 50% positive responses (agree, moderately agree). With the statement "There is a well-established whistleblowing system in place in the company", there was the most doubt and ambiguity among respondents, expressed as 43% of "neither agree nor disagree" responses.

It should be noted, however, that despite the lack of implementation of the EU Whistleblower Protection Directive into the Polish legislation, some of the surveyed organisations have already introduced specific procedures on whistleblowing. However, the need to popularise this topic through appropriate training and workshops is recognised (see Winnicka-Wejs, 2023). The results of the survey in this regard are in line with the report *HR Compliance Canary on the Roof. How do we approach whistleblowers?* (DGTL Kibil Picuch and Partners, 2021), which is based on 40 interviews with heads of HR, compliance and law departments of companies operating on the Polish market.

The results of the survey indicated differences in the evaluation of the different elements of the company's whistleblowing system. HR specialists, managers and personnel directors do not agree in their assessment of the existing level of employee confidence in the proper functioning of the company's whistleblowing system and its reliable verification. Previous research available in the literature has shown that the low level of confidence of potential whistleblowers in their personal safety in the event of disclosure of information bearing the characteristics of a criminal offence may be a significant barrier to the implementation of a whistleblowing system in Polish organisations (see Skoczylas-Tworek, 2020, pp. 103-105). Despite some limitations (lack of random sampling and representativeness), the present study provides theoretical as well as empirical knowledge on the characteristics of the whistleblowing system in Polish organisations. It is surprising that one third of the respondents do not have a well-defined opinion on the evaluation of the whistleblowing system. It is not clear what the reason for this is - perhaps another survey (e.g. qualitative) would provide some specific answers in this regard. Is it ignorance, inexperience, lack of participation in this type of procedures? Without relevant data, it is difficult to pass judgment on this situation, although some respondents admitted in open comments that they would like to participate in training and workshops in this area, assessing their knowledge to be unsatisfactory, despite their experience in the HR field. Perhaps there is a need for greater awareness and sensitivity to the topic of HR Compliance on the part of professionals, managers, executives and HR directors (more in: Winnicka-Wejs, 2023).

The author hopes that the article has drawn attention to the need for reporting irregularities in organisations, promoting whistleblowing and remove the "spell" of the pejorative meaning of the term in Polish business practice.

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## BUSINESS ANALYTICS IN THE CASE OF INVENTORY MANAGEMENT IN INDUSTRY 4.0 CONDITIONS

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**Purpose:** The purpose of this publication is to present the applications of usage of business analytics in inventory management.

**Design/methodology/approach:** Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

**Findings:** Industry 4.0 has ushered in a transformative era of technological innovation, particularly in inventory management. Business Analytics has emerged as a crucial tool for optimizing inventory control and supply chain management in this context. This integration of digital technologies, the Internet of Things, artificial intelligence, and big data has made inventory management more complex yet highly efficient. Business Analytics, driven by machine learning and predictive analytics, empowers organizations to make data-driven decisions, improve demand forecasting, and enhance supplier relationships, resulting in cost reduction, increased customer satisfaction, and sustainability efforts. Industry 4.0 has also introduced various software solutions that streamline inventory management, albeit with challenges. Overcoming these challenges, businesses leverage the advantages to adapt to a dynamic market, reduce costs, and enhance sustainability, solidifying the critical role of Business Analytics in inventory management in an evolving landscape.

**Keywords:** business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; inventory management.

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

### 1. Introduction

The advent of Industry 4.0 has ushered in a new era of technological innovation and transformation across various industries (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021; Wolniak et al., 2023; Wolniak, Grebski, 2023; Wolniak,

Skotnicka-Zasadzień, 2023; Jonek-Kowalska, Wolniak, 2023). One of the most critical areas that has seen significant changes is inventory management. In this context, Business Analytics plays a pivotal role in optimizing inventory control and supply chain management. This article delves into the implications and applications of Business Analytics in the context of inventory management within the framework of Industry 4.0.

Industry 4.0, often referred to as the Fourth Industrial Revolution, is characterized by the integration of digital technologies, the Internet of Things (IoT), artificial intelligence, machine learning, and big data into the manufacturing processes. In this highly connected and automated environment, inventory management becomes more complex, but also more efficient.

The purpose of this publication is to present the applications of usage of business analytics in inventory management.

## **2. The selected aspects of business analytics usage in inventory management**

One of the key aspects of Industry 4.0 is the massive amount of data generated by various sensors, devices, and systems. This data can be harnessed through Business Analytics to make informed decisions about inventory (Ghibakholl et al., 2022). Businesses can analyze historical data, real-time data, and predictive analytics to optimize stock levels, demand forecasting, and reorder points. Business Analytics, powered by machine learning algorithms, can predict future demand patterns with high accuracy. This enables companies to reduce excess inventory and avoid stockouts, ultimately saving costs and improving customer satisfaction. The predictive models can adapt to changing market conditions, making the supply chain more agile (Bakir, Dahlan, 2022).

With the integration of IoT sensors and connected devices, businesses can monitor their inventory in real-time. Analytics tools can interpret this data, helping managers make instant decisions, such as rerouting shipments, reordering stock, or optimizing production schedules. Business Analytics can optimize inventory levels by considering multiple factors such as lead times, carrying costs, and demand variability. This optimization leads to cost reduction and working capital efficiency (Olsen, 2023).

In Industry 4.0 conditions, the relationship between suppliers and manufacturers has evolved (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021, Orzeł, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). Business Analytics helps in supplier evaluation, risk assessment, and performance monitoring, ensuring a smooth supply chain. This reduces lead times and enhances overall inventory management. Advanced analytics can segment inventory into different categories

based on their demand patterns, lead times, and other factors. This allows for more focused management and allocation of resources. By using predictive maintenance, companies can reduce the risk of machine breakdowns that can disrupt the supply chain and increase holding costs. Analytics tools can help identify when equipment needs servicing or replacement, thereby reducing unforeseen downtime and costs (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

In Industry 4.0, sustainability is a growing concern. Analytics can be used to minimize waste, optimize shipping routes to reduce emissions, and make environmentally conscious decisions about inventory management (Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023; Wolniak, 2013, 2016; Hys, Wolniak, 2018). The use of Business Analytics in inventory management within Industry 4.0 conditions is an iterative process. Companies continually refine their models and strategies based on historical data and real-time feedback, adapting to the ever-changing market dynamics (Greasley, 2019).

In Industry 4.0, Business Analytics has emerged as a game-changer in the realm of inventory management. It empowers businesses to make data-driven decisions, optimize supply chains, reduce costs, enhance customer satisfaction, and contribute to sustainability goals. As technology continues to advance, the role of Business Analytics in inventory management will only become more critical, helping companies stay competitive in the evolving landscape of Industry 4.0 (Nourani, 2021).

Table 1 contains descriptions of how business analytics is used in inventory management. This table provides a concise overview of how Business Analytics is applied to various aspects of inventory management. It showcases the diverse ways in which analytics can be used to enhance efficiency, reduce costs, and make data-driven decisions in the management of inventory.

**Table 1.**

*The usage of business analytics in inventory*

Aspect of Inventory Management	Application of Business Analytics
Demand Forecasting	Predicting future demand patterns using historical and real-time data. Implementing machine learning models for accuracy.
Real-time Inventory Monitoring	Utilizing IoT sensors for real-time tracking of inventory. Interpreting data to make instant decisions for rerouting shipments or reordering stock.
Inventory Optimization	Balancing stock levels to minimize carrying costs while ensuring demand fulfillment. Considering lead times and demand variability for optimization.
Supplier Relationship Management	Evaluating supplier performance and risk through analytics. Monitoring supplier data for supply chain efficiency and risk management.
Inventory Segmentation	Categorizing inventory based on demand patterns and other relevant factors. Efficient allocation of resources and management.

Cont. table 1.

Cost Reduction	Predictive maintenance to prevent machine breakdowns and reduce downtime. Identifying opportunities for cost savings and efficiency improvements.
Sustainability and Environment	Optimizing shipping routes for reduced emissions and environmental impact. Minimizing waste through data-driven inventory management decisions.
Continuous Improvement	Iterative process of refining models and strategies based on historical data and real-time feedback. Adaptation to changing market dynamics and ongoing improvements.
Safety Stock Management	Analyzing historical data and variability to determine optimal safety stock levels. Setting parameters for automated reordering when safety stock thresholds are met.
Lead Time Management	Analyzing historical lead time data to optimize procurement and production schedules. Predicting lead time variations for proactive inventory management.
Inventory Turnover	Monitoring inventory turnover ratios and identifying slow-moving or obsolete items. Recommending actions to reduce excess inventory or promote fast-moving items.
Seasonal and Trend Analysis	Identifying seasonal demand patterns and trends in product categories. Adapting inventory management strategies to align with seasonal fluctuations.
ABC Analysis	-Categorizing inventory items based on value or importance. Allocating more resources and attention to high-value items using data-driven insights.
Multi-Location Inventory	Managing inventory across multiple locations efficiently. Optimizing stock transfer between locations based on demand patterns and cost considerations.
Demand Volatility	Assessing the volatility of demand for various products. Implementing dynamic pricing or stocking strategies to respond to fluctuations.
Compliance and Regulation	Ensuring inventory management practices align with industry regulations and standards. Implementing analytics to monitor and maintain compliance.
Excess and Obsolete Inventory	Identifying excess or obsolete items through data analysis. Implementing strategies to minimize excess inventory and reduce write-offs.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022, Javaid, Haleem, 2020, Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

### 3. Software used in inventory management in Industry 4.0 conditions

Inventory management in Industry 4.0 conditions has evolved significantly with the integration of advanced software solutions. Industry 4.0, also known as the Fourth Industrial Revolution, is characterized by the extensive use of automation, data exchange, and smart technologies (Scappini, 2016). These changes have led to a fundamental transformation in how inventory is managed, making it more efficient, accurate, and responsive. IMS (Inventory Management Systems) software has been upgraded to incorporate real-time data tracking and analysis. These systems allow for the continuous monitoring of stock levels, order history, and demand forecasting. They enable companies to optimize their inventory levels, reduce



carrying costs, and prevent stockouts or overstock situations. IMS can also be integrated with other systems, such as Enterprise Resource Planning (ERP) and Customer Relationship Management (CRM) software (Aslam et al., 2020).

Radio-Frequency Identification (RFID) is a crucial element in Industry 4.0 inventory management. RFID tags and readers enable the automatic and real-time tracking of inventory items, reducing the need for manual input and minimizing errors. This technology improves accuracy, reduces labor costs, and allows for more precise control over the movement of products throughout the supply chain. IoT devices, such as sensors and beacons, are used to monitor the condition and location of inventory items. These devices provide valuable data, such as temperature, humidity, and handling conditions. By collecting and analyzing this data in real-time, businesses can ensure the quality and safety of their products while reducing waste due to spoilage or damage (Charles et al., 2023).

Machine learning algorithms and artificial intelligence are employed for demand forecasting and predictive analytics. These technologies analyze historical data, market trends, and other variables to anticipate future inventory needs accurately. They also optimize reorder points, lead times, and safety stock levels, which is especially valuable in just-in-time inventory systems (Javaid, Haleem, 2020). Cloud-based inventory management software offers several benefits in Industry 4.0. It allows for remote access, collaboration, and scalability, making it easier for businesses to adapt to changing market conditions and expand their operations. Cloud solutions also provide secure data storage and backup, essential in a digital and data-driven environment (Peter et al., 2023).

Blockchain can be used to create transparent and tamper-proof supply chain records. It provides end-to-end visibility, enabling businesses to trace the origin and journey of each product (Akundi et al., 2022). This is particularly valuable in industries where traceability and compliance are critical, such as pharmaceuticals and food. RPA (Robotic Process Automation) software automates routine and rule-based tasks in inventory management. It can handle data entry, order processing, and even autonomous decision-making for restocking and routing inventory. RPA not only reduces human error but also speeds up the overall process. Data analytics software is used to gain insights from the vast amount of data generated in Industry 4.0. Advanced reporting and visualization tools help organizations make informed decisions and identify areas for improvement in their inventory management processes (Cillo et al., 2022).

The software solutions mentioned above play a pivotal role in improving efficiency, accuracy, and adaptability in inventory management, helping businesses thrive in a rapidly changing and highly competitive environment (Adel, 2022).

Table 2 highlighting examples of software and applications used in inventory management, along with descriptions of their usage. These software and applications play an important role in energy management, enabling organizations to monitor, analyze, and optimize their energy

usage, reduce costs, and meet sustainability objectives in an increasingly data-driven and interconnected world.

**Table 2.**

*The usage of business analytics in inventory*

Aspect of Energy Management	Usage of Business Analytics
Energy Consumption Analysis	<ol style="list-style-type: none"> <li>1. Real-time monitoring and analysis of energy consumption patterns.</li> <li>2. Identifying energy usage trends and anomalies.</li> <li>3. Predictive analytics to forecast future consumption.</li> </ol>
Demand Forecasting	<ol style="list-style-type: none"> <li>1. Using historical data and predictive models to anticipate energy demand.</li> <li>2. Optimizing energy generation, distribution, and storage based on forecasts.</li> </ol>
Cost Optimization	<ol style="list-style-type: none"> <li>1. Identifying cost drivers in energy consumption.</li> <li>2. Implementing cost-saving strategies based on analytics insights.</li> </ol>
Sustainability Monitoring	<ol style="list-style-type: none"> <li>1. Tracking and reporting on greenhouse gas emissions and energy efficiency.</li> <li>2. Setting and monitoring sustainability targets.</li> <li>3. Assessing the environmental impact of energy usage.</li> </ol>
Equipment Efficiency	<ol style="list-style-type: none"> <li>1. Real-time monitoring of equipment performance and energy usage.</li> <li>2. Predictive maintenance to reduce downtime and improve efficiency.</li> </ol>
Energy Procurement	<ol style="list-style-type: none"> <li>1. Analyzing energy market data for strategic procurement decisions.</li> <li>2. Evaluating energy supplier contracts and pricing structures.</li> <li>3. Identifying opportunities for cost savings.</li> </ol>
Renewable Energy Integration	<ol style="list-style-type: none"> <li>1. Evaluating the feasibility of incorporating renewable energy sources.</li> <li>2. Assessing the economic benefits of renewable energy adoption.</li> <li>3. Monitoring the performance of renewable energy systems.</li> </ol>
Energy Policy Compliance	<ol style="list-style-type: none"> <li>1. Ensuring compliance with energy regulations and standards.</li> <li>2. Generating reports and documentation for regulatory purposes.</li> </ol>
Risk Management	<ol style="list-style-type: none"> <li>1. Identifying and mitigating risks associated with energy supply and consumption.</li> <li>2. Using analytics to respond to unforeseen events, such as power outages or supply disruptions.</li> </ol>

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022; Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

#### **4. Advantages and problems of business analytics usage in inventory management**

Utilizing business analytics in inventory management offers a multitude of advantages, transforming the way businesses handle their stock levels and supply chains. Business analytics empowers organizations to make informed decisions based on real-time and historical data. This helps in optimizing inventory levels, supplier relationships, and order management, leading to more accurate forecasting and better strategic planning. Through data analysis and tracking, businesses can minimize the risk of stockouts and overstock situations. This leads to better inventory accuracy, reduced carrying costs, and the elimination of dead or obsolete inventory (Di Marino et al., 2023).

Table 3 contains the advantages of using business analytics in inventory management within Industry 4.0 conditions, along with descriptions for each advantage.

**Table 3.**

*The advantages of using business analytics in inventory management*

<b>Advantages</b>	<b>Description</b>
<b>Improved Demand Forecasting</b>	Accurate prediction of customer demand, reducing stockouts and overstock situations.
<b>Cost Reduction</b>	Lower holding and carrying costs, leading to minimized costs related to rush orders and excess inventory.
<b>Optimized Inventory Levels</b>	Right-sized inventory, minimizing overstock and ensuring efficient capital allocation for strategic investments.
<b>Enhanced Supplier Performance</b>	Evaluation and selection of reliable suppliers, leading to improved negotiation leverage and better terms.
<b>Reduced Working Capital</b>	Reduced capital tied up in inventory, freeing up funds for other investments and growth.
<b>Increased Customer Satisfaction</b>	Consistent product availability and on-time delivery, resulting in higher customer loyalty and positive word-of-mouth.
<b>Streamlined Supply Chain</b>	Identification and elimination of bottlenecks, reducing lead times and enhancing operational efficiency.
<b>Risk Mitigation</b>	Early identification and mitigation of supply chain risks, with the development of effective contingency plans.
<b>Support for Strategic Growth</b>	Allocation of resources to support expansion and identification of new market opportunities.
<b>Compliance and Regulatory Support</b>	Ensuring adherence to industry regulations and generating necessary reports and documentation.
<b>Environmental Sustainability</b>	Assessment of the environmental impact of inventory management and support for sustainability initiatives.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022; Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

Table 4 contains the problems of using business analytics in inventory management within Industry 4.0 conditions, along with descriptions for each advantage. It's important to note that while these problems are associated with the use of business analytics in inventory management, many can be addressed through careful planning, proper training, and ongoing maintenance. The benefits of improved inventory management through analytics often outweigh the challenges, but organizations must be prepared to address these issues.

**Table 4.**

*The problems of using business analytics in energy management*

<b>Problems</b>	<b>Description</b>
<b>Data Quality Issues</b>	Inaccurate or incomplete data can lead to flawed analysis and incorrect decisions. Data must be clean and consistent for analytics to be effective.
<b>High Implementation Costs</b>	Setting up business analytics systems can be expensive, particularly for small businesses with limited budgets.
<b>Complex Implementation</b>	Implementing business analytics solutions can be technically challenging, requiring expertise in data management and analytics tools.
<b>Staff Training Requirements</b>	Employees may require training to effectively use and interpret analytics tools, adding to the implementation costs.
<b>Data Security Concerns</b>	Storing and handling sensitive inventory data can pose security risks, and protecting data is paramount.

Cont. table 4.

<b>Integration Challenges</b>	Integrating business analytics with existing inventory management systems and other enterprise software can be complex and time-consuming.
<b>Overemphasis on Historical Data</b>	Relying solely on historical data may not account for sudden changes or external factors that impact inventory management.
<b>Complexity of Interpretation</b>	Complex analytics models and data can make it challenging to extract actionable insights, particularly for non-technical staff.
<b>Lack of Scalability</b>	Inventory data and analytics needs may outgrow the capabilities of existing systems, requiring costly upgrades.
<b>Maintenance and Updates</b>	Regular maintenance and updates are essential to keep analytics systems running efficiently and securely.
<b>Resistance to Change</b>	Employees and management may resist changes to traditional inventory management methods, hindering adoption.
<b>Misinterpretation of Data</b>	Misunderstanding or misinterpretation of analytics results can lead to erroneous decisions.
<b>Data Overload</b>	A surplus of data can overwhelm decision-makers, making it challenging to focus on the most critical information.
<b>Incompatibility with Legacy Systems</b>	Older inventory management systems may not be compatible with advanced analytics tools.
<b>Unforeseen Implementation Delays</b>	Unexpected issues or challenges during implementation can delay the rollout of analytics solutions.
<b>Vendor Reliability Issues</b>	Depending on third-party vendors for analytics tools can introduce reliability concerns if the vendor experiences issues or goes out of business.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022; Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

## 5. Conclusion

The advent of Industry 4.0 has brought about a transformative era of technological innovation, particularly in the realm of inventory management. Business Analytics has emerged as a pivotal tool for optimizing inventory control and supply chain management within the context of Industry 4.0. The integration of digital technologies, the Internet of Things, artificial intelligence, and big data has led to a more complex yet efficient inventory management environment. Business Analytics, driven by machine learning and predictive analytics, allows organizations to make data-driven decisions, accurately forecast demand, monitor inventory in real-time, and enhance supplier relationships. This leads to reduced costs, increased customer satisfaction, and improved sustainability efforts.

Furthermore, Industry 4.0 has given rise to an array of software solutions that streamline inventory management, including Inventory Management Systems (IMS), Radio-Frequency Identification (RFID), IoT devices, machine learning algorithms, and cloud-based systems. These software tools provide real-time data tracking, enhanced demand forecasting, and increased automation, making inventory management more efficient and adaptable to changing market conditions.

While the advantages of employing Business Analytics in inventory management are evident, challenges also exist. Issues such as data quality, implementation costs, staff training, and data security must be addressed. Furthermore, integrating Business Analytics with legacy systems and overcoming resistance to change can be complex. However, with the right strategies, these challenges can be mitigated, and the benefits far outweigh the drawbacks.

In the evolving landscape of Industry 4.0, Business Analytics is undeniably a game-changer in the field of inventory management. It empowers businesses to adapt to changing market dynamics, reduce costs, enhance customer satisfaction, and contribute to sustainability goals. As technology continues to advance, the role of Business Analytics in inventory management will only become more critical, ensuring that companies remain competitive in this dynamic environment.

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## THE APPLICATION OF BUSINESS ANALYTICS IN PERSONALIZED CUSTOMER EXPERIENCE

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**Purpose:** The purpose of this publication is to present the applications of usage of business analytics in personalized customer experience.

**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 applications of business analytics in personalized customer experiences span data collection, segmentation, predictive analytics, and multi-channel personalization, delivering greater customer satisfaction, revenue, and competitive advantage. Achieving this transformation requires the use of various software solutions, including CRM systems, marketing automation tools, analytics platforms, predictive analytics software, and recommendation engines. Harnessing the power of data and analytics is the key to gaining a competitive edge in this customer-centric era. Businesses that tailor their offerings to each customer's unique preferences and needs can not only meet but exceed customer expectations, ensuring growth and long-term success. Ultimately, personalized customer experiences, driven by business analytics, are not merely a response to customer demands; they are the path to unlocking the full potential of customer relationships and establishing a strong position in the ever-evolving marketplace.

**Keywords:** business analytics, Industry 4.0, digitalization, artificial intelligence, real-time monitoring; customization, personalization.

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

### 1. Introduction

Business analytics is the systematic use of data, statistical and quantitative analysis, and predictive modeling to drive fact-based decision-making in an organization. This approach involves collecting and analyzing vast amounts of data to extract valuable insights that can be used to enhance various aspects of a business, including customer experience. Personalization

in the customer experience is not merely a buzzword; it's a fundamental aspect of modern marketing and service. Customers today expect businesses to know them, understand their preferences, and offer solutions tailored to their specific needs. When customers feel seen and appreciated, they are more likely to remain loyal, spend more, and recommend the business to others.

Business analytics, often described as the systematic exploration of data using various statistical and quantitative methods, is an indispensable tool for organizations looking to optimize their operations, make informed decisions, and, most importantly, enhance the way they interact with their customers. The focus on personalized customer experience has become a pivotal point of differentiation in the modern marketplace, and here's how business analytics is driving this transformation (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021; Wolniak et al., 2023; Wolniak, Grebski, 2023; Wolniak, Skotnicka-Zasadzień, 2023; Jonek-Kowalska, Wolniak, 2023):

The purpose of this publication is to present the applications of usage of business analytics in personalized customer experience.

## **2. Personalized customer experience**

Business analytics helps in the collection, integration, and processing of vast amounts of data from various sources. This data can include customer interactions, purchase history, online behavior, and feedback. Through data analysis, businesses can segment their customer base into distinct groups based on behavior, preferences, demographics, and more. These segments can then be targeted with personalized offers and communications. By applying predictive analytics, businesses can forecast customer behavior and preferences. This enables them to proactively meet customer needs, such as suggesting products or services before the customer even realizes they need them (Du et al., 2023; Fjellström, Osarenkhoe, 2023).

E-commerce giants like Amazon have shown how effective recommendation systems can be. These systems use customer data to suggest products or content that the customer is likely to be interested in, thereby enhancing the shopping experience. Through real-time data analysis, businesses can make instant decisions on personalizing the customer experience. This could involve showing tailored content on a website, sending personalized emails, or customizing in-store experiences. Businesses can use analytics to gain insights from customer feedback and reviews. By understanding the sentiment and identifying common issues, they can make improvements to better serve their customers (Castro et al., 2014; Wang et al., 2023).

The application of business analytics in personalized customer experience is not just a trend; it's a strategic imperative in the modern business world. To succeed in a customer-centric marketplace, businesses must harness the power of data and analytics to better understand and cater to the unique needs and preferences of each customer, ultimately driving growth, loyalty, and success (Adel, 2022).

At the heart of personalized customer experiences is data, and lots of it. Business analytics plays a vital role in gathering and integrating data from numerous sources, including CRM systems, e-commerce platforms, social media, point-of-sale systems, and customer feedback channels. This data is then centralized and processed to create a comprehensive customer profile. The key is to obtain a 360-degree view of each customer, capturing their interactions, preferences, behaviors, and transaction history (Wolniak, Skotnicka-Zasadzień, 2008, 2010, 2014, 2018, 2019, 2022; Wolniak, 2011, 2013, 2014, 2016, 2017, 2018, 2019, 2020, 2021, 2022; Gajdzik, Wolniak, 2023; Wolniak, 2013, 2016; Hys, Wolniak, 2018).

One-size-fits-all approaches no longer cut it in today's market. With the help of business analytics, organizations can segment their customer base into distinct groups based on demographics, behavior, purchasing history, and other attributes. This segmentation allows businesses to tailor their marketing efforts, product recommendations, and communication to the unique needs and preferences of each segment. In essence, it transforms marketing from a scattershot approach to a highly targeted one. Predictive analytics, a subset of business analytics, leverages historical data to forecast future customer behavior and preferences (Zeng et al., 2022; Pech, Vrchota, 2022). It's like having a crystal ball for understanding what customers might need or want next. With these insights, businesses can anticipate customer needs and proactively offer solutions, making the customer feel seen and valued (Wolniak, Grebski, 2018; Wolniak et al., 2019, 2020; Wolniak, Habek, 2015, 2016; Wolniak, Skotnicka, 2011; Wolniak, Jonek-Kowalska, 2021; 2022).

E-commerce giants like Amazon have shown the immense power of recommendation systems. Using customer data and machine learning algorithms, these systems suggest products or content that align with a customer's past purchases and interests. This not only enhances the shopping experience but also drives additional sales. The power of business analytics isn't just in crunching historical data; it also extends to real-time decision-making. By analyzing customer data in the moment, businesses can make instant decisions on personalization. For example, an e-commerce website can dynamically adjust its homepage content based on a customer's browsing behavior, offering products that are most likely to appeal to that individual (Ghibakholl et al., 2022).

Listening to the voice of the customer has never been more critical. Feedback, whether from surveys, reviews, or social media, provides invaluable insights. Business analytics can be used to extract meaning from this data, identifying sentiment, common issues, and areas for improvement. It's a direct feedback loop to help businesses refine their products and services continually (Jonek-Kowalska, Wolniak, 2021, 2022; Jonek-Kowalska et al., 2022; Kordel,

Wolniak, 2021; Orzeł, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021).

Table 1 contains descriptions of how business analytics is used in personalized customer experience. This comprehensive table highlights the diverse applications of business analytics in personalizing the customer experience, spanning data collection, segmentation, predictive analytics, and real-time personalization, to name a few. These applications ultimately lead to enhanced customer satisfaction, increased sales, and a significant competitive advantage in the modern business landscape.

**Table 1.**

*The usage of business analytics in personalized customer experience*

Aspect of Personalized Customer Experience	Application of Business Analytics
<b>Data Collection and Integration</b>	Aggregating data from various sources such as CRM systems, websites, mobile apps, social media, point-of-sale systems, and customer surveys. Integrating data into a centralized repository to create comprehensive customer profiles. Employing data cleansing and enrichment techniques to ensure data accuracy and completeness. Ensuring compliance with data privacy regulations (e.g., GDPR or CCPA) during data collection and storage. Implementing robust data security measures to protect customer data from breaches and cyber threats.
<b>Customer Segmentation</b>	Utilizing data analytics to classify customers into distinct segments based on demographics, behavior, preferences, and purchase history. Crafting marketing campaigns, product offerings, and content tailored to the unique needs of each segment. Conducting cluster analysis and machine learning algorithms to identify hidden patterns within customer data. Regularly updating customer segments as new data becomes available or customer behavior changes. Conducting in-depth customer journey mapping to understand the end-to-end customer experience.
<b>Predictive Analytics</b>	Applying predictive modeling to forecast customer behavior, purchasing patterns, and future needs. Proactively providing customers with personalized recommendations and solutions based on these predictions. Utilizing machine learning and artificial intelligence for predictive modeling. Refining predictive models over time by incorporating new data and adapting to changing customer preferences. Conducting sensitivity analysis to assess the impact of different variables on predictive outcomes.
<b>Recommendation Systems</b>	Developing recommendation engines that analyze customer behavior and preferences to suggest relevant products, services, or content. Enhancing the customer experience through personalized product recommendations and content delivery. Incorporating collaborative filtering and content-based recommendation algorithms. Continuously improving recommendation algorithms through customer feedback and usage data. Implementing recommendation explainability features to build trust with customers.
<b>Real-time Personalization</b>	Implementing real-time data analysis to make instant decisions on personalization. Customizing website content, email marketing, and in-store experiences based on customers' current interactions, location, and real-time preferences. Leveraging real-time decision engines and adaptive content delivery. Ensuring high system availability and performance to deliver real-time personalization without delays. Monitoring customer behavior during peak traffic hours for accurate real-time personalization.



Cont. table 1.

<b>Feedback Analysis</b>	Mining customer feedback, reviews, surveys, and social media comments for valuable insights and sentiment analysis. Identifying recurring issues, complaints, and compliments to drive continuous improvement in products and services. Employing natural language processing (NLP) and sentiment analysis techniques. Monitoring and addressing negative feedback promptly to mitigate reputational damage. Conducting root cause analysis for recurring issues identified through feedback analysis.
<b>Enhanced Customer Satisfaction</b>	Offering personalized recommendations and support based on individual customer profiles. Tailoring communication to convey appreciation, understanding, and acknowledgment of customer needs, preferences, and feedback. Implementing chatbots and AI-driven customer service for real-time personalized support. Continuously training customer service agents on personalized communication and conflict resolution. Monitoring customer satisfaction metrics and Net Promoter Score (NPS) to measure the impact of personalized customer service.
<b>Increased Sales and Revenue</b>	-Suggesting products or services that align with a customer's purchase history, interests, and browsing behavior. Implementing cross-selling and upselling strategies that leverage data-driven insights to increase customer spending and boost revenue. Tracking and analyzing conversion funnels for optimization. Monitoring the impact of personalized offers on sales and making adjustments as needed. Implementing dynamic pricing strategies based on customer behavior and market conditions.
<b>Improved Customer Retention</b>	Using analytics to identify customers at risk of churn or dissatisfaction and proactively addressing their concerns. Implementing loyalty programs, personalized offers, and retention strategies to reduce churn rates and improve customer retention. Developing customer lifetime value (CLV) models for retention strategies. Conducting post-churn analysis to identify reasons for customer attrition and address root causes. Measuring customer lifetime value (CLV) regularly and using it as a key performance indicator (KPI) for retention efforts.
<b>Competitive Advantage</b>	Leveraging data and analytics to stay ahead of competitors by providing more personalized and relevant experiences. Gaining an edge in the market through data-driven decision-making, product innovation, and exceptional customer service. Continuously monitoring the competitive landscape and adapting strategies accordingly. Benchmarking against industry leaders and innovators to identify areas for improvement. Collaborating with cross-functional teams to ensure a unified approach to maintaining a competitive advantage.
<b>Efficient Marketing Spend</b>	-Optimizing marketing campaigns by targeting the right audience with highly personalized messages and content. Reducing wasteful spending on generic marketing efforts by analyzing customer preferences, engagement data, and marketing ROI to improve campaign effectiveness. A/B testing and attribution modeling for marketing optimization. Adhering to a strict budget allocation strategy that balances customer acquisition and retention. Monitoring and adjusting the marketing mix in response to shifts in customer behavior and market trends.
<b>Multi-Channel Personalization</b>	Ensuring consistent and personalized customer experiences across various touchpoints, including websites, mobile apps, social media, email, in-store interactions, and call centers. Utilizing analytics to track and analyze customer behavior and preferences across multiple channels. Implementing cross-channel integration to provide a seamless and coherent personalized experience regardless of the customer's chosen interaction point. Customizing content and recommendations based on the specific channel and device, recognizing that customer expectations may vary.
<b>Geo-Location Based Personalization</b>	Utilizing geolocation data from customers' mobile devices to personalize content, offers, and recommendations based on their current physical location. Leveraging geo-fencing technology to trigger location-specific notifications and promotions when customers are near physical stores or specific geographic points of interest. Analyzing location data to understand regional preferences and behaviors, allowing for tailored regional marketing campaigns. Ensuring data privacy and consent management when collecting and using location data to personalize the customer experience.

Cont. table 1.

<b>Custom Product and Service Bundles</b>	Analyzing customer purchase history and preferences to create custom bundles of products or services that align with individual customer needs. Implementing dynamic pricing for bundled offerings, taking into account customer willingness to pay and historical purchase patterns. Offering personalized package recommendations that cater to both cost-conscious and premium customers. Monitoring the success of personalized bundles through conversion rates and customer feedback to fine-tune offerings over time.
<b>Loyalty Program Personalization</b>	Utilizing customer loyalty program data to personalize rewards, incentives, and offers based on individual customer behavior and engagement with the loyalty program. Creating personalized tiers or segments within the loyalty program to provide exclusive benefits and incentives to high-value customers. Analyzing the impact of personalized loyalty program offers on customer retention and repeat purchases.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022; Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023).

### 3. Software used in personalized customer experience

The evolution of customer expectations and the increasing competition in today's business landscape have made personalized customer experiences a paramount differentiator. To meet this demand, companies employ various software solutions to collect, analyze, and act on customer data in ways that enhance the overall customer journey.

CRM software is the foundation of personalized customer experiences. It stores and manages customer data, including contact information, purchase history, and interactions. CRM systems enable businesses to create comprehensive customer profiles and deliver tailored experiences based on this information. Popular CRM software includes Salesforce, HubSpot, and Microsoft Dynamics. Marketing automation tools help businesses automate and personalize their marketing efforts. They use customer data to segment audiences and deliver personalized content, emails, and campaigns. Software like HubSpot, Marketo, and Pardot allows for dynamic content, email personalization, and customer journey mapping (Scappini, 2016).

Analytics platforms like Google Analytics and Adobe Analytics provide insights into customer behavior, preferences, and interactions with your digital properties. Business intelligence tools like Tableau and Power BI help organizations make data-driven decisions by visualizing and analyzing customer data. Predictive analytics tools, such as IBM SPSS and RapidMiner, use historical data to predict future customer behavior. This enables businesses to anticipate customer needs, offer tailored product recommendations, and take proactive measures to enhance the customer experience (Nourani, 2021).

Recommendation engines are integral for e-commerce and content-based platforms. Solutions like Amazon Personalize and Adobe Target use algorithms to analyze user behavior and make real-time product or content recommendations, increasing engagement and conversions. A CMS (Content Management Systems) like WordPress, Drupal, or Joomla is crucial for personalized content delivery. They enable businesses to dynamically customize website content, landing pages, and blogs based on user behavior and preferences (Charles et al., 2023).

Email marketing platforms like MailChimp and SendinBlue allow businesses to send personalized emails. They use customer data to create segmented email lists and tailor content to individual interests, thereby increasing email open rates and engagement. Customer service software, such as Zendesk and Freshdesk, integrates customer data to provide personalized support. Agents can access customer histories, preferences, and issues, offering tailored solutions and enhancing customer satisfaction. Personalization engines like Dynamic Yield and Evergage specialize in creating unique, individualized experiences across various channels. They offer dynamic content, product recommendations, and real-time personalization capabilities (Bakir, Dahlan, 2022).

Software such as SurveyMonkey and Qualtrics enables companies to collect feedback from customers and analyze sentiment. These insights help identify areas for improvement and tailor responses to customer suggestions and concerns. Tools like Hootsuite and Sprout Social allow companies to track and engage with customers on social media. By understanding customer sentiment and responding to personalized inquiries, businesses can build stronger relationships (Greasley, 2019).

CDPs, (Customer Data Platform) including Segment and Tealium, centralize customer data from various sources. They unify data to create a single customer view, facilitating more accurate and personalized experiences (Javaid, Haleem, 2020).

AI and machine learning platforms such as TensorFlow and PyTorch are crucial for building custom recommendation engines and predictive models. They enable the development of advanced personalization algorithms. Tools like Optimizely and Google Optimize allow businesses to conduct A/B tests on personalized content and features to determine their impact on user engagement and conversions (Cillo et al., 2022).

Table 2 is listing examples of software and applications used in the case of personalized customer experience. These software examples represent key categories within personalized customer experience, ranging from CRM systems that store customer data to marketing automation platforms, analytics tools, and business intelligence solutions that enable personalization at various touchpoints in the customer journey (Akundi et al., 2022).

**Table 2.***The usage of business analytics in customization and personalization of product*

Category	Software	Description
<b>Customer Relationship Management</b>	Salesforce	Salesforce is a widely used CRM platform that allows businesses to manage customer data, interactions, and relationships, enabling personalized engagement.
	HubSpot	HubSpot's CRM provides tools for customer data management and marketing automation, helping businesses tailor marketing efforts based on customer data.
	Microsoft Dynamics	Microsoft Dynamics CRM offers comprehensive customer data management and sales automation capabilities, enabling personalized sales and customer service.
<b>Marketing Automation</b>	Marketo	Marketo is a marketing automation platform that helps businesses create personalized marketing campaigns and nurture leads based on customer behavior.
	Pardot	Pardot, by Salesforce, is a marketing automation tool that assists in personalizing email marketing, lead scoring, and nurturing campaigns.
	Eloqua	Oracle Eloqua offers marketing automation solutions, allowing businesses to create personalized marketing campaigns, track customer interactions, and segment audiences.
<b>Analytics and Business Intelligence</b>	Google Analytics	Google Analytics provides insights into website and app traffic, user behavior, and audience segmentation, enabling data-driven decisions and personalized content.
	Adobe Analytics	Adobe Analytics offers robust analytics and reporting tools, helping businesses understand customer interactions and personalize digital experiences.
	Tableau	Tableau is a data visualization platform that enables businesses to analyze customer data and create interactive dashboards for personalized decision-making.
<b>Predictive Analytics</b>	IBM SPSS	IBM SPSS is a predictive analytics software that uses historical data to forecast customer behavior and preferences, enabling personalized recommendations and proactive measures.
	RapidMiner	RapidMiner is a data science platform that allows businesses to build predictive models for personalized customer experiences, such as dynamic product recommendations.
	SAS Analytics	SAS Analytics offers advanced analytics tools that enable businesses to create predictive models, segment customers, and deliver personalized marketing campaigns.
<b>Recommendation Engines</b>	Amazon Personalize	Amazon Personalize is a machine learning service that allows businesses to create personalized product recommendations for their customers in real-time.
	Adobe Target	Adobe Target is a personalization and A/B testing tool that helps businesses deliver personalized content, offers, and experiences based on customer segments and behavior.
	Dynamic Yield	Dynamic Yield is a personalization platform that offers tools for e-commerce companies to customize content, product recommendations, and messaging for individual customers.

Source: (Adel, 2022; Akundi et al., 2022; Olsen, 2023; Aslam et al., 2020; Bakir, Dahlan, 2022; Cillo et al., 2022; Ghibakholl et al., 2022; Javaid, Haleem, 2020; Javaid et al., 2020; Cam et al., 2021; Charles et al., 2023; Greasley, 2019; Hurwitz et al., 2015; Nourani, 2021; Peter et al., 2023; Castro et al., 2014; Wang et al., 2023; Du et al., 2023; Fjellström, Osarenkhoe, 2023; Zeng et al., 2022; Pech, Vrchota, 2022).

## 4. Conclusion

Business analytics is not just a tool for data analysis; it's a strategic imperative for organizations looking to excel in the modern business landscape. Personalized customer experience has evolved from a trend to a pivotal point of differentiation. Customers expect businesses to know them intimately, understand their preferences, and offer tailored solutions to meet their unique needs. This expectation is the driving force behind the transformation of how businesses interact with their customers.

The heart of personalized customer experiences is data. Business analytics plays a central role in collecting, integrating, and processing vast amounts of data from various sources, creating comprehensive customer profiles. These profiles are the foundation for understanding and addressing the unique needs and preferences of each customer.

Segmentation, predictive analytics, recommendation engines, and real-time personalization are the pillars of personalized customer experiences. Businesses leverage these analytics tools to anticipate customer needs and proactively offer solutions. By doing so, they create an atmosphere where customers feel seen, valued, and appreciated. Moreover, feedback analysis, enhanced customer satisfaction, increased sales, and improved customer retention are outcomes of employing business analytics in the pursuit of personalized customer experiences. By mining customer feedback and reviews, businesses refine their products and services continuously, leading to higher customer satisfaction, increased sales, and customer loyalty.

The applications of business analytics in personalized customer experiences are diverse and extend across various aspects, from data collection and segmentation to predictive analytics and multi-channel personalization. This comprehensive table provides a clear overview of how business analytics drives the enhancement of customer satisfaction, revenue, and competitive advantage. To achieve this transformation, businesses rely on an array of software solutions, including CRM systems, marketing automation tools, analytics platforms, predictive analytics software, and recommendation engines. These software applications help collect, process, and act on customer data to deliver personalized experiences across various channels.

In this age of customer-centricity, businesses that harness the power of data and analytics gain a significant competitive edge. To succeed, they must tailor their marketing, products, and services to the unique needs and preferences of each customer. With the right software and analytics in place, businesses can not only meet but exceed customer expectations, ultimately driving growth and success. In the end, personalized customer experiences driven by business analytics are not just a response to customer demands; they are the key to unlocking the full potential of customer relationships and securing a strong foothold in the ever-evolving marketplace.

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## THE METHODS OF QUALITY MANAGEMENT IN QUALITY 4.0

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**Purpose:** The purpose of this publication is to present the usage of quality management methods in Quality 4.0 conditions.

**Design/methodology/approach:** Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

**Findings:** The applications of business analytics in personalized customer experiences span data collection, segmentation, predictive analytics, and multi-channel personalization, delivering greater customer satisfaction, revenue, and competitive advantage. Achieving this transformation requires the use of various software solutions, including CRM systems, marketing automation tools, analytics platforms, predictive analytics software, and recommendation engines. Harnessing the power of data and analytics is the key to gaining a competitive edge in this customer-centric era. Businesses that tailor their offerings to each customer's unique preferences and needs can not only meet but exceed customer expectations, ensuring growth and long-term success. Ultimately, personalized customer experiences, driven by business analytics, are not merely a response to customer demands; they are the path to unlocking the full potential of customer relationships and establishing a strong position in the ever-evolving marketplace.

**Keywords:** Industry 4.0; Quality 4.0, quality management; quality methods.

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

### 1. Introduction

Quality 4.0, also known as Industry 4.0 for Quality, is a modern approach to quality management that leverages digital technologies and data-driven methods to enhance the quality control processes in manufacturing and other industries. It is a response to the evolving technological landscape and the increasing demand for higher product quality, efficiency, and transparency.

Quality 4.0 is a concept that has gained prominence with the advent of Industry 4.0, the fourth industrial revolution characterized by the integration of cyber-physical systems, the Internet of Things (IoT), big data analytics, and artificial intelligence (AI) into various industrial processes. Quality 4.0 extends these technologies into the domain of quality management.

Quality 4.0 utilizes a network of sensors and IoT devices to collect real-time data from machines and processes. These sensors provide continuous monitoring and data capture, allowing for early detection of issues. Quality 4.0 processes vast amounts of data generated by IoT devices and other sources. Advanced analytics and machine learning are used to identify patterns, anomalies, and correlations, which can help in quality prediction and optimization (Bousdekis et al., 2023). AI algorithms are employed for predictive maintenance, quality control, and fault detection. Machine learning models can analyze historical data to make real-time decisions and improvements in quality processes. Quality 4.0 often employs digital twins, which are digital replicas of physical products or processes. These digital models can be used for simulation and analysis, allowing for the virtual testing and optimization of products and processes (Barsalou, 2023).

Blockchain technology is utilized to create transparent and immutable records of product quality and supply chain information. This ensures traceability and trust throughout the production and distribution processes. AR and VR technologies enhance training, maintenance, and quality inspection processes. They provide immersive experiences and aid in troubleshooting and problem-solving. Collaborative robots are used to assist workers in repetitive or precise tasks, enhancing quality and productivity while ensuring worker safety (Maganga, Taifa, 2023).

Quality 4.0 represents a significant shift in how quality management is approached, leveraging digital technologies to improve product quality, process efficiency, and overall competitiveness. As industries continue to embrace digital transformation, Quality 4.0 will play a pivotal role in ensuring that organizations meet the evolving demands of the global market (Antony et al., 2023).

The purpose of this publication is to present the usage of quality management methods in Quality 4.0 conditions.

## **2. The basics of quality management methods**

Quality management is a critical component of any organization's operations, regardless of the industry or sector. It encompasses a set of systematic approaches, principles, and methods aimed at ensuring that products or services consistently meet or exceed customer expectations.



TQM is a comprehensive approach that focuses on involving all employees in the organization to continuously improve processes, products, and services. It emphasizes customer satisfaction and the elimination of waste through methods such as Six Sigma and Lean. Six Sigma is a data-driven approach that seeks to identify and eliminate defects or variations in processes to achieve a level of quality where there are fewer than 3.4 defects per million opportunities. It employs the DMAIC (Define, Measure, Analyze, Improve, Control) methodology to achieve this. Lean principles aim to minimize waste and increase efficiency. It involves identifying and eliminating non-value-added activities, reducing lead times, and improving the flow of processes. International Organization for Standardization (ISO) standards provides a framework for quality management. ISO 9001, for example, outlines requirements for a quality management system, emphasizing customer focus, leadership, and continuous improvement.

SPC uses statistical techniques to monitor and control processes. It involves the use of control charts, histograms, and other statistical tools to maintain process stability and predictability. QFD is a method used to translate customer needs and expectations into specific product or service features. It helps in aligning design and production processes with customer requirements (Maganga, Taifa, 2023).

FMEA is a systematic approach to identifying and addressing potential failure modes in a product or process. It assigns a risk priority number to each failure mode, helping organizations prioritize improvements. Kaizen is a Japanese term that means "continuous improvement". It involves making small, incremental changes to processes and systems over time, with the goal of achieving long-term improvements.

The Pareto principle, also known as the 80/20 rule, states that 80% of the problems come from 20% of the causes. This method helps organizations identify and prioritize the most critical issues for improvement. Benchmarking involves comparing an organization's processes and performance against industry best practices or competitors to identify areas for improvement.

Quality circles are small groups of employees who meet regularly to discuss and solve quality-related issues, fostering a culture of employee involvement and continuous improvement. Managing the quality of materials and components supplied by external sources is critical. Techniques such as supplier audits and performance monitoring are used to ensure high-quality inputs.

Table 1 contains quality management methods and provides a brief description of each method. This table provides a concise overview of each quality management method and its key characteristics, making it easier to understand the differences and purposes of these approaches.

**Table 1.**  
*Examples of quality management methods*

Quality Management Method	Description
Total Quality Management (TQM)	TQM is an organization-wide approach that focuses on continuous improvement and customer satisfaction. It involves all employees in quality-related efforts and emphasizes process efficiency.
Six Sigma	Six Sigma is a data-driven methodology that aims to reduce defects and variations in processes. It uses the DMAIC (Define, Measure, Analyze, Improve, Control) framework to achieve high levels of quality.
Lean Management	Lean principles focus on eliminating waste and improving process efficiency. It emphasizes value stream mapping, just-in-time production, and continuous improvement.
ISO Standards	ISO standards, such as ISO 9001, provide a framework for quality management systems. They promote consistency, customer focus, and continual improvement in organizations.
Statistical Process Control (SPC)	SPC employs statistical techniques to monitor and control processes, helping maintain process stability and predictability through tools like control charts and histograms.
Quality Function Deployment (QFD)	QFD is a method for translating customer needs and expectations into specific product or service features. It aligns product design with customer requirements.
Failure Mode and Effects Analysis (FMEA)	FMEA is a systematic approach to identify and mitigate potential failure modes in products or processes. It assigns a risk priority number to each failure mode.
Kaizen	Kaizen is a Japanese concept that promotes continuous, incremental improvements in processes, products, and operations through the involvement of all employees.
Pareto Analysis	The Pareto Principle (80/20 rule) is used to identify and prioritize the most critical issues by recognizing that 80% of problems often result from 20% of the causes.
Benchmarking	Benchmarking involves comparing an organization's processes and performance with industry best practices or competitors to identify areas for improvement.
Quality Circles	Quality circles are small groups of employees who meet regularly to discuss and solve quality-related issues, fostering a culture of employee involvement and continuous improvement.
Supplier Quality Management	This method focuses on managing the quality of materials and components supplied by external sources, ensuring they meet specified standards.
Root Cause Analysis (RCA)	RCA is used to identify the underlying causes of problems or defects, addressing issues at their source rather than merely treating symptoms.

Source: (Almeida, Abreu, 2023; Jokovic et al., 2023; Khourshed, Gouhar, 2023; Maganga, Taifa, 2023; Liu et al., 2023; Yanamandra et al., 2023; Escobar et al., 2023; Bousdekis et al., 2023; Antony et al., 2023).

### 3. How quality management methods are integrated in Quality 4.0 concept

TQM has always emphasized the importance of data for making informed decisions. Quality 4.0 takes this to a new level by providing real-time, high-volume data from IoT sensors and other sources (Escobar et al., 2023). This data is then processed and analyzed using advanced analytics and machine learning algorithms. It allows for more accurate, timely, and predictive decision-making, which aligns with the core principles of TQM. TQM places a strong emphasis on continuous improvement (Sureshchandar, 2023). Quality 4.0 enhances this by providing tools and data that enable organizations to identify areas for improvement with greater precision

and agility. The real-time monitoring and analytics capabilities of Quality 4.0 allow companies to make incremental changes swiftly and accurately (Almeida, Abreu, 2023).

Both TQM and Quality 4.0 prioritize customer satisfaction. Quality 4.0, however, leverages big data analytics and customer feedback collected through digital channels to gain deeper insights into customer needs and preferences. This data can be used to tailor products and services to a highly individualized level, thus delivering higher levels of customer satisfaction. Quality 4.0 integrates various digital technologies like IoT, AI, machine learning, and blockchain. These technologies facilitate advanced quality control and risk management. In the context of TQM, this means better process control and faster problem-solving (Jokovic et al., 2023).

TQM often relies on historical data and manual processes for issue identification and resolution. Quality 4.0 is proactive, using predictive analytics and AI to identify potential issues before they escalate. This shift from a reactive to a proactive approach aligns with TQM's objective of preventing defects and improving quality. Quality 4.0 offers real-time monitoring and control of processes through digital tools. This level of transparency and control ensures that quality standards are consistently met and deviations are quickly addressed, in line with TQM's principle of process management (Amat-Lefort et al., 2023).

Quality 4.0 integrates blockchain technology to create transparent and immutable records of product quality and supply chain information. This ensures complete traceability, which is vital in TQM for tracking defects and ensuring accountability. TQM promotes employee involvement in quality initiatives. Quality 4.0 supports this by providing digital platforms and collaborative tools for employees to actively participate in quality management. This aligns with the collaborative spirit of TQM. Quality 4.0 can help organizations reduce costs and improve operational efficiency by optimizing processes in real time. The efficient use of resources, a key goal of TQM, is enhanced through data-driven optimization (Maganga, Taifa, 2023).

Six Sigma relies on data and statistical analysis to identify and reduce defects and variations in processes. Quality 4.0 takes this to the next level by providing real-time data from IoT sensors, machines, and various sources. This high-volume data is processed and analyzed using advanced analytics and machine learning algorithms. Quality 4.0 enhances the accuracy and speed of data-driven decision-making in the Six Sigma process (Yanamandra et al., 2023). In traditional Six Sigma, control charts and historical data are used to monitor processes and identify deviations. Quality 4.0 introduces predictive analytics, allowing organizations to identify potential issues before they occur. This shift from reactive to proactive quality control aligns with the core goals of Six Sigma, which are to prevent defects and improve process efficiency (Khourshed, Gouhar, 2023).

Both Six Sigma and Quality 4.0 emphasize continuous improvement. Quality 4.0 enhances this by providing tools and data that enable organizations to identify areas for improvement with greater precision and agility. The real-time monitoring and analytics capabilities of Quality 4.0 enable companies to make incremental changes quickly and accurately. Quality 4.0 integrates various advanced technologies such as IoT, AI, machine learning, and blockchain (Alrabadi et al., 2023). These technologies offer new opportunities for quality control, process optimization, and risk management, complementing the methodologies used in Six Sigma. Both Six Sigma and Quality 4.0 focus on customer satisfaction. Quality 4.0 leverages big data analytics to gain deeper insights into customer needs and preferences. This data-driven approach allows organizations to tailor products and services to meet customer expectations more precisely, aligning with the customer-centric objectives of Six Sigma (Antony et al., 2023).

Quality 4.0 offers advanced problem-solving tools, such as real-time root cause analysis, which enables organizations to quickly identify and address issues (Salimbeni, Redchuk, 2023). This rapid problem resolution aligns with the DMAIC (Define, Measure, Analyze, Improve, Control) methodology of Six Sigma. Quality 4.0 provides real-time monitoring and control of processes through digital tools, enhancing the process control aspects of Six Sigma (Saihi et al., 2023). This ensures that quality standards are consistently met and deviations are quickly addressed. Six Sigma encourages employee involvement in quality initiatives. Quality 4.0 supports this by providing digital platforms and collaborative tools for employees to actively participate in quality management, fostering a culture of data-driven improvement (Swarnakar et al., 2023). Quality 4.0 is a natural extension of the principles and methodologies of Six Sigma. By integrating digital technologies, data-driven decision-making, real-time monitoring, and predictive analytics, Quality 4.0 empowers organizations to achieve even higher levels of quality, efficiency, and process improvement, ultimately ensuring customer satisfaction and competitive excellence (Singh et al., 2023).

Quality 4.0 integrates blockchain technology to create transparent and immutable records of product quality and supply chain information. This ensures complete traceability, a critical aspect in both Six Sigma and Quality 4.0 for tracking defects and ensuring accountability (Liu et al., 2023).

Table 2 is listing examples of integration of selected quality management methods with Quality 4.0. By integrating these quality management methods into Quality 4.0, organizations can harness the full potential of digital technologies and data-driven approaches to achieve higher quality, efficiency, and transparency in their operations.

**Table 2.**  
*Quality management methods in Quality 4.0*

Quality Management Method	Integration with Quality 4.0
Total Quality Management (TQM)	TQM, when integrated into Quality 4.0, becomes a holistic approach to quality that harnesses digital tools and data. Quality 4.0 utilizes IoT devices and real-time data analytics to continuously improve processes, enhance customer satisfaction, and involve all employees in quality-related efforts. This approach promotes a culture of data-driven decision-making, transparency, and agility in adapting to changing customer needs.
Six Sigma	In the context of Quality 4.0, Six Sigma leverages advanced analytics, machine learning, and IoT data to identify and reduce defects. This method is driven by data and focuses on achieving high levels of quality through the DMAIC framework. It provides a structured approach to quality control, enhancing precision and efficiency by predicting issues before they occur.
Lean Management	Quality 4.0 augments Lean Management by using real-time data from IoT devices to eliminate waste and optimize process efficiency. With digital tools such as value stream mapping and continuous improvement platforms, organizations can make data-driven decisions to streamline their operations and minimize resources while maintaining product quality.
ISO Standards	ISO standards serve as the foundation for Quality 4.0's digital quality management systems. These standards help establish compliant and consistent quality processes within the context of Industry 4.0. Quality 4.0 integrates data-driven decision-making and real-time monitoring, ensuring that ISO requirements are met with greater efficiency and transparency.
Statistical Process Control (SPC)	Quality 4.0 enhances SPC by incorporating sensors and IoT devices for real-time process monitoring and control. Advanced analytics and machine learning algorithms enable a more precise analysis of process data, ensuring process stability and predictability while identifying issues and defects as soon as they occur.
Quality Function Deployment (QFD)	In Quality 4.0, QFD benefits from the use of digital twin models, which allow for advanced simulations and virtual assessments of customer needs. These digital replicas enable organizations to align their product design more precisely with customer requirements and improve the product development process.
Failure Mode and Effects Analysis (FMEA)	Quality 4.0 enhances FMEA by using predictive analytics and AI to identify potential failure modes and their impact in real-time. This proactive approach to risk assessment ensures that issues are addressed before they lead to defects, improving overall product quality and reliability.
Kaizen	Quality 4.0 augments Kaizen by providing real-time data analytics and collaborative digital tools. This allows employees to make data-driven, incremental improvements continuously. It encourages a culture of continuous improvement and agility in adapting to changing circumstances, ultimately leading to higher quality and efficiency.
Pareto Analysis	In Quality 4.0, Pareto analysis becomes more efficient by using advanced data analytics to identify and prioritize critical issues more accurately. By considering the digital data landscape, organizations can focus their efforts on the most impactful areas for improvement, resulting in better resource allocation and faster problem resolution.
Benchmarking	Quality 4.0 integrates benchmarking by using real-time data and digital tools to compare processes with industry leaders. This allows organizations to make immediate adjustments and improvements to their processes, ensuring that they remain competitive in the digital era.
Quality Circles	In the context of Quality 4.0, quality circles benefit from digital communication and collaborative tools. Remote problem-solving and data-driven discussions become more effective, allowing employees to contribute to continuous improvement efforts from anywhere in the world.

Cont. table 2.

Supplier Quality Management	Quality 4.0 enhances supplier quality management by incorporating real-time monitoring and blockchain technology. This transparency in the supply chain tracking ensures that the quality of materials and components from external sources is maintained, meeting specified standards and ensuring product quality.
Root Cause Analysis (RCA)	RCA in Quality 4.0 benefits from data-driven insights and predictive analytics. It identifies the root causes of problems more accurately and quickly by analyzing large datasets. This approach facilitates more efficient problem resolution and prevents recurrence, leading to improved product quality and customer satisfaction.

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

## 4. Conclusion

The advent of Quality 4.0, a response to the ever-evolving technological landscape, has transformed the way organizations approach quality management. This modern approach leverages digital technologies and data-driven methodologies to enhance quality control processes in manufacturing and other industries. It aligns with the broader concept of Industry 4.0, which integrates cyber-physical systems, IoT, big data analytics, and artificial intelligence into industrial processes.

Quality 4.0 capitalizes on a network of sensors and IoT devices, which continuously collect real-time data from machines and processes. This data is then analyzed using advanced analytics, machine learning, and AI, facilitating predictive quality control and optimization. Moreover, digital twins enable virtual testing and optimization, and blockchain technology ensures transparent and immutable records for traceability.

In the context of Quality 4.0, traditional quality management methods are seamlessly integrated to further improve product quality, process efficiency, and overall competitiveness. Total Quality Management (TQM), for instance, benefits from real-time data and advanced analytics, supporting a culture of data-driven decision-making and process improvement. Six Sigma, which traditionally relies on data analysis and historical information, now thrives on real-time data and predictive analytics in Quality 4.0. This shift from reactive to proactive quality control aligns perfectly with the goals of defect prevention and process enhancement.

The integration of Lean Management principles in Quality 4.0 leads to waste reduction and efficiency improvement, with data-driven decisions contributing to enhanced value stream mapping and continuous process improvement. ISO standards provide a framework for Quality 4.0's digital quality management systems, emphasizing consistency, customer focus, and continuous improvement, thus ensuring organizations meet evolving industry demands more efficiently.

Statistical Process Control (SPC) benefits from real-time data and digital tools to monitor and control processes, maintaining predictability and stability. Quality Function Deployment (QFD) translates customer needs into specific features more precisely, aligning product design with customer requirements in the digital landscape.

These are just a few examples of the integration of quality management methods in Quality 4.0. Each method harnesses the power of digital technologies and data-driven approaches to achieve higher quality, efficiency, and transparency. Quality 4.0 serves as a pivotal driver in the ongoing digital transformation, ensuring organizations remain competitive and meet the ever-changing demands of the global market. It is a testament to the continuous evolution of quality management in the face of technological advancement.

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## WASTE MANAGEMENT IN SMARTPHONE APPLICATIONS AS ELEMENT OF SMART CITY DEVELOPMENT

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**Purpose:** The purpose of this publication is to present the usage of smartphone application in Smart Cities in waste management.

**Design/methodology/approach:** Critical literature analysis. Analysis of international literature from main databases and polish literature and legal acts connecting with researched topic.

**Findings:** The integration of smartphone apps in smart city waste management promises enhanced urban sustainability, efficiency, and citizen engagement. These apps, detailed in Tables 1 and 2, offer real-time monitoring, data-driven decision-making, and environmental benefits. Yet, challenges like the digital divide and data privacy, discussed in Table 3, must be overcome. A comprehensive approach, focusing on accessibility, data security, and sustainability, is essential. Smartphone apps are a critical step toward creating cleaner, healthier, and more sustainable smart cities.

**Keywords:** Smart City, waste management, smartphone applications, smart mobility.

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

### 1. Introduction

In the 21st century, the concept of a "smart city" has gained tremendous momentum, driven by the need for more efficient and sustainable urban environments. One key aspect of smart city development is waste management, a critical component of maintaining cleanliness, health, and sustainability in urban areas. Smartphone applications have emerged as powerful tools to enhance waste management practices, contributing significantly to the realization of smart cities. The integration of smartphone applications into waste management is a tangible and effective means of advancing smart city development. These apps not only enhance operational efficiency but also foster a sense of environmental responsibility among citizens. As cities continue to grow and evolve, waste management through smartphone applications will remain

a fundamental element in the pursuit of cleaner, healthier, and more sustainable urban environments.

The purpose of this publication is to present the usage of smartphone application in Smart Cities in the case of waste management.

## **2. The usage of smartphone applications in waste management**

Smartphone applications play an integral role in the evolution of waste management in urban areas. These applications enable real-time monitoring of waste collection, transportation, and disposal. Sensors embedded in waste bins can transmit data to these apps, allowing waste management authorities to optimize routes, schedules, and resources. As a result, collection trucks can be dispatched more efficiently, reducing fuel consumption and traffic 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).

Smartphone apps engage citizens in the waste management process. Users can report issues such as overflowing bins, illegal dumping, or missed collections through these apps. Such citizen participation fosters a sense of community ownership and responsibility for waste management, which, in turn, leads to cleaner and more sustainable cities. Many applications provide information about waste sorting and recycling, guiding users on how to properly dispose of different types of waste. This educational aspect is vital for reducing contamination in recycling streams and promoting eco-friendly practices (Rachmawati et al., 2021; Dutta et al., 2021; Ivanyi, Biro-Szigeti, 2019).

In some smart cities, waste collection services are billed based on usage. Smartphone apps allow users to make payments conveniently, check their billing history, and receive digital receipts. This not only streamlines the payment process but also reduces the need for physical paperwork. Smartphone applications often include features like news feeds and updates related to waste management and environmental issues. This helps in raising awareness among the community about the importance of responsible waste disposal and encourages eco-conscious behaviors.

By accumulating and analyzing data from these apps, city authorities can gain valuable insights into waste generation patterns, peak disposal times, and areas with recurring waste management issues. Such data-driven decision-making leads to more effective waste management strategies and resource allocation. In smart cities, IoT devices and sensors are increasingly used to monitor waste bins' fill levels, allowing for timely collection. Smartphone applications can integrate seamlessly with these technologies, enabling a more automated and responsive waste management system (Rahman, Dura, 2022).



By optimizing waste collection routes and reducing fuel consumption, these apps contribute to a reduction in greenhouse gas emissions. Furthermore, better waste sorting and recycling practices promote sustainability and environmental conservation (Herdiansayah, 2023; Rose et al., 2021).

Table 1 contains descriptions of how smartphone applications are used in waste management.

Waste management apps often integrate with IoT sensors placed in waste bins and containers. These sensors monitor the fill levels of the bins and transmit data in real time to the application. This enables waste management authorities to optimize collection routes and schedules, ensuring that collection trucks are dispatched only when necessary, which minimizes fuel consumption and traffic congestion. Smartphone apps use the data collected from real-time monitoring to create efficient collection routes and schedules. This ensures that waste collection trucks take the most direct and time-efficient paths, reducing operational costs and environmental impact.

Citizens can report issues related to waste management through these applications. Whether it's reporting overflowing bins, illegal dumping, or missed collections, user-generated feedback helps authorities respond to problems more quickly and efficiently. Many waste management apps provide guidance on waste sorting and recycling. They educate users on how to properly dispose of various types of waste, helping to reduce contamination in recycling streams and encouraging eco-friendly practices.

In some smart cities, waste collection services are billed based on usage. Waste management apps allow users to make payments conveniently through their smartphones, view their billing history, and receive digital receipts, eliminating the need for physical paperwork and streamlining the payment process (Jonek-Kowalska, Wolniak, 2021, 2022, 2023; Rosak-Szyrocka et al., 2023; Gajdzik et al., 2023; Jonek-Kowalska et al., 2022; Kordel, Wolniak, 2021; Orzeł, Wolniak, 2021, 2022; Ponomarenko et al., 2016; Stawiarska et al., 2020, 2021; Stecuła, Wolniak, 2022; Olkiewicz et al., 2021). Waste management apps often include features like news feeds and updates related to waste management and environmental issues. These features help raise awareness among the community about responsible waste disposal and encourage environmentally conscious behaviors (Chmielarz et al., 2021).

Smartphone applications collect and analyze data on waste generation patterns, fill levels, and recurring issues (Rose et al., 2021). By harnessing this data, waste management authorities can make data-driven decisions to improve operational efficiency, reduce costs, and allocate resources more effectively. By optimizing waste collection routes and schedules, these apps lead to a reduction in fuel consumption and greenhouse gas emissions. Additionally, promoting responsible waste disposal and recycling practices through these apps contributes to environmental sustainability (Simonofski et al., 2023; Chmielarz et al., 2021).

Many smart cities use IoT devices and sensors to monitor waste containers. Smartphone applications can integrate seamlessly with these technologies to create a more automated and responsive waste management system. Some waste management apps include educational resources and campaigns that promote sustainable waste disposal practices, increasing public awareness about the environmental impact of waste (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).

Smartphone applications have become integral to waste management in smart cities by improving operational efficiency, increasing user engagement, and promoting environmentally sustainable practices. By harnessing real-time data, citizen participation, and advanced technologies like IoT, these applications play a crucial role in transforming waste management into a smarter, more eco-friendly, and efficient process within the context of smart city development.

**Table 1.**

*How smartphone applications are used in waste management*

<b>Aspect of Waste Management</b>	<b>Application in Smart City Development</b>
Real-Time Monitoring	Integration with IoT sensors for real-time monitoring of fill levels in waste bins, enabling optimized collection routes and schedules.
Efficient Routing and Scheduling	Utilizing real-time data to create efficient waste collection routes and schedules, reducing operational costs and environmental impact.
User Reporting and Feedback	Allowing citizens to report issues like overflowing bins, illegal dumping, and missed collections for quicker problem resolution.
Waste Sorting Guidance	Educating users on proper waste sorting and recycling through the app to reduce contamination in recycling streams.
Payment and Billing	Enabling users to make payments for waste collection services conveniently, view billing history, and receive digital receipts.
Community Engagement	Engaging citizens through news feeds and updates on waste management and environmental issues to raise awareness and promote eco-friendly behaviors.
Data Analytics	Collecting and analyzing data on waste generation patterns and recurring issues to make data-driven decisions for operational improvements.
Environmental Impact Reduction	Optimizing waste collection to reduce fuel consumption and greenhouse gas emissions, contributing to sustainability.
Integration with IoT and Sensors	Seamless integration with IoT devices and sensors to create an automated and responsive waste management system.

Public Awareness Campaigns	Including educational resources and campaigns within the app to promote sustainable waste disposal practices and increase public awareness.
Collection Point Information	Providing information on the locations of waste collection points and nearby recycling centers, improving accessibility.
User Notifications	Sending reminders and notifications to users about upcoming collection schedules and recycling events.
Waste Reduction Strategies	Offering tips and strategies to help users reduce waste generation and make eco-friendly choices.
Digital Waste Bins	Using digital bins that interact with the app, providing fill-level updates and location details.
Regulatory Compliance	Assisting waste management authorities in ensuring regulatory compliance and monitoring waste-related permits.
Fleet Management	Monitoring and managing the waste collection fleet, optimizing vehicle maintenance and operational efficiency.
Emergency Response	Facilitating quick response during emergencies, such as hazardous waste spills or natural disasters.
Data Security and Privacy	Ensuring the security and privacy of user data and adherence to data protection regulations.
Multilingual Support	Providing support for multiple languages to accommodate diverse user populations in smart cities.
Integration with Payment Systems	Integrating with payment gateways and systems to manage waste service fees securely.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani & Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera & Boutueil, 2018).

Table 2 highlighting the advantages of using smartphone applications in waste management within smart cities. The integration of smartphone applications into waste management systems in smart cities results in a range of benefits, from improved operational efficiency to increased citizen engagement and environmental sustainability.

**Table 2.***Advantages of using smartphone applications in waste management*

<b>Advantages</b>	<b>Description</b>
Real-Time Monitoring	Allows for immediate, data-driven decision-making and optimization of waste collection and disposal processes.
Enhanced Efficiency	Improves operational efficiency by optimizing collection routes, reducing fuel consumption, and decreasing operational costs.
User Engagement and Awareness	Encourages citizen participation in waste management, fosters community responsibility, and raises awareness about environmental issues.
Waste Sorting and Recycling Guidance	Educates users about proper waste sorting and recycling, reducing contamination and promoting eco-friendly practices.
Streamlined Payment and Billing	Simplifies waste service payments, reduces paperwork, and enhances transparency for users.
Data-Driven Decision-Making	Provides valuable insights into waste generation patterns and recurring issues, enabling data-driven decisions for operational improvements.
Environmental Impact Reduction	Contributes to environmental sustainability by optimizing waste management, reducing greenhouse gas emissions, and promoting responsible waste disposal.
Integration with IoT and Sensors	Enhances efficiency by integrating seamlessly with IoT devices and sensors for real-time monitoring.
Public Awareness Campaigns	Raises public awareness about the importance of sustainable waste disposal and the environmental impact of waste.
Accessibility and Inclusivity	Provides information and services in multiple languages, ensuring accessibility for diverse populations in smart cities.
Emergency Response Capabilities	Facilitates quick response during waste-related emergencies, ensuring a safer and more efficient crisis management process.
Regulatory Compliance and Reporting	Helps authorities ensure regulatory compliance, monitor permits, and generate reports on waste management activities.
Data Security and Privacy	Ensures the security and privacy of user data, promoting trust and compliance with data protection regulations.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani & Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera & Boutueil, 2018).

Table 3 highlighting some of the common problems and challenges associated with the usage of smartphone applications in waste management within smart cities. Addressing these problems requires careful planning, investment, user education, and consideration of inclusivity to ensure that waste management apps are effective and accessible to all residents in a smart city.

**Table 3.**

*Problems of using smartphone applications in waste management within smart cities*

<b>Problems</b>	<b>Description</b>
Digital Divide	Not all citizens have access to smartphones or reliable internet connections, leading to potential exclusion from waste management services.
Data Privacy and Security	Handling personal data through apps raises concerns about data security, privacy breaches, and misuse of user information.
Technological Barriers	Some users may struggle to use waste management apps due to limited technological literacy or accessibility issues.
Maintenance and Updates	Frequent updates and maintenance of the application are necessary, which can lead to disruption and compatibility issues.
Costs and Funding	Developing, maintaining, and supporting waste management apps can be expensive and may strain municipal budgets.
Limited Coverage	The availability and coverage of waste management apps may not extend to all areas of a city, leaving some regions underserved.
User Reliability	Relying on user-generated data and reports may result in inaccuracies and unreliable information.
Digital Divide Among Waste Bins	Equipping waste bins with IoT sensors is costly and might not be practical in all areas, leading to disparities in monitoring.
Technological Infrastructure	In areas with limited technological infrastructure, such as poor network connectivity, apps may not function optimally.
Resistance to Change	Users or waste management authorities may resist adopting new technologies, hindering the application's success.
Environmental Impact of Smartphone Use	The production and disposal of smartphones and their impact on the environment may be at odds with sustainability goals.
Compatibility and Interoperability Issues	Integrating waste management apps with existing systems, including those from different vendors, can pose challenges.

Source: (Kalasova et al., 2021; Chmielarz et al., 2021; Rose et al., 2021; Dutta et al., 2019; Ivani & Biro-Szigeti, 2019; Leal et al., 2023; Chowdhury et al., 2023; Sanchez et al., 2018; Aguilera & Boutueil, 2018).

Using smartphone applications in waste management within smart cities offers numerous advantages, but it also comes with its fair share of challenges and problems. Not everyone in a city has access to smartphones or a reliable internet connection. This digital divide can result in exclusion, with some residents unable to take advantage of the services provided through waste management apps (Dutta et al, 2019).

Handling personal data, including billing information and location data, through these apps raises concerns about data security and privacy breaches. It's crucial to ensure robust security measures to protect user information. Some users may struggle to use waste management apps due to limited technological literacy or accessibility issues, especially among older or less tech-savvy demographics (Kalasova et al., 2021).

Smartphone applications require regular updates and maintenance to ensure their functionality and security. These updates can sometimes lead to temporary disruptions, compatibility issues, or usability problems for users. Developing, maintaining, and supporting waste management apps can be expensive, potentially straining municipal budgets. Funding challenges may limit the scope and quality of these applications.

The availability and coverage of waste management apps may not extend to all areas of a city. Some regions may be underserved, leaving residents without access to the benefits of these apps. Relying on user-generated data and reports can lead to inaccuracies and unreliable information, affecting the overall effectiveness of waste management operations. Equipping waste bins with IoT sensors can be costly and may not be practical in all areas, leading to disparities in monitoring and data collection (Boichuk, 2020).

In areas with limited technological infrastructure, such as poor network connectivity or outdated hardware, waste management apps may not function optimally or may not be accessible to all residents. Users and waste management authorities may resist adopting new technologies due to familiarity with existing processes or concerns about the learning curve, hindering the application's success (Benevolo et al., 2016; Kalasova et al., 2021).

The production, use, and disposal of smartphones themselves can have a significant environmental impact, which may be at odds with sustainability goals of smart cities. Integrating waste management apps with existing systems, especially those from different vendors, can pose technical challenges and hinder smooth interoperability (Wolniak, 2016; Czerwińska-Lubszczyk et al., 2022; Drozd, Wolniak, 2021; Gajdzik, Wolniak, 2021, 2022; Gębczyńska, Wolniak, 2018, 2023; Grabowska et al., 2019, 2020, 2021).

To harness the full potential of smartphone applications in waste management within smart cities, it is essential to consider these problems and work toward solutions that ensure inclusivity, data security, and usability while minimizing the negative environmental and social

impacts. This can involve comprehensive user education, infrastructure development, and effective policies and regulations.

### 3. Conclusion

The integration of smartphone applications into waste management systems within smart cities presents a promising avenue for enhancing urban sustainability, operational efficiency, and citizen engagement. These applications, as detailed in Table 1, offer a multifaceted approach to waste management, encompassing real-time monitoring, user engagement, data-driven decision-making, and environmental impact reduction. The advantages, as outlined in Table 2, are evident in the form of improved efficiency, increased environmental awareness, and streamlined processes, contributing to more sustainable urban environments.

However, the adoption of these applications is not without its challenges, as highlighted in Table 3. The digital divide, data privacy concerns, and technological barriers can potentially hinder accessibility and effectiveness. Maintenance costs, funding constraints, and resistance to change also present significant obstacles that need to be addressed. Moreover, the environmental impact of smartphone production and disposal raises important questions about the alignment of these technologies with sustainability goals.

To overcome these challenges and fully realize the potential of smartphone applications in smart city waste management, a comprehensive approach is necessary. This approach should encompass equitable access, robust data security measures, technology literacy programs, and infrastructure development. It should also address issues related to funding, resistance to change, and sustainability considerations.

In the 21st century, the vision of smart cities is intrinsically linked to innovation and sustainability. Smartphone applications for waste management represent a significant step towards achieving these goals. With careful planning, investment, and a commitment to inclusivity, these applications can play a pivotal role in shaping cleaner, healthier, and more sustainable urban environments for generations to come.

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## SUSTAINABLE ENERGY AND CLIMATE CHANGE UNIVERSITIES: ECONOMIC ANALYSIS AND ORGANIZATIONAL ASPECTS

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**Purpose:** Universities are driving a creative and innovative approach to economic, social, and environmental change in line with the directions set by the Sustainable Development Goals. Green universities are higher education institutions that educate global citizens about the most important environmental challenges and shape their awareness, strive to minimize the environmental footprint of campus activities, and enable students and staff to understand and engage in ongoing research and development to work towards environmental sustainability and make it a priority. The aim of the article is to present the research in terms of the developing the concept of green and sustainable university.

**Design/methodology/approach:** The research is based on the results of the international UI GreenMetric ranking. The research verifies the regression relationships between the evaluation of the costs of universities for energy conservation and climate change and their overall total evaluation and provides conclusions about the efficiency of sustainable universities.

**Findings:** The analysis shows that the practices and initiatives at universities have to be accelerated towards sustainable development. In order to support universities in their green transformation, it is, therefore, necessary to create a research program and tools to support them at the national and regional levels.

**Research limitations/implications:** We used The UI GreenMetric ranking. However, it is worth checking what criteria other such rankings follow and comparing their results.

**Social implications** There is a weakness in cooperation between universities at sharing knowledge of successful management, implementation, research, and teaching in area of sustainable university change. To improve the situation, it is necessary to create a universal model for the maturity of a green university.

**Originality/value:** The results of the analysis prove that the concept of green universities, although widely discussed and presented in global politics and rankings, does not find a corresponding level of practical application.

**Keywords:** sustainable development, green university, green campus, green curriculum, green ranking correlation-regression analysis, statistical significance.

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

## 1. Introduction

Implementing the concept of sustainable development at universities (Galleli et al., 2022), which integrates a number of green strategies (Filho, 2021), is among the most important challenges faced by universities in today's world.

The green policies at universities must be developed and implemented within the framework of the 2030 Agenda for Sustainable Development declared by the United Nations (<https://sdgs.un.org/2030agenda>) and the 17 Sustainable Development Goals indicated in the Agenda (<https://www.un.org/sustainabledevelopment/sustainable-development-goals/>). As an example, we would like to give a brief overview of the Sustainable Development Strategy for 2022-2024 at the University of Information Technology and Management in Rzeszow, Poland (UITM). The strategy will focus on four key areas:

*Education:* including the subject of sustainable development at all levels of education; developing new on-line courses and trainings to qualify properly educated staff, application of technologies to increase student involvement, implementation of blended learning, virtual group classes and interactive learning.

*Research and development:* using information systems/technologies in research that will ensure more efficient use and allocation of existing resources, improve data and information management/sharing, supporting the activities of scientific and student clubs, promoting the principles of sustainable development in lectures, seminars and conferences through environmentally friendly organizational solutions (e.g. electronic conference materials, recycled materials for bags, notebooks, water dispenser, collective transport for conference participants), open-access publications.

*Infrastructure and organization:* effective water management on both campuses of the University, the use of alternative, renewable energy sources, biodiversity activities in Kielnarowa Campus, reducing the amount of paper/plastic waste and increasing the recycling rate to at least 50% on both university campuses, transformation of research and teaching laboratories towards the so-called green laboratories, consolidation of data centers and data migration to cloud-based systems to reduce energy consumption.

*Partnerships:* developing an integrated environment (in the form of a system/platform) to support open cooperation, exchange and access to relevant data and information; international cooperation to promote institutional and management decisions and models; intergenerational communicational various levels of education, including the Academy 50+ and the Higher

Academic School (ALO), collaboration with national and international institutions working in the field of sustainable development, including PRME, RESPONSIBLE BUSINESS FORUM and UI GREEN METRIC.

In the digital era, the green status of a university, similarly to many facets of our life, tend to be measured in figures. Currently several green metrics have been developed and implemented to rank universities worldwide. Additionally, a set of green metrics may serve as a clearinghouse of green best practices to support their implementation and discussion of new ideas about green initiatives. Some ranking systems have taken leading positions in this field. Among them are:

- The Academic Ranking of World Universities (ARWU, <https://www.shanghairanking.com/rankings/arwu/2021>). It was first published in June 2003 by the Center for World-Class Universities (CWCU), Graduate School of Education (formerly the Institute of Higher Education) of Shanghai Jiao Tong University, China, and updated on an annual basis. Universities are ranked by several academic or research performance indicators, including alumni and staff winning Nobel Prizes and Fields Medals, highly cited researchers, papers published in Nature and Science, papers indexed in major citation indices, and the per capita academic performance of an institution. For each indicator, the highest scoring institution is assigned a score of 100, and other institutions are calculated as a percentage of the top score.
- QS World University Rankings compiled by global higher education analyst Quacquarelli Symonds (QS, <https://www.topuniversities.com/about-qs>). The rankings are based on a methodology that considers a range of factors, including academic reputation, employer reputation, research impact, and internationalization. The methodology is reviewed annually to ensure that it remains relevant and up-to-date.
- Times Higher Education (THE, <https://www.timeshighereducation.com/world-university-rankings>). It provides the definitive list of the world's best universities, with an emphasis on the research mission. Other core missions evaluated: teaching (the learning environment); research (volume, income and reputation); citations (research influence); industry income (knowledge transfer) and international outlook (staff, students and research). It uses 13 carefully calibrated performance indicators to provide the most comprehensive and balanced comparisons.
- UI Green Metrics (<https://greenmetric.ui.ac.id/>). Every year the University of Indonesia (UI) publishes the UI GreenMetric World University Rankings on sustainability. Universities are given a score reflecting their efforts in reducing the ecological footprint of the university and sustainability in education and research.

Lately the UITM was awarded as the 291st World's Most Sustainable University in 2022 UI GreenMetric World University Rankings (<https://wsiz.edu.pl/wp-content/uploads/2022/12/WSIIZ-UI-Green-Metric.pdf>), and it was #2 in the country ranking.

As is clear from the short list above, most ranking systems focus on education and research missions of universities. The data they contain can help potential students and researchers when choosing a university for study and research work. Only the UI Green Metrics contains data of key interest for the study presented in this article. That is why this ranking system was chosen as the main source of data for subsequent statistical analysis.

## 2. Search and Method Procedure

The research is based on the results of the international UI GreenMetric ranking (<https://greenmetric.ui.ac.id/rankings/ranking-by-category-2021/2>). The UI GreenMetric ranking has been assessing university activities related to sustainability and climate protection since 2010 (Atici et al., 2021; Ragazzi et al., 2017; Galleli et al., 2022; Safarkhani et al., 2022). The ranking methodology draws from best practice models including: Times Higher Education, Webometric, HEEACT, QS Ranking, The College Sustainability Report Card.

The UI GreenMetric ranking of the universities taking part in the ranking is based on their self-assessment in relation to 39 indicators divided into 6 categories:

1. environment and infrastructure - weighting 15% (percentage of campus dedicated to green spaces, size of budget for sustainability measures, adaptation of campus for disabled people and mothers with children),
2. energy and climate change - weighting 21% (carbon footprint, renewable energy sources, devices to reduce energy consumption, university climate change programs),
3. waste - weighting 18% (recycling programs, how organic, inorganic and toxic waste is managed and wastewater management),
4. water - weighting 10% (water conservation programs, water recycling programs, use of devices to reduce water intake),
5. transport - weighting 18% (percentage of parking areas in relation to campus area, transport services offered by the university, green transport programs),
6. education and research - weighting 18% (research for sustainability, events promoting sustainability, number of student organizations for sustainability).

For each indicator, the self-assessment must be documented, in the form of photos, videos or calculations based on the formulas indicated.

### 3. Results

According to the overall final assessment of sustainability of the UI GreenMetric, ten universities of the world are the leaders (Table 1).

**Table 1.**  
*Overall Rankings of sustainability of world's universities, 2021*

University	Country	Total Score	Energy and climate change	Education and research	Transportation	Waste	Setting and infrastructure	Water
1	2	3	4	5	6	7	8	9
Overall assessment to the highest number of points								
Wageningen University & Research	Netherlands	<b>9300</b>	1825	1800	1550	1800	1325	1000
University of Nottingham	United Kingdom	<b>8850</b>	1525	1650	1500	1800	1375	1000
University of Groningen	Netherlands	<b>8800</b>	1550	1525	1650	1800	1275	1000
Nottingham Trent University	United Kingdom	<b>8750</b>	1750	1750	1450	1800	1200	800
University of California, Davis	USA	<b>8750</b>	1650	1675	1450	1725	1300	950
Umwelt-Campus Birkenfeld (Trier University of Applied Sciences)	Germany	<b>8725</b>	1950	1600	1650	1500	1025	1000
Leiden University	Netherlands	<b>8700</b>	1825	1525	1650	1800	900	1000
University College Cork	Ireland	<b>8700</b>	1650	1700	1550	1650	1300	850
University of Connecticut	USA	<b>8700</b>	1500	1750	1475	1725	1250	1000
Universidade de Sao Paulo USP	Brazil	<b>8700</b>	1475	1600	1675	1650	1350	950

Source: based on the data from the UI GreenMetric ranking.

Wageningen University & Research University of Groningen, Leiden University (Netherlands) are in the first, third and sixth places, the second and fourth ranks are occupied by two UK universities – the University of Nottingham and Nottingham Trent University. According to the world sustainability rating, the University of California, Davis (USA) takes the leading fourth place, and the sixth position is taken by the University of Connecticut. The fifth position is occupied by Umwelt-Campus Birkenfeld (Trier University of Applied Sciences), a German university. Irish (University College Cork) and Brazilian (Universidade de Sao Paulo USP) universities round out the top ten best, sharing the sixth position, respectively.

Table 2 presents the assessment of world universities according to the indicator of sustainable energy use in 2021.

**Table 2.***Assessment of world universities according to the indicator of sustainable energy use, 2021*

University	Country	Total Score	Energy and climate change	Education and research	Transportation	Waste	Setting and infrastructure	Water
1	2	3	4	5	6	7	8	9
Assessment according to the indicator of sustainable energy use								
Umwelt-Campus Birkenfeld (Trier University of Applied Sciences)	Germany	8725	<b>1950</b>	1600	1650	1500	1025	1000
Luiss University	Italy	8475	<b>1925</b>	1550	1650	1500	950	900
University of Eastern Finland	Finland	8325	<b>1875</b>	1575	1300	1800	775	1000
University of Kashan	Iran	7725	<b>1875</b>	1375	1425	1275	875	900
Leuphana Universitat Luneburg	Germany	8525	<b>1850</b>	1650	1600	1575	1000	850
Wageningen University & Research	Netherlands	9300	<b>1825</b>	1800	1550	1800	1325	1000
Leiden University	Netherlands	8700	<b>1825</b>	1525	1650	1800	900	1000
University of Southern Denmark	Denmark	8675	<b>1825</b>	1600	1550	1725	975	1000
Universidad de Alcalá	Spain	8200	<b>1825</b>	1550	1375	1425	1175	850
Politecnico di Torino	Italy	8500	<b>1775</b>	1725	1600	1800	600	1000

Source: based on the data from the UI GreenMetric ranking.

However, according to the indicator of sustainable energy use, which is critical in the modern civilized world, universities have a slightly different distribution: here the leaders are: Germany (Umwelt-Campus Birkenfeld (Trier University of Applied Sciences), Leuphana Universitat Luneburg); Italy (Luiss University, Politecnico di Torino); Finland (University of Eastern Finland); Iran (University of Kashan), Netherlands (Wageningen University & Research, Leiden University); Denmark (University of Southern Denmark), Spain (Universidad de Alcalá). Most of these universities are European ones, except two universities in Iran and Brazil.

Based on the UI GreenMetric Ranking by Category 2021 – Energy and Climate Change this study explores the relationship between indicators regarding energy conservation and climate change estimations for world universities and their overall evaluation. Correlation-regression analysis was performed. The results of mathematical data processing are shown in Table 3. For the clarity of the data, a graph was constructed, and a trend line was drawn between the indicators under consideration, which are presented in Figure 1. The study summarizes the assessment of 956 universities in the world located in different countries.

Mathematical modeling and correlation-regression analysis are used to determine the dependence between the estimation of the universities regarding energy conservation and climate change and their overall evaluation (Table 3).

**Table 3.**

*Regression statistics and model values dependence between the evaluation of the world universities regarding energy conservation and climate change and their overall estimation*

Indicators	Results of modeling				
	df	SS	MS	Fisher's Cr. (F)	Significance F
Regression	1	2049810174	2135342.413	1960,570418	1,1064E-233
The rest	955	998468965,2	2408.077733	$F_{cr}$	3,851214
Total	956	3048279139		$t_{cr}$	1,962451136
Standard Error	t-Statistics		P-value	Coefficients	Upper 95%
6.936926579	22,82739144		2,17448E-92	$b_0 = 1980,969492$	2151,272
0.186223649	44,27832899		1,1064E-233	$b_1 = 3,646988304$	3,808626
Regression Statistics					
Multiple Correlation coefficient R			0,82002946		
Coefficient of determination R-square			0,672448316		
Adjusted R-square			0,67210533		
Standard error			1022,505375		
Cases			956		

Source: the authors' own calculation.

The choice of the analytical form of the model, which describes the dependence between the university indicators on energy conservation and climate change and their overall evaluation, is based on the constructed scattering diagram, which is a graphical representation of the selected statistical sample. This relationship is close to linear, so in this case, as a relationship between variables, it is advisable to choose a linear function. The linear regression function, in this case, will look as follows:

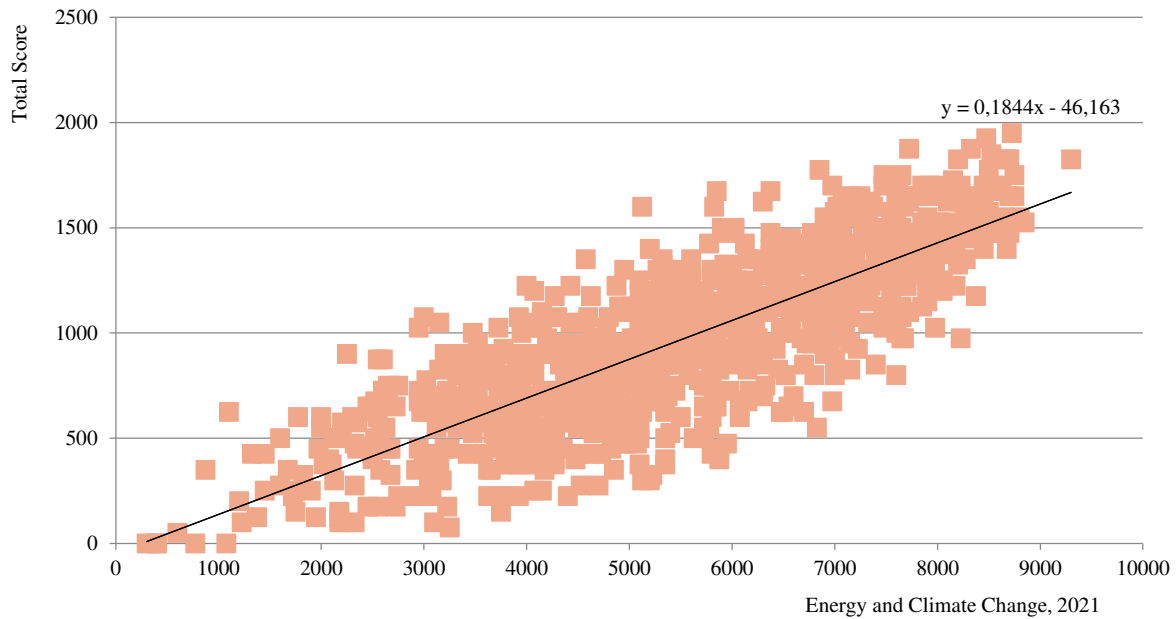
$$\hat{y} = b_0 + b_1 x \quad (1)$$

where  $\hat{Y}$  – an estimate of mathematical expectation of the dependent model variable (overall evaluation of a university);  $x$  – independent model variable (evaluation of the costs of universities for energy conservation and climate change);  $b_0$ ,  $b_1$  – selective regression parameters.

Accordingly, the model describing the dependence between indicators of universities regarding energy conservation and climate change and their overall evaluation is:

$$Y = 1980 + 3,65x \quad (2)$$

The indicators of universities on energy conservation and climate change and their overall total evaluation were used to determine estimates of the  $b_0$ ,  $b_1$  model parameters (Table 2).



**Figure 1.** The trend line for evaluating the university rankings regarding energy conservation and climate change in the overall system of the university sustainable development.

Source: calculated based on the data from the UI GreenMetric Ranking.

As it can be seen in the Figure, there is a linear relationship describing the data on energy conservation and climate change in the overall system of university sustainable development. A trend line between the investigated indicators is a linear function of the following form:

$$Y = 0,1844x - 46,163 \quad (3)$$

The verification of the model for adequacy, quality, and significance was carried out to check if the choice of the structure of the model to explore the link between evaluating universities based on indicators of energy conservation and climate change and their overall evaluation in the form of linear regression is correct. The determination and correlation coefficients are used to assess the quality of this model. The model statistical significance has been tested on the basis of Student and Fisher criteria.

To assess the adequacy of the model with statistical data, the value of this determination coefficient  $R^2$  is calculated (0,672). Since the value of the coefficient of determination  $R^2 = 0,672$ , the impact of evaluating the universities by indicators of energy conservation and climate change is quite significant. The strength of the linear relationship between the model variables is estimated using the correlation coefficient. Based on the value of  $R = 0,82$ , the close linear relationship between the indicators of the model is detected. The following F-statistics (Fisher's  $F$ -criteria) are used for verification:

$$F = \frac{R^2}{1 - R^2} \cdot \frac{n - k}{m} \quad (4)$$

which has a Fisher distribution with degrees of freedom  $\nu_1 = m$  i  $\nu_2 = n - k$ .



According to the statistical tables of Fisher's F-distribution at a given level of significance  $\alpha = 0.05$ , the critical value of Fisher's criterion  $F_{cr} = 3,851214$ . Since Fisher's criterion is  $F = 1960,570418$ , which is more than its critical value, the model is adequate and statistically significant. To determine the significance of the model parameters contributing to the overall statistical significance, t-statistics was used (Student's criterion):

$$t_{b_j} = \frac{b_j}{\hat{\sigma}_{b_j}}, \quad j = \overline{0, m} \quad (5)$$

where:

$b_j$  – estimation of the parameter  $\beta_j$  of the theoretical regression,

$\hat{\sigma}_{b_j}$  – standard error of the  $j$  parameter of the model.

According to the selected significance level of  $\alpha = 0.05$  and freedom degrees available in the statistical tables of the Student's  $t$ -distribution, the Student's criterion critical value  $t_{cr} = 1,962451136$  was found. The values of  $b_0 = 1980,969492$  and  $b_1 = 3,646988304$  exceed the critical value  $t_{cr} = 1,962451136$ , which also confirms the adequacy and significance of this regression model (Table 3).

The verification of the model of dependence between evaluating universities by energy conservation and climate change and their overall evaluation indicates the adequacy of the model and the existence of a close linear relationship between its variables, as well as the significance of the model as a whole and its parameters.

It is worth noting that the parameters of maintaining sustainability in the use and conservation of energy in order to reduce the negative effects of climate change reflect the general economic and social influence of universities on the regions where these universities are located, forming a positive image of the respectable area and its capacity for sustainable development. Availability of sufficient resources in the budgets of universities gives them the opportunity to develop their local community, to provide their residents with more diverse and quality services, not only educational, but also research, consulting, transport, information-structural, etc. In addition, the advantage of such sustainable universities is the ability to implement large infrastructure projects with significant investments and substantial social benefits, create conditions to attract investment capital and business development, form partnerships between the government, business and science, support other types of activities, research, economic development.

#### 4. Discussion and Conclusions

The work summarizes the assessment of 956 universities in the world located in different countries. The authors conclude that sustainable universities are the “business card” of local communities, and in the future, they will become the ground for the marketing strategy of their development and positive territorial image promotion.

The research determines an interrelation between the evaluation of universities by energy conservation and climate change and their overall total evaluation. The verification of modeling results indicated the adequacy of the model in terms of statistics and the existence of a close linear relationship between its variables, as well as the significance of the model as a whole and its parameters. The correlation coefficient is close to 1,0 and is 0,82. This means that 82% of the change in the annual evaluation of universities regarding energy conservation and climate change rate depends on their overall evaluation.

The value of the research lies in a multidisciplinary approach to substantiating the indicators of sustainable development of universities for the effective future socio-economic development of the regions where these universities are located. Such universities become centers of socio-economic and cultural development, allow to attract significant investments, create clusters and incubators of science, develop cooperation between business and government on legal grounds. In addition to the educational function, a modern university has many tasks and areas of activity – it takes care of the preservation of the environment and energy, is able to provide transport and consulting services for the population, build infrastructure facilities, form the foundations of ecological and economic security, and contribute to the formation of information environment.

The value of the research results is the improvement of the concept of sustainable development and the application of the tools of green economy at modern universities, which is the basis for the new global strategy of sustainable development of universities, increasing the level of socio-ecological and economic security of local communities, and revitalizing local economies.

Further research will deal with theories of university management known in world science, which will be supplemented by new concepts and approaches taking into account sustainable energy conservation and prevention of climate change in the world, formation of the economic value of a modern university as a cultural, educational, scientific and economic center.

We used the UI GreenMetric ranking, this presents a limitation. It is worth checking what criteria other rankings follow and comparing their results.

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## DROWNING PREVENTION EDUCATION IN POLAND AND THE ATTITUDES OF BATHERS

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**Purpose:** The article presents a comprehensive study of the attitudes of bathers within identifying potential challenges and opportunities as well as recommendations for the future of drowning prevention education.

**Design/methodology/approach:** The study employs literature analysis, tabular comparisons, and questionnaires of bathers. The approach for the research was based on a desktop evaluation of accessible information, statistics, and other data from international and sources. The qualitative data acquired from self-research was used in the statistical analysis. The research group had 314 respondents, and the research was scheduled for the summer vacation season of 2021.

**Findings:** Parallels exist in governance and policy alignment, while disparities are evident in economic development and sectoral priorities. These findings offer a nuanced understanding of shared traits and distinct differences shaping the business landscapes and economic paths of these Central European nations.

**Research limitations/implications:** The research has limitations, such as its specific timeframe and omitted variables.

**Practical implications:** Practical implications extend to i.a. the need of implementing effective prevention programs (level 1 prevention) of safe behavior on the water and include this from the municipal level through the regional and national levels and introducing of a multi-year, unified national program of education and behavior in water areas, will increase the swimming skills of all age groups and reduce drowning.

**Social implications:** The study suggests indicating systemic measures aimed directly at people enjoying water activities, with educational activities playing the most important role in eliminating the so-called "low swimming culture," which manifests itself in a lack of basic knowledge of the specifics of the water area used for swimming and the swimming skills possessed.

**Originality/value:** The uniqueness of this research lies in the development of a technique to survey bathers' sentiments via an innovative, self-developed questionnaire mobile application, which allowed the interviewer to conduct the survey on a mobile device and independently by the tourist after receiving a link or scanning a "QR code". The research findings are applicable

to both academic discourse and practical implementations, providing unique insights to foster collaboration and development within policymakers' institutions and organizations.

**Keywords:** Swimming, drowning, water rescue, drowning prevention, recreation, bathers, Poland.

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

## 1. Introduction

Drowning is a global public health challenge (Leavy, Gray, Della Bona et al., 2023) and it is recognized as one of the top causes of unintentional injuries and a leading cause of injury-related deaths in many countries, including Poland (Turgut, Yaman, Turgut, 2004).

Drowning prevention is a tough and diverse public health concern that necessitates local, national, and worldwide actions (Leavy et al., 2016, Leavy et al., 2015). Preventive activities, specifically drowning prevention education, are characterized in the literature as a set of planned and timed actions targeted at causing subject changes with the goal of producing a specified consequence. such example of such activity is the teaching of first aid in schools, the goal of which is to improve the status of safety in a given area or social group through improved awareness and education. The essence of this form of activity is the subject's intention, which he chooses to achieve a specific goal (Adamczyk, 2020; Zalewski, Sikora, Czapiewski, 2021). Subject organizations, particularly the Water Volunteer Rescue Service of the Zachodniopomorskie Voivodeship, (*Zachodniopomorskie Wodne Ochotnicze Pogotowie Ratunkowe, org.*), pursue their purpose of improving safety in Poland through a system of rescue, preventative, and prophylactic actions. The work of WOPR WZ is focused on achieving the main aim stated in the organization's statute by coordinating aid and preserving people's lives or health in water areas. Statutory preventative tasks are carried out in preventive financial and educational programs involving the understanding of the risks connected with the usage of water areas, particularly through educational campaigns among children and young people. In Poland, the legislator defines the profile of preventative activities in Article 4 of the Act of August 18, 2011 on the protection of persons residing in water areas (Sikora, 2020; Adamczyk, 2023; Ustawa..., 2011). Within the context of statutory activities, the tasks outlined in the Act are assigned to water area managers as well as WOPR WZ economically. Taking the challenges posed by the legislator and the organization into account, the purpose of this article was defined as analyzing the profile of people using bathing beaches in the West Pomeranian region in the context of outreach and the effectiveness of preventive water education activities (Adamczyk, 2020; Zalewski, Sikora, Czapiewski, 2021). The obtained results are a probe to profile the people who use the bathing beaches and to identify the locations and social groups that are

subject to insufficient preventive measures and are vulnerable to the occurrence of a life-threatening event (WHO, 2023).

By rearranging preventive actions so that they are targeted to audiences from risk categories, a holistic approach to the issue and application of conducted results into organizational activities can improve the condition of security in Poland. Moreover, it emphasizes the need of building strong alliances and global governance to support multisectoral and intersectoral action for drowning prevention (Jagnoor, Kobusingye, Scarr, 2021).

The study's findings also contribute to future discussions about the cooperation of socioeconomic environment actors, quadruple helix model actors in the implementation of drawing prevention education, and the development of a type of social capital aimed at the formation of social networks of drawing prevention education actors (Zakrzewska, 2016).

## 2. Literature review and research gap

Preventive initiatives carried out by Polish services aim to raise community awareness and prevent situations that endanger human health and life. Each socioeconomic entity (e.g., the police, fire department, entities allowed to perform water rescue) that has this type of activity as part of its statutory and regulatory obligations disseminates knowledge within the scope specified for the service. The Water Volunteer Rescue Service of the Zachodniopomorskie Voivodeship is one nity in the West Pomeranian Voivodeship that plans, coordinates, and reports on initiatives to promote water safety. This entity's primary instructional tasks include issues such as drowning and sudden cardiac arrest (SCA). According to the World Health Organization (hereafter WHO), drowning is one of the most prevalent causes of unintended injury or loss of life, accounting for up to 7% of all deaths. Poland, like the United Kingdom and France, has a system in place to ensure maritime safety. Despite this, Poland has a drowning rate of 2.1 incidents per 100,000 inhabitants, placing it between highly developed countries that provide water safety and poorly developed countries that do not. The ease of access to unsecured bodies of water along the Baltic coast and on inland seas is one element in occurrences. Everyone involved in water tourism is responsible for ensuring safety by reducing the likelihood of an incident (taking care of equipment, reporting the outing, planning the activity - observing the route, meteorological conditions, ensuring communication) and its consequences (providing vests, rescue equipment, weather listening, communication, as well as training in operating a craft and first aid) (Zalewski, Sikora, Czapiewski, 2021; Ustawa..., 2011; Yusuf, Hawken, Ounpuu et al., 2004). After reviewing the literature and assessing the operations of worldwide organizations and educational organizations with a similar profile to WOPR WZ, it is vital to highlight the relevant

correlations by presenting the primary activities that comprise a chain of water safety in Poland, namely:

- prophylaxis (first-degree prevention) - actions taken prior to the implementation of the proper water activity, preparing participants and the location for its safe implementation.
- prevention (level II prevention) - actions taken during the implementation of water activities, based on rescue supervision and countermeasure interventions and active events; and
- rescue - rescue and search actions undertaken in the event of an emergency event (Zalewski, 2017).

Although the problem of drowning in the context of preventive measures is widely discussed by authors of the world literature on an annual basis, only few publications on the subject of research and on the subject of correlation of profiles of people using bathing beaches and organization of preventive measures of services ensuring the safety of people in water areas have been found for Poland (Zalewski, Sikora, 2020).

### **3. Conducted research – methodology and research group**

For the purposes of this study, the analysed region of the West Pomeranian region compared to Poland is identified with each of the sixteen existing regions in accordance with the Nomenclature of Territorial Units for Territorial Statistics (NTS) in force in Poland, prepared based on the European Nomenclature of Territorial Statistics Units (NUTS) (Zalewski, Sikora, Czapiewski, 2021). The region included in the study is of size corresponding in this classification to the NUTS 2 level as a unit of the administrative division of the second-level country, as indicated by many authors (Korenik, 1999; Strahl, 2005; Paradysz, 2012).

The research methodology was based on a desktop-based review of available information, statistics, and other data from international and sources (Embase), reports and publications of the European Environment Agency (EEA), and reports of Poland's Chief Sanitary Inspector. The statistical analysis was carried out using qualitative data gathered through self-research. The research time frame was scheduled for the summer vacation season of 2021.

The quantitative study's goal was to examine the profile of people who use aquatic places as well as the functional capacity of the perception of water safety in an aquatic area, allowing us to define the decision-making elements for selecting a bathing area. The research was carried out using a unique, self-developed questionnaire mobile application. The preparation of a survey in the form of a web application allowed the interviewer to conduct the survey on a mobile device and independently by the tourist after getting a link or scanning a "QR code". The first three questions included respondents' preferences and choices in terms of the kind of swimming locations they used. The next four questions included swimming abilities and water



survival skills, as well as the predicted degree of swimming ability among the public. The eighth and ninth questions examined the regularity with which people spent time at Polish beaches and the kind of activities they did during that time. The final two questions were analyzing personal emotions of safety during water tourism and the Polish water safety system.

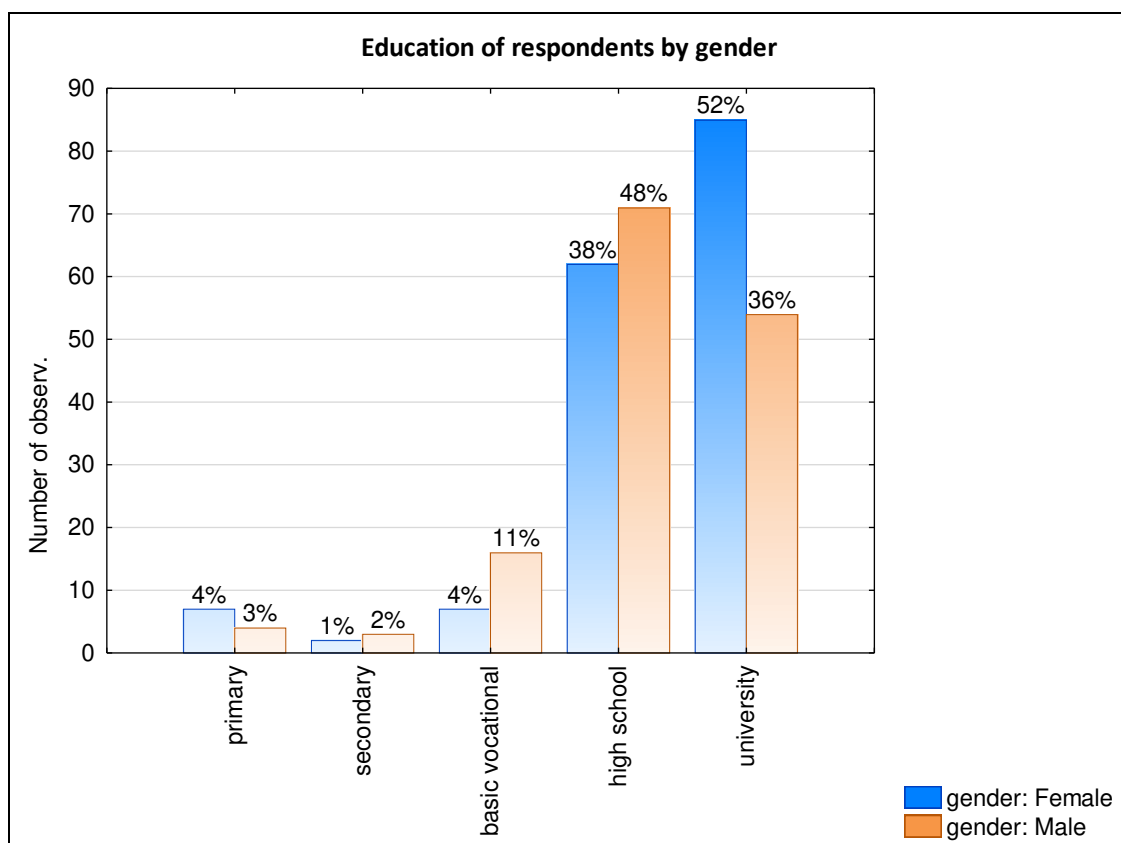
The research group included people staying on the beaches of the West Pomeranian region in the towns of: Międzyzdroje, Kołobrzeg, Jarosławiec, Stępnica, Szczecin, Szczecinek, Stargard, and Czaplinek. As a result, the research group consisted of 314 respondents who completed the questionnaire, 3 of whom were eliminated owing to incompleteness or deceptive responses (3 participants stated their age as 1 year).

The study included 163 women aged 16 to 73 and 148 men aged 17 to 76 (Table 1). In terms of education, the majority of respondents had a secondary or higher education (Figure 1).

**Table 1.**  
*Age distribution of respondents*

Variable	Gender	Valid surveys	Minimum	Maximum	Bottom quartile	Upper quartile
Age	Women	163	16	73	35	49
Age	Men	148	17	76	30	50

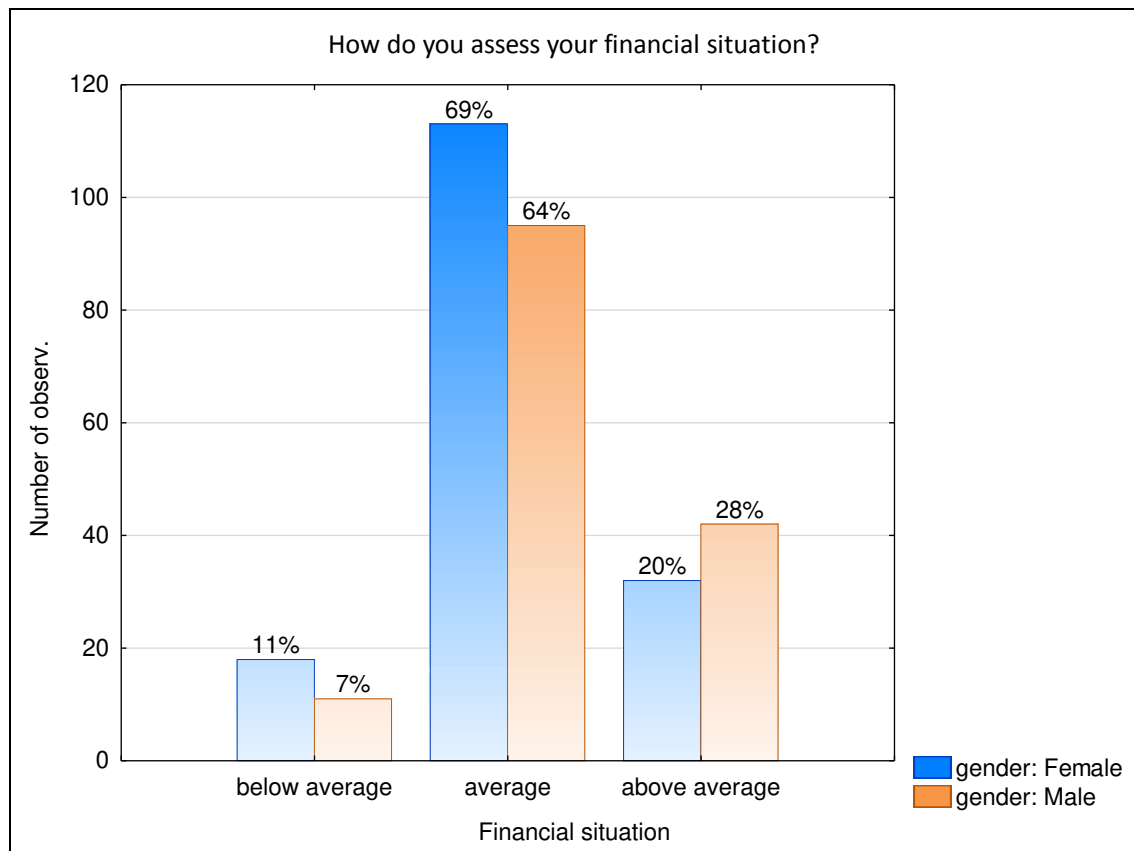
Source: Authors' own research.



**Figure 1.** Research group, variable: respondent education level, gender.

Source: Authors' own research.

In terms of respondents' material situations, they largely classified it as ordinary, one in five respondents thought it was above average, and only a small percentage believed it was below average (Figure 2).



**Figure 2.** Respondents' financial situation.

Source: Authors' own research.

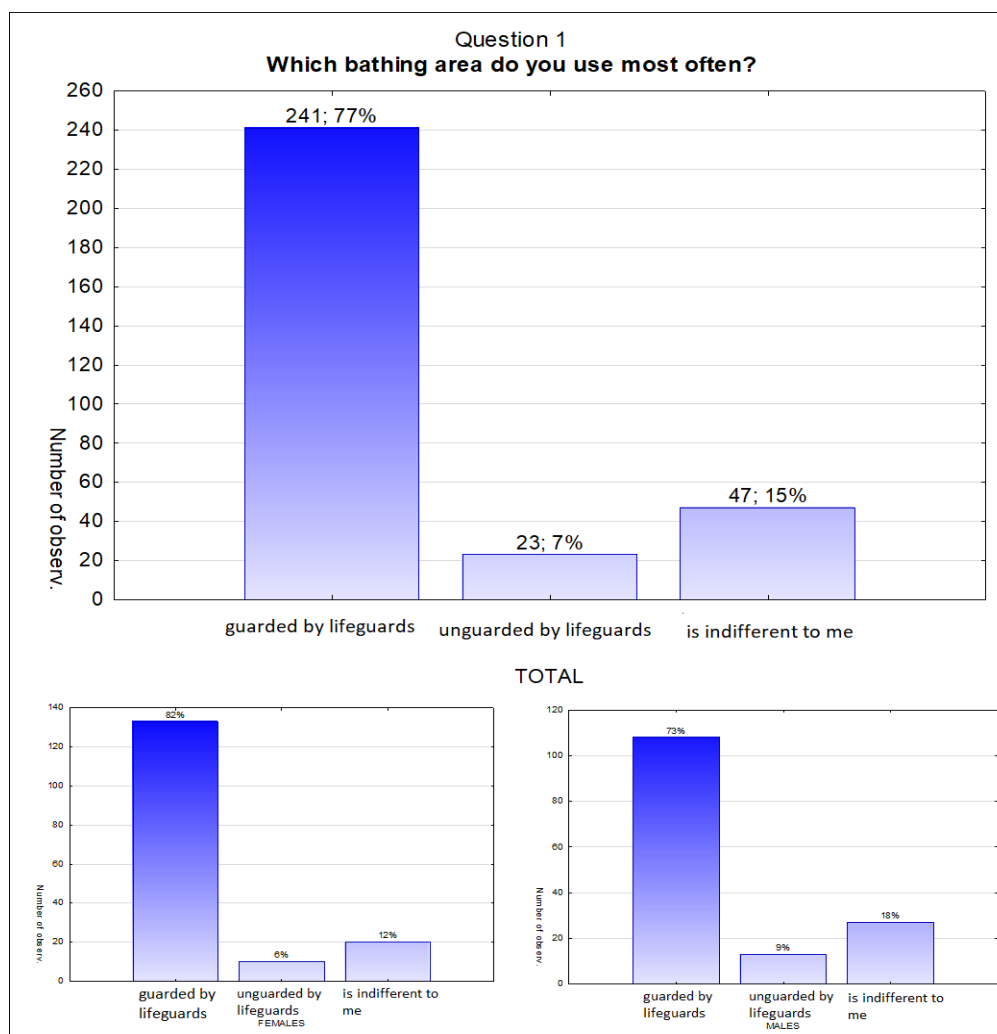
#### 4. Research results considering bathing area

Taking into account the responses to the question "Which bathing site do you use the most often?" 77% of respondents stated they prefer to bathe at a lifeguarded beach, 7% prefer unsecured beaches, and 15% said they were indifferent. Respondents' choice of bathing locations was not influenced by their level of education. Men utilize safe bathing sites less frequently (72%) than women (82%), and they are more likely to pick unguarded locations (9%) or none at all (Table 2, Figure 3).

**Table 2.**  
Answers to the question "Which swimming area do you use?"

		Education				
		basic	middle school	basic vocational	average	higher
Which swimming area do you use most often?	guarded by lifeguards	7	4	16	108	106
	% from column	64%	80%	70%	81%	76%
	Unattended	1	1	2	9	10
	% from column	0%	20%	9%	7%	7%
	it is indifferent to me	3	0	5	16	23
	% from column	1%	0%	22%	12%	17%
Total		11	5	23	133	139

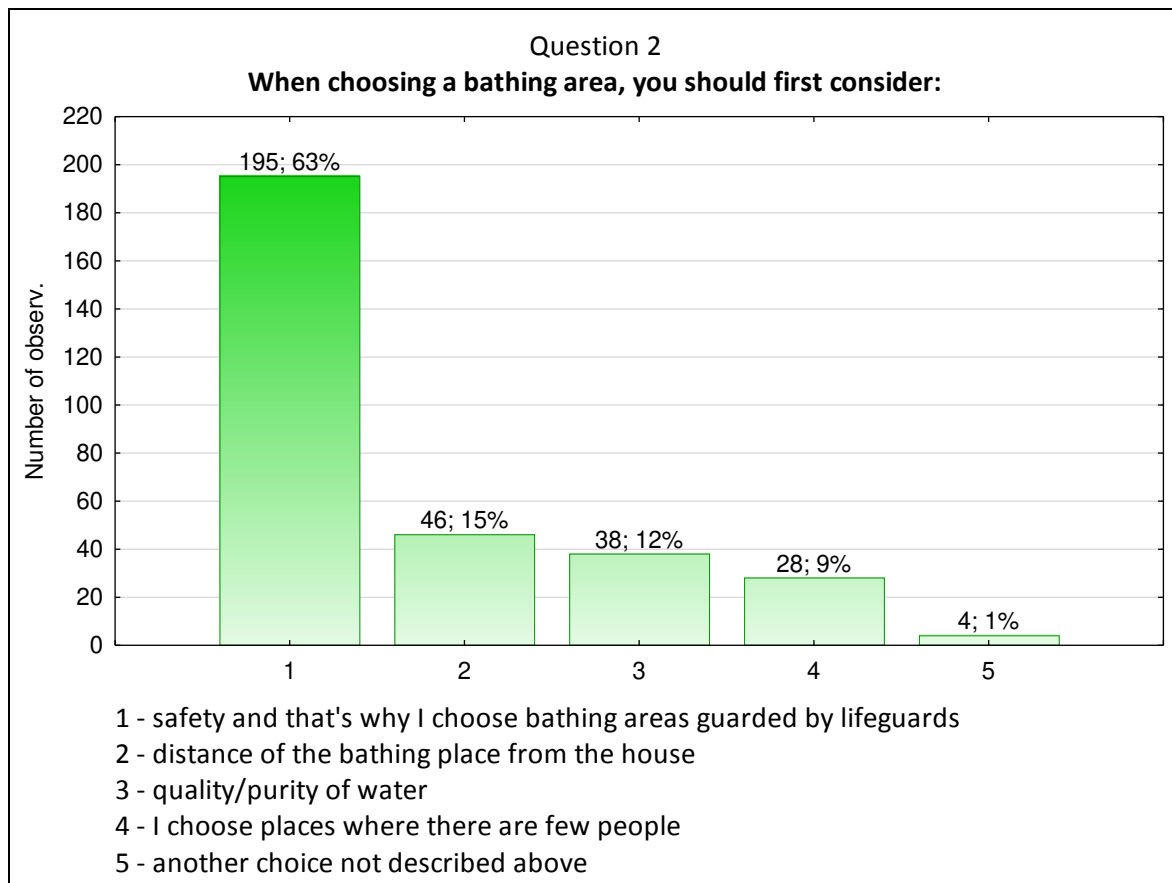
Source: Authors' own research.



**Figure 2.** Respondents' answer to the question "Which swimming equipment do you use?".

Source: Authors' own research.

According to the study, while selecting the water's spot, respondents are guided by safety, preferring bathing areas guarded by lifeguards (63%). Other respondents, on the other hand, are often guided by distance from home (14%), cleanliness and water quality (12%), or choosing bathing areas with few people (9%) (Figure 3).



**Figure 3.** The answers given by respondents to the question: What is your primary consideration when selecting a swimming area?

Source: Authors' own research.

Despite the fact that more than 75% of respondents indicate they prefer secured bathing areas, only 43% claim they never use unguarded bathing areas. Only little more than a third of men (35%) use unsecured bathing areas, while half of women (50%) do. Those who choose to bathe where there is no lifeguard, on the other hand, most often tell someone to swim out or go with another person (47%), plunge into the water calmly exploring the bottom and potential dangers (43%), or use an individual means of belay, e.g., buoy, float, wheel, foam, etc. (26%) (Table 3).

**Table 3.**

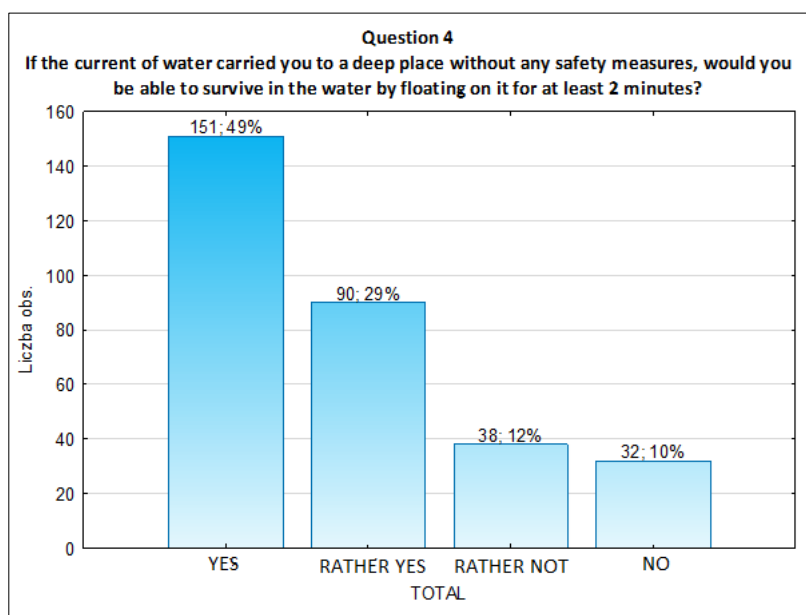
*Answers to the question: When you use an unguarded swimming site...?*

When you bath in an unguarded place is:	Women	Men	Total
I do not use unguarded places	81 50%	52 35%	133 43%
I'm informing someone to go out or I'm going with someone	63 39%	82 55%	145 47%
I have an individual means of belay (buoy, float, wheel, foam, other)	29 18%	51 34%	80 26%
I plunge into the water calmly studying the bottom and possible dangers	60 37%	73 49%	133 43%

Source: Authors' own research.

## 5. Research results considering swimming skills

Analyzing respondents' basic swimming skills<sup>1</sup>, data analysis shows that nearly 50% of respondents confirmed that they could survive floating in the water for at least 2 minutes in a situation when the water current carried them to a deep place without any means of belaying, and another 29% were fairly certain of this. Only 38% answered they would rather not hang on for such a long period of time without a belay in deep water, and 10% were certain they would not be able to cope (Figure 4). On the contrary, the results suggest that men are significantly more confident in the water, with as many as 63% of them secure in their abilities, compared to only 36% of female respondents. Figure 5 shows that 33% of women would prefer or definitely not be able to float 2 minutes without belay in deep water, but only 11% of males agree (Figure 4).

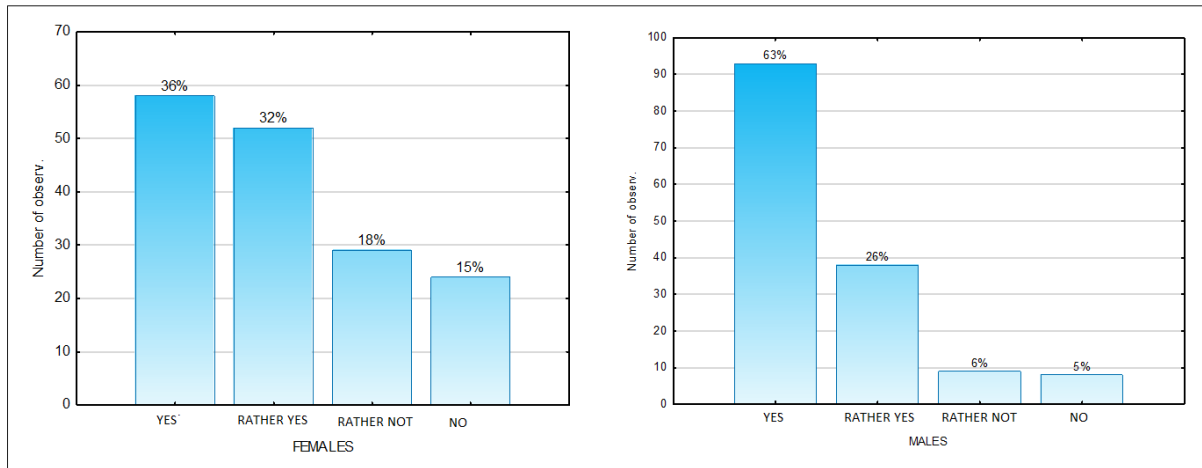


**Figure 4.** The answers given by respondents to the question: If the current of water...

Source: Authors' own research.

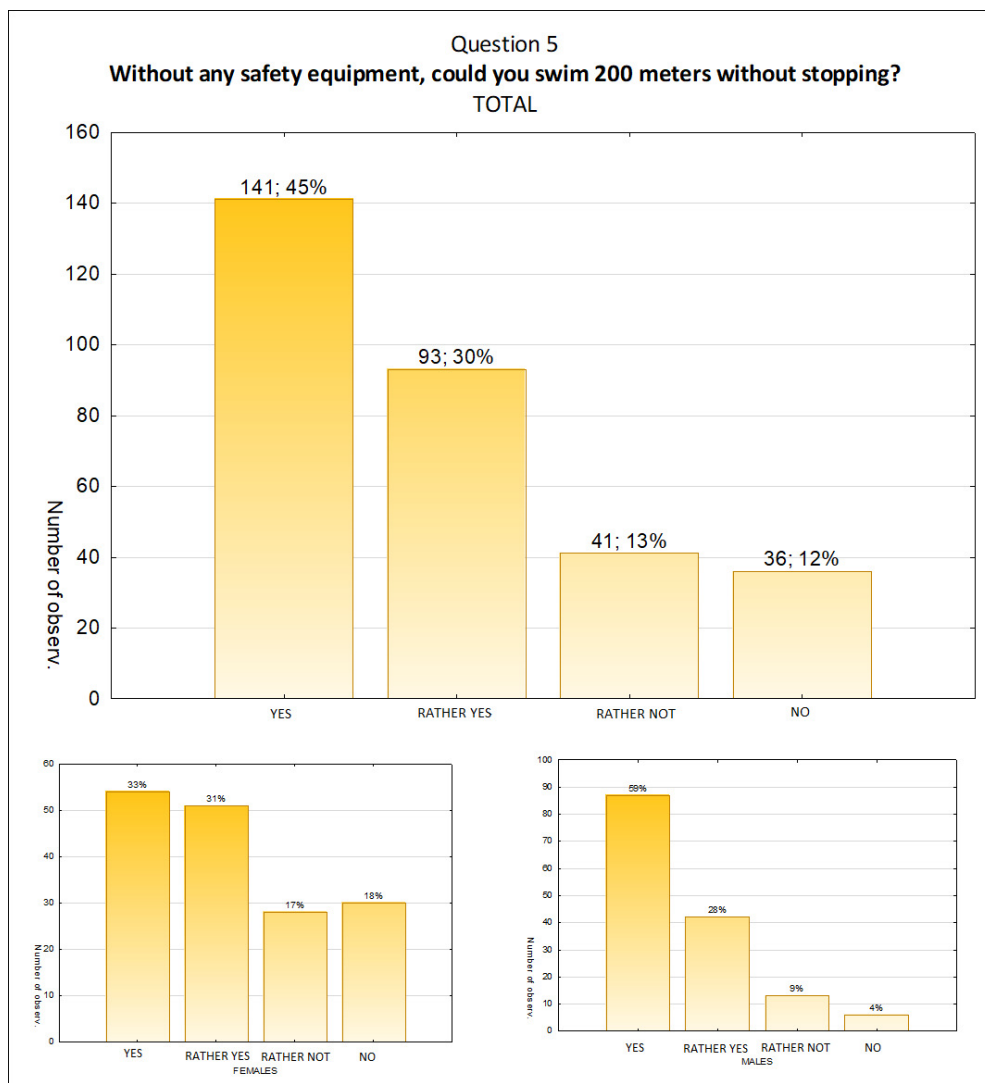
On the contrary, the results suggest that men are significantly more confident in the water, with as many as 63% of them secure in their abilities, compared to only 36% of female respondents. Figure 5 shows that 33% of women would prefer or definitely not be able to float 2 minutes without belay in deep water, but only 11% of males agree (Figure 5).

<sup>1</sup> The authors consider that basic swimming skills comprise swimming 100 meters without using flotation devices and without pausing.



**Figure 5.** The answers given by respondents to the question: If the current of water... variable: gender.  
Source: Authors' own research.

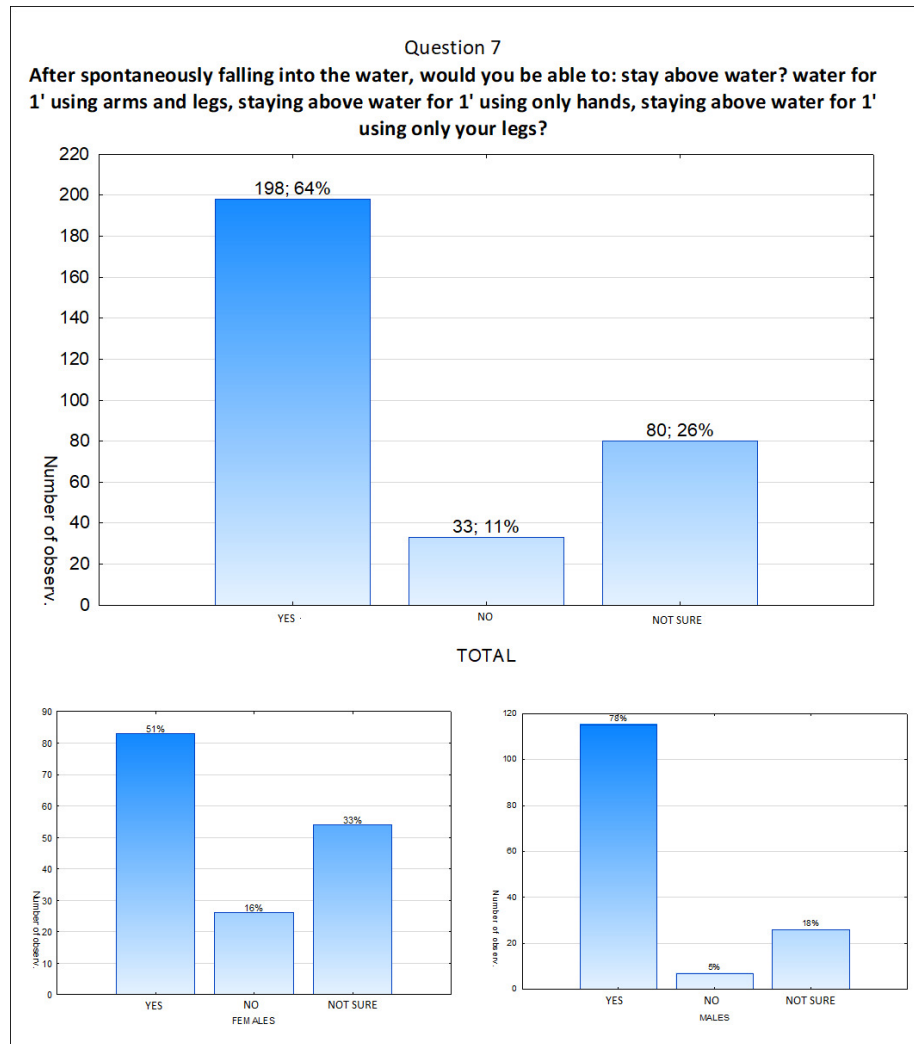
As it comes to basic swimming skills, respondents are slightly less confidence if they have to swim 200m without help without stopping. According to the respondents, 45% would easily cross such a distance, and 35% are fairly certain, with a total of 87% of male respondents and 64% of female respondents. Women are far more likely to indicate they would prefer not be able to swim such a distance (17%) or that they are certain (18%). Men who would prefer not to swim 200m without pausing, on the other hand, account for 11% of the total (Figure 6).



**Figure 6.** The answers given by respondents to the question about their swimming confidence.

Source: Authors' own research.

Simultaneously, respondents were asked whether they could stay afloat for 1 minute using their arms and legs, stay afloat for 1 minute using only their arms, or stay afloat for 1 minute using only their legs after spontaneously falling into the water. Such abilities are claimed with certainty by 64% of those polled, including 78% of men and 51% of women. Among women, one-third are unsure whether they could stay afloat for a minute in the aforementioned fashion, while 16% are certain they could not. In terms of such abilities, 18% of the males polled are unsure, and 5% are certain they do not have them (Figure 7).



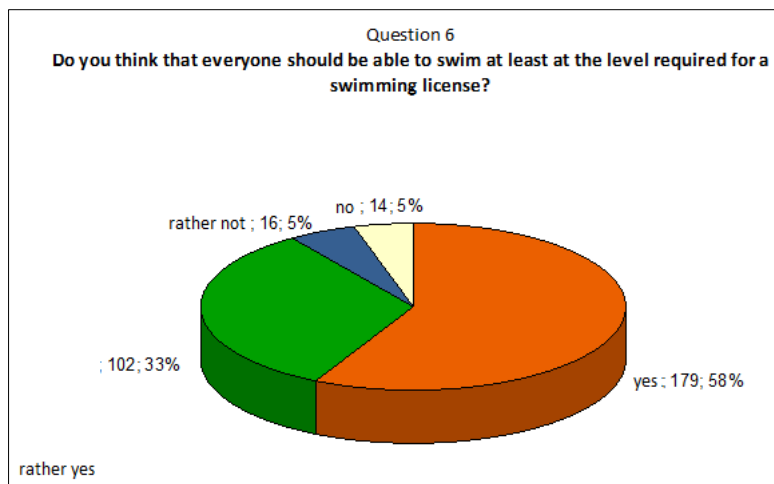
**Figure 7.** The answers given by respondents to the question about their swimming confidence after spontaneously falling into the water.

Source: Authors' own research.

According to the findings of the research, it was also interesting to examine respondents' attitudes toward the requirements of the so-called Swim Card - a document certifying the ability to swim<sup>2</sup>, i.e. whether they believe everyone should be able to swim at least at the level required for the Swim Card. Moreover half of those polled (58%) replied "yes," with an additional 33% strongly convinced. Only 10% of those polled felt that this level of swimming is not appropriate for everyone (Figure 8).

<sup>2</sup> A Swim Card can be acquired by passing an exam that includes: a) swimming 200 meters in standing water in any direction and at any time, including at least 50 meters in the backstroke, b) jumping into the water from a height of at least 0.7 m, c) swimming at least 5 meters beneath the water's surface in standing water, beginning at the water's edge.





**Figure 8.** Respondents' attitudes toward the requirements of the so-called Swim Card.

Source: Authors' own research.

## 6. Research results considering frequency and the type of water activity

Respondents were also questioned how often they spent time on the water and what activities they did in Polish water regions in the previous year. Only 10% of respondents spend at least once a week on the water (5% of women and 15% of men), while another 10% do so at least once a month (7% of women and 12% of men). Respondents say they are more likely to spend a dozen (43%) or several (37%) days each year on vacation. (Table 4).

**Table 4.**

*Responses to the question: How many days do you spend your free time on the water in a year?*

How many days a year do you spend your free time on the water?						
	women		men		total	
regularly at least once a week	8	5%	22	15%	30	10%
regularly at least once a month	12	7%	18	12%	30	10%
several days a year	83	51%	53	36%	136	43%
a few days a year	60	37%	55	37%	115	37%
TOTAL	163	100%	148	100%	311	100%

Source: Authors' own research.

Respondents most frequently bathe at guarded bathing beaches (68%), with 75% of women and 68% of males doing so. In contrast, 23% of respondents bathe in wild beaches, with women bathing at half the rate of men. Kayaking is a common pastime among responders. This pastime is undertaken by 20% of respondents, however men (28%) are more inclined to do it than ladies (13%). Fishing is another sport that is far more popular among men, with 16% of them participating compared to 7% of female respondents. Sailing, on the other hand, is practiced by approximately 9% of those polled. Women (9%) and men (10%) both like sailing. Rowing

(including rowing tourist boats, pedal boats, and other watercraft) is popular with both sexes, with 8% participating. Scuba diving (4%), windsurfing (4%) and kitesurfing (2%) are among the less popular water activities (Table 5).

**Table 5.**

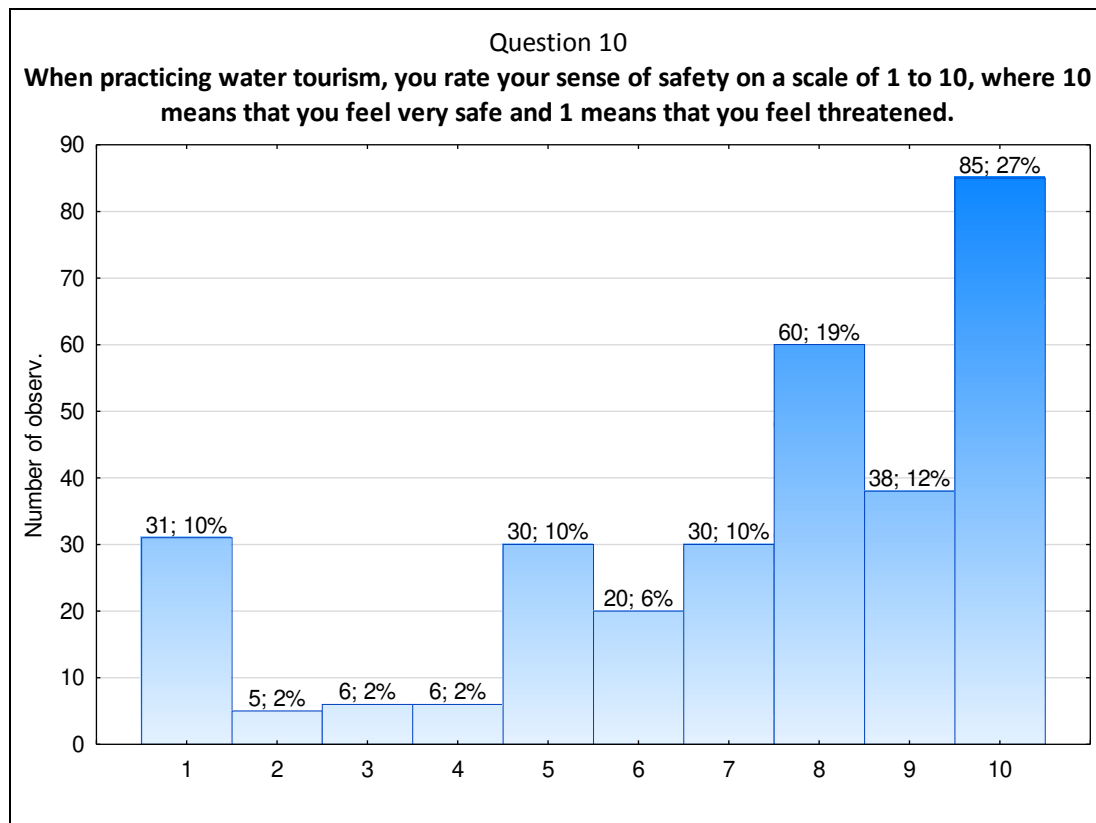
*Respondents' answers to the question: During the past year, I have carried out the following activities in Polish water areas*

During the past year, I have carried out the following activities in Polish water areas:						
	women		men		total	
bathing in guarded swimming areas	122	75%	90	61%	212	68%
swimming on wild beaches	26	16%	46	31%	72	23%
windsurfing	5	3%	8	5%	13	4%
kitesurfing	3	2%	4	3%	7	2%
sailing	14	9%	15	10%	29	9%
Motor boating (motor boats, scooters, jet skis, other craft pulled behind a motorboat)	0	0%	0	0%	0	0%
fishing	11	7%	24	16%	35	11%
kayaking	21	13%	41	28%	62	20%
rowing (including rowing tourist boats, pedal boats, other watercraft)	12	7%	13	9%	25	8%
scuba diving	6	4%	7	5%	13	4%
other	8	5%	14	9%	22	7%

Source: Authors' own research.

## 7. Research results considering sense of security

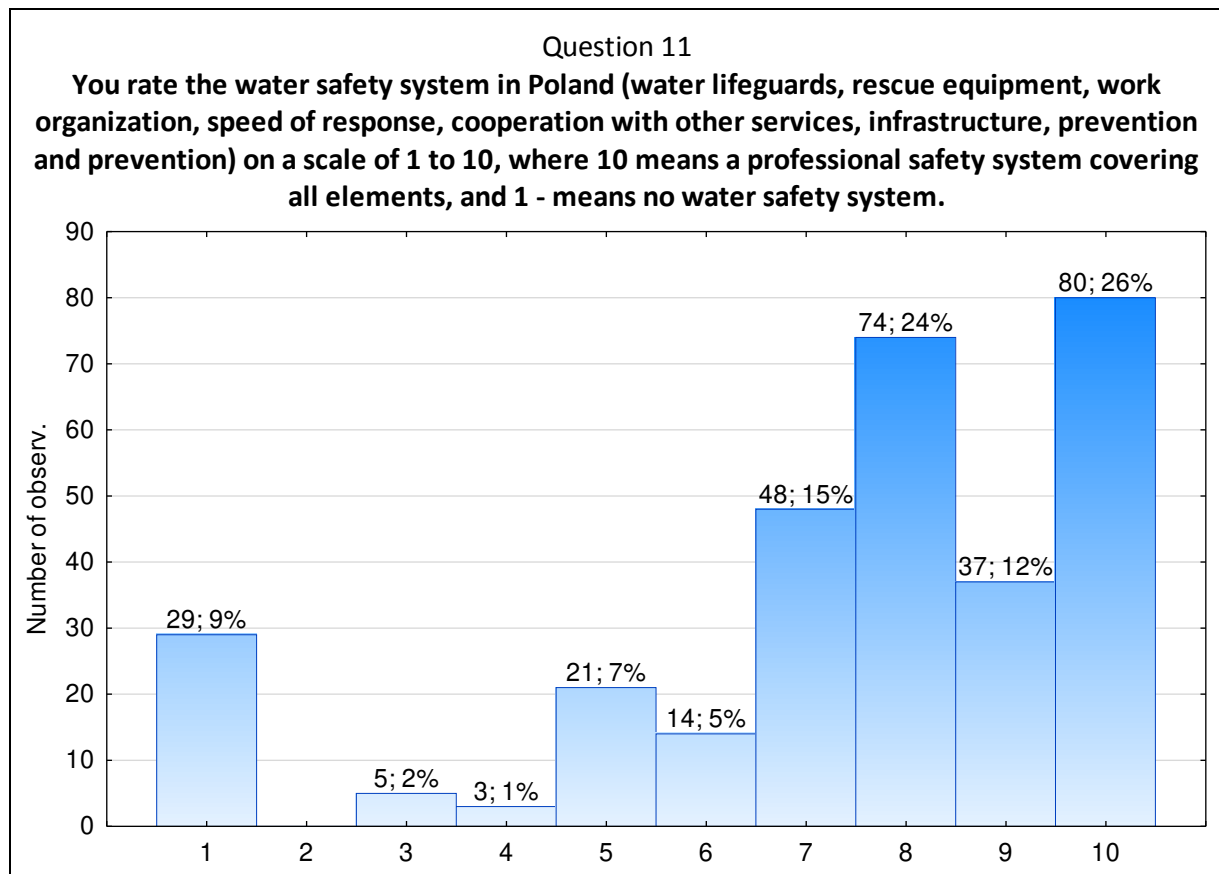
On a scale of 1 to 10, respondents were asked to rate their degree of safety when participating in water tourism, with 1 indicating that they felt endangered and 10 indicating that they felt very safe. Almost half of the respondents (48%) assessed their own sense of safety on the water as at least 8, indicating that they feel safe on the water, with 10% feeling very safe. 10% of respondents reported feeling uncomfortable on the water, with 16% rating it at or above 4 (Figure 9).



**Figure 9.** Respondents' attitudes toward their sense of security.

Source: Authors' own research.

Those interviewed also rated Poland's water safety system (water rescuers, rescue equipment, work organization, response time, collaboration with other services, infrastructure, prevention, and education) on a scale of 1 to 10, with 1 indicating no water safety system and 10 indicating an existing professional water safety system. 16% of respondents assessed the safety system as inadequate, while 62% regarded it as good or even professional (26%) (Figure 10).



**Figure 10.** Residents' assessment on Poland's water security system.

Source: Authors' own research.

## 8. Conclusions and findings

As a result of surveys on the demographics of those who use aquatic places and the usefulness of the perception of water safety in an aquatic area, authors have interpreted the data as follows:

- the frequency of staying at the water is related to the fact that staying on the water is a type of vacation spent,
- men are more likely than women to engage in various water activities,
- while the majority of respondents claim that they would definitely swim a distance of 200 m without stopping, not everyone believes that everyone should be able to swim at least the level required for a swimming card. 72% of this group agrees, while 21% are not convinced. At the same time, 7% do not expect similar abilities from others,
- among those who are unsure if they would be able to swim 200m without stopping, 43% are certain that society should be able to swim at the swimming card level, while 48% are less convinced,

- those who believe they would rather not swim 200m would prefer (41%) or are quite sure (49%) that others should swim well. This is also the assumption of 78% of those who stated that they could not swim 200m without assistance.

Furthermore, one of the primary methodological findings from the research is that education in the field of drowning prevention in Poland, as well as the attitudes of people who use water areas, provide material for investigating this phenomenon on a national basis. The research and analysis allowed for the creation of a profile of people who engage in water activities, as well as the functional ability to perceive their own safety in an aquatic setting.

Taking into account the practical findings from the research, the author made an attempt to recommend the following:

- implement effective prevention programs (1st level prevention) of safe water behavior from the municipal to the regional and national levels.
- the implementation of a multi-year, comprehensive national program of water education and behavior will improve swimming skills in all age groups and minimize drowning.
- education on the principles of water behavior for adults over the age of 50 who are at high risk of drowning, especially because their physical fitness is limited and their body's capacity may be lowered.

It is recommended to implement systemic measures aimed directly at people participating in water-related activities, with educational activities playing the most important role in eliminating the so-called "low swimming culture," which manifests itself in a lack of basic knowledge of the specifics of the water area used for swimming and the swimming skills possessed.

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## CULTURAL ASPECTS OF THE USE OF TRADE CREDIT

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**Purpose:** This paper aims to (1) provide insight into the cultural issues of the use of trade credit, focusing on the links between trade credit and trust, religion, and national culture, and (2) suggest potential directions for future research in this area.

**Design/methodology/approach:** A literature review was conducted to identify the key cultural issues addressed in previous studies on trade credit and to summarize the research on the use of trade credit in three focus areas: trust, religion, and national culture.

**Findings:** A literature review confirms that cultural factors, such as trust, religion, and national culture, play crucial roles in the provision and receipt of trade credit. Therefore, future research on trade credit should adopt a more comprehensive approach that extends beyond a purely financial perspective.

**Research limitations/implications:** This review does not address all potential cultural factors that may impact the use of trade credit. In addition, the review is constrained by the limited research conducted in this area and the heterogeneity of the studies analyzed.

**Practical implications:** Given the significance of trade credit in business operations, a thorough understanding of its cultural underpinnings can prove vital for the parties involved in a trade credit agreement.

**Originality/value:** Despite the crucial importance of trade credit for companies and the extensive research devoted to it, the cultural dimension of its use remains an underexplored field. This article addresses this issue by providing an overview of the current state of research on trade credit concerning three cultural aspects: trust, religion, and national culture. Furthermore, the article outlines several potential directions for future research in the subject of the study. The article's subject matter falls within the expanding domain of culture and finance.

**Keywords:** trade credit, trust, religion, national culture, ethics.

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

### 1. Introduction

Trade credit occurs when a supplier delivers goods to a customer for which the customer does not pay immediately but promises to pay later (Wu, Firth, Rui, 2014; Chen et al., 2020).

Trade credit is ubiquitous worldwide (El Ghouli, Zheng, 2016) and used in multiple industries (Boone, Kurtz, Berston, 2019) and by companies of all sizes (Cowton, San-Jose, 2017). It is a permanent feature of market transactions and an important source of short-term financing (Seifert, D., Seifert, R.W., Protopappa-Sieke, 2013). For many firms, trade credit is vital to their operations (Atanasova, 2007; Cheng, Pike, 2003). The literature emphasizes the considerable importance of this source of business financing for smaller firms (Moro, Belghitar, Mateus, 2021; Peel, Wilson, Howorth, 2000; Van Horne, Wachowicz, 2008) and in particular for growing firms that encounter difficulties in accessing financing from institutional lenders (Wilson, Summers, 2002).

Research on trade credit is the subject of several reviews. For example, Paul and Boden (2008) synthesize research on the supply of trade credit. Del Gaudio, Porzio, and Verdoliva (2018) review the literature on trade credit with a particular focus on the SME environment. D. Seifert, R.W. Seifert, and Protopappa-Sieke (2013) analyze in detail four strands of literature on trade credit, including trade credit motives, order quantity decisions, credit period decisions, and settlement period decisions. Pattnaik et al. (2020) provide an overview of trade credit research's state-of-the-art by examining 1191 papers published from 1955 to 2019.

Culture is among the most critical factors influencing business decisions (Goodell et al., 2023). According to Bedendo, Garcia-Appendini, and Siming (2020), a manager's cultural background significantly affects the financing structure of firms. So far, empirical research on trade credit has especially covered such cultural aspects as trust (e.g., Wu, Firth, Rui, 2014; Levine, Lin, Xie, 2018; Xu et al., 2023), religion (e.g., Cao et al., 2019; Chen et al., 2020; Li, Zhu, 2021), and national culture (e.g., El Ghouli, Zheng, 2016; Moro, Belghitar, Mateus, 2021; Hoang et al., 2023). Despite the apparent interest in trade credit, there is a lack of studies that synthesize dispersed research on the cultural issues related to this financial tool.

As Guiso, Sapienza, and Zingales (2004) note, financial contracts depend not only on the legal enforceability of contracts but also on the degree to which the financier trusts the financed party. Offering trade credit requires trust that it will be repaid in the future (Johnson, McMillan, Woodruff, 1999). The payment situation related to trade credit is an example of a "trust situation" (Tammi, 2013, p. 315). Like other financial agreements, trade credit requires trust, one of the fundamental cultural issues in the economics and finance literature (Xu et al., 2023). Although trade credit is the informal source of financing (Cao et al., 2019), its providers, just like institutional lenders, are exposed to the future risk of default by their customers. As a result, people's belief plays a prominent role in trade credit decisions (Chen et al., 2020).

Religion is one of the crucial dimensions of culture (Barro, McCleary, 2003). Religiosity is recognized as an important element impacting ethical norms and judgments (Vitell, 2009). The literature supports a positive relationship between the predominant religiosity of a firm's environment and its ethical behavior (Cai, Shi, 2019). By fostering an atmosphere of good faith among the parties involved, religiosity helps to promote informal finance (Cao et al., 2019).



Research on the cultural aspects of trade credit also pays attention to the effect of national culture on the variation across countries in providing and receiving trade credit. In examining the above issue, this strand of literature refers particularly to Hofstede's cultural dimensions theory.

Given the increasing interest among researchers in the relevance of informal institutions to the use of trade credit and the critical importance of trade credit to firms, this paper aims to (1) provide insight into the cultural issues of the use of trade credit, focusing on the links between trade credit and trust, religion, and national culture, and (2) suggest potential directions for future research in this area.

According to the aim of this paper, the following is hypothesized: Cultural issues, such as trust, religion, and national culture, affect the companies' granting and receiving of trade credit.

This paper employs a literature review to examine the cultural aspects of the use of trade credit. A literature review is an essential research method as advancing knowledge requires recognizing the boundaries of a given field. It aids in comprehending the extent of current research and, therefore, identifying areas that necessitate exploration (Xiao, Watson, 2019). This review integrates trade credit issues with trust, national culture, and religion, making a unique approach to the subject matter. It contributes to the literature on trade credit and aligns with the expanding research domain of culture and finance. In addition, review articles serve as useful sources of information for practitioners seeking up-to-date evidence to guide their decisions and professional practice (Paré et al., 2015). As such, this study is valuable for trade credit decision-makers as it enhances their understanding of this financial instrument. In sum, this study aims to increase awareness and comprehension of the cultural issues of trade credit use that benefit both researchers and practitioners.

The rest of this paper is organized as follows. Section 2 provides a brief introduction to the concept of trade credit. Section 3 presents the methodology adopted in this study. Section 4 reviews trade credit works considering the issues of trust, religion, and national culture. Finally, the last section provides concluding remarks and suggests possible future research avenues.

## **2. The nature of trade credit – theoretical background**

The separation between the moment of delivery of goods and services and the time of payment gives rise to trade credit (Paul, Boden, 2008). Thus, unlike cash or near-cash payments, goods or services are provided "on credit," typically with an invoice outlining the payment terms (Cowton, San-Jose, 2017).

Trade credit acts as “a facilitative financial vehicle” as neither the demand nor supply of credit is the primary objective of the trading transactions or businesses involved (Paul, Boden, 2008, p. 273). Trade credit is a spontaneous source of financing resulting from ordinary business transactions (Brigham, Daves, 2021; Petty et al., 2015). As it is flexible and relatively easy to obtain (Moyer, McGuigan, Rao, 2017), trade credit is sometimes referred to as a source of on-demand financing (Petty et al., 2015). Since suppliers are more liberal in granting credit than financial institutions (Van Horne, Wachowicz, 2008), trade credit can provide financing for companies that encounter obstacles in obtaining funds via formal channels.

Numerous theories explain why suppliers extend trade credit to customers and why buyers use it (for an overview see, e.g., Petersen, Rajan (1997); Wilson, Summers (2002); Summers, Wilson (2003); Paul, Boden (2008); Zawadzka (2009); Kreczmańska-Gigol (2013); Becella (2019)). Since Schwartz’s (1974) formulation of two motives for trade credit sales, i.e., the financing and the transaction motive, further explanations for the use of trade credit have emerged. These various theories emphasize the benefits that counterparties derive from using trade credit. In this regard, it is also important to note the two-way nature of the transaction, as firms often decide to both provide trade credit as suppliers and use it as customers, which requires managing net trade credit position (Peel, Wilson, Howorth, 2000).

Although trade credit differs from bank credit, it is subject to similar risks of late payment or non-payment by the customer. Therefore, under a trade credit agreement, the seller finances the buyer’s inventory and is exposed to credit risk (Cheng, Pike, 2003). The belief that the debtor will meet his obligations is an inherent part of the decision to extend trade credit. Thus, it is possible to consider trade credit as a promise, as highlighted by Cowton and San-Jose (2017). According to this view, prompt payment is a promise-keeping case, while late payment represents a promise-breaking case (Cowton, San-Jose, 2017).

Trade credit creates “a network of financial dependency” (Białek-Jaworska, Nehrebecka, 2016, p. 190). While “stretching” accounts payable (also known as “leaning on the trade”), i.e., postponing payment beyond the end of the net (credit) period, provides a company with an additional source of short-term financing (Van Horne, Wachowicz, 2008, p. 284), it can also have multidimensional consequences for the parties directly (but not only) involved in the transaction. In addition, such debtor behavior raises ethical questions (Cowton, San-Jose, 2017). However, the ethical aspect of trade credit use has not been the subject of much in-depth research (Li, Zhu, 2021).

### **3. Research methodology**

This study employs a literature review as a research method to examine previous research in the field and pinpoint areas that require further exploration. Conducting a literature review

is a crucial aspect of academic research (Xiao, Watson, 2019) since research is a collaborative effort where researchers build on previous work (vom Brocke et al., 2009). Literature reviews, as independent studies, move the academic discussion forward (Kraus et al., 2022). The rationale for choosing this research approach is that a literature review can efficiently tackle research questions by combining outcomes and viewpoints from different empirical studies, surpassing the efficacy of individual studies (Snyder, 2019). An effective review provides a solid basis for the advancement of knowledge. It promotes theory development, closes over-researched domains, and spotlights areas necessitating additional exploration (Webster, Watson, 2002). A literature review can be regarded as a literature investigation (Chigbu, Atiku, Du Plessis, 2023) that serves multiple purposes. The rapid pace at which knowledge is produced in business research, combined with its interdisciplinary and fragmented nature, creates a challenge in keeping up with the latest research and evaluating collective evidence in a specific research area. Hence, the literature review as a research method is currently highly pertinent (Snyder, 2019).

The search for relevant literature for this review was conducted using Google Scholar. Given that the boundaries of what culture encompasses are unclear (Goodell et al., 2023), it was essential to limit the scope of the study. Therefore, an initial search was performed using keywords such as *trade credit + culture*, which revealed three areas of interest for further exploration: trade credit in the context of trust, religion, and national culture. Combinations of relevant terms, including *trade credit + trust*, *trade credit + religion*, and *trade credit + national culture*, were then searched to identify literature related to these topics. This search was supplemented by forward and backward reference searching. During the search, emphasis was placed on empirical studies published within the last five years.

## 4. Results

### 4.1. Trust as an inherent element of trade credit

As viewed by Arrow, “Trust is an important lubricant of a social system. It is extremely efficient; it saves a lot of trouble to have a fair degree of reliance on other people’s word” (Arrow, 1974, p. 23). Trust is a valuable factor in many forms of exchange (Doney, Cannon, Mullen, 1998).

According to Arrow (1972), trust is present in nearly all commercial transactions, particularly those that occur over an extended period. Similarly, Knack and Keefer (1997) note that trust-sensitive transactions comprise, among other things, exchanging goods and services for future payment. Koralun-Bereźnicka and Szramowski (2021) also emphasize this point, remarking that historically, trade credit was based on a relationship of trust between the

merchant and the buyer, i.e., trust that the other party would fulfill the agreement and make payment within the agreed timeframe. Trade credit is so tightly fused with trust that it is even noted that it would vanish without trust (Dupont, Karpoff, 2020).

Trust is one of the building blocks of the buyer-seller relationship. As Ganesan (1994) shows, credibility, a dimension of trust, is vital for establishing long-term relationships between retailers and vendors. The significance of trust in building such relationships is further supported by Doney and Cannon (1997). They find that when buyers trust the supplier company and the salesperson, they are more likely to anticipate future interactions with the supplier.

The mechanism of trade credit involves the parties in a mutual relationship (Koralun-Bereźnicka, Szramowski, 2021). This results in trade credit being closely intertwined with issues of trust. Establishing and maintaining trust in credit relationships is an essential requirement for the functioning of trade credit in both developed and developing countries (Amoako, Akwei, Damoah, 2021). Without trust between the parties, transactions that could be mutually beneficial will not occur (Dasgupta, 2005). In the context of trade credit, a lack of confidence in the trustworthiness of customers and the associated concern that the company will not receive payment and will not be able to enforce repayment can lead to trade credit rationing (Fafchamps, 1997).

Since building and developing trust takes time (Doney, Cannon, 1997), suppliers may use some verification solutions when dealing with customers lacking a proven payment history. According to Fafchamps (1997), unfamiliar customers may receive trade credit only after an adequately long trial period. This period is an opportunity to build trust between the parties. Fafchamps also states that large companies may have an advantage in obtaining trade credit due to their reputation and market power. Amoako, Akwei, and Damoah (2021) further address the above issue, noting that companies may resort to partial payments in relatively new trade credit relationships where trust has yet to be established.

Although numerous studies explore the impact of trust on formal financial markets, there is a paucity of research examining its effect on trade credit. One such study by Wu, Firth, and Rui (2014), based on a sample of non-state listed firms in China, demonstrates the importance of social trust in overcoming institutional difficulties in financing private firms. Specifically, Wu, Firth, and Rui find that firms in higher social trust regions are more likely to offer and receive trade credit than those in regions with lower social trust. Furthermore, they provide evidence that social trust can substitute for a well-developed legal system in supporting the receipt and provision of trade credit. Notably, according to Wu, Firth, and Rui, social trust also influences the payment behavior of firms and the efficient collection of trade receivables. Their findings show that firms in higher social trust regions tend to pay their accounts payable with greater timeliness and receive their accounts receivable faster. The latter observation holds significant value as the problem of delayed payment presents a severe threat to business operations, and the question of the determinants of this phenomenon is relatively rarely addressed in the literature.

In their research, Hasan and Habib (2019) provide different results than Wu, Firth, and Rui (2014); however, their study employs a broader category of social capital. Using US county-level data, Hasan and Habib find that firms headquartered in high social capital counties use less trade credit as a source of financing (as measured by the relative level of accounts payable). In examining the mechanism for the impact of social capital on the use of trade credit, Hasan and Habib also identify two effects of social capital on the use of trade credit, i.e., a direct effect and an indirect effect (as social capital reduces financial constraints).

The interest in the relationship between trade credit and trust is also evident in studies embedded in various extreme situations that generate shocks to firms. One such study, conducted by Levine, Lin, and Xie (2018), addresses the problem of systemic banking crises. Using a sample of over 3,500 firms across 34 countries between 1990 and 2011 they document that liquidity-dependent firms in countries with higher social trust receive more trade credit and experience smaller profits and employment declines during systemic banking crises than those in countries with lower social trust. Their results suggest a “cushioning” role of social trust in mitigating the impact of systemic financial crises on trade credit financing and firm performance.

The functioning of trade credit during exceptional events is a question that arises not only in the context of financial crises. It also emerges in the pandemic shock setting. The research by Zhang et al. (2023) is particularly noteworthy in this area as it investigates the influence of both formal and informal institutions on trade credit across 107 countries during six pandemic crises (including COVID-19). Zhang et al. identify that formal institutions, grouped into legal-law and information transparency categories, affect trade credit differently than informal institutions, represented by religious attributes, social trust, and policy stability during pandemics. They document that while the country’s formal institutions lead to less use of trade credit during pandemics, informal institutions mitigate the negative effects of pandemic crises on trade credit.

The beneficial impact of social trust on trade credit usage is also revealed by Liu and Dong's (2020) research, which is embedded in an environment of economic policy uncertainty (EPU). Their findings indicate that although EPU decreases the provision of trade credit, social trust significantly mitigates this negative effect. Liu and Dong's results underscore the relevance of a favorable social setting in times of high policy uncertainty that constrain economic activities.

It is stressed that trust-based relationships take on particular importance in settings where legal institutions are weak. Amoako, Akwei, and Damoah (2021) indicate that entrepreneurs in such environments rely on personal trust and parallel institutional trust anchored in the norms of social and cultural institutions, including family/kin and friendships, community and trade associations, and religion, to extend trade credit to their partners. In addition, their findings show that the mentioned factors affect both the provision of trade credit and the enforcement of related agreements.

In the context of the significance of trade associations in the trust-building process, it is also worth noting the research of Xiu et al. (2023). Employing data on privately owned enterprises in China's stock market, Xiu et al. show that merchant guild culture contributes to increased access to trade credit, especially in regions characterized by poor general social trust. As they note, merchant guild culture, which refers to the codes of ethics followed by all business people in a merchant guild, can alleviate information asymmetry and build relational trust, thereby fostering greater access to trade credit for firms.

Some novelty in the approach to the issue at hand can be seen in the study by Xu et al. (2023), as they focus on the relationship between trust and firms' access to trade credit, examining the category of inherited trust. Based on a literature review, they propose two hypotheses about how trust affects access to trade credit for firms facing barriers to finance through formal channels. Since trust encourages information sharing and the perception of information as reliable, thereby reducing information asymmetry, the first hypothesis assumes a disproportionately positive effect of trust on access to trade credit for such firms. On the other hand, given that trust may weaken the motive for signaling product quality, the second hypothesis states a disproportionately negative effect of trust on access to trade credit for financially constrained firms. Using data from 19 countries from 2009-2019, Xu et al. find evidence supporting the first hypothesis. In addition, their study shows that trust plays a role in boosting the sales growth of financially constrained firms as it facilitates their access to trade credit.

Trade credit is so saturated with trust that it is sometimes treated as a trust variable. For example, McMillan and Woodruff (1999) refer to the amount of trade credit granted to capture a firm's trust in a customer. Johnson, McMillan, and Woodruff (1999) operationalize the notion of trust in two ways. The first method gauges a company's trust in its customers by asking about trade credit. The second method measures a company's trust in a supplier by assessing whether it would switch to a new, previously unknown supplier offering a 10% lower price. Further, Vučković, Škuflić, and Mangafić (2023) use the trade credit variable (based on the share of goods sold on credit) as a proxy for interpersonal trust in business relations and show its positive impact on firm productivity measured as sales per employee and expectations of sales growth in the coming period. In justifying the reference to trade credit as a proxy for trust, they point out that the decision to sell on credit is underpinned by the belief that firms will obtain payment because of trust in economic actors or a third party's ability to enforce payment. Their approach is consistent with that of Berulava (2013), who also employs the trade credit variable (based on the share of goods sold on credit) as a proxy for trust-based relationships in a study of their effect on firm performance in transition economies. On the other hand, Raiser et al. (2008), in examining the extent of trust in business relationships, refer to the level of prepayment suppliers require from their customers as a measure of dis(trust).

## 4.2. Trade credit and religion

According to Dana (2009), religions act as depositories of wisdom and values. Religion is thought to provide social capital, like religious beliefs that support more ethical behavior (Cao et al., 2019). Through promoting ethics and morality, religious culture transmits information about two fundamental values: honesty and faithfulness (Li, Zhu, 2021). According to Guiso, Sapienza, and Zingales (2003), religious people tend to trust others, government institutions, and the legal system more. They are also less likely to engage in illegal conduct (Guiso, Sapienza, Zingales, 2003). The ethical dimension of trade credit draws attention to the relevance of religiosity to its use. However, this area of research is relatively new and still leaves room for extensive investigation.

Among the few papers that address the above issue is the work of Cao et al. (2019), which provides insights into understanding the impact of religiosity on trade credit use and firms' payment discipline. Examining Chinese non-state listed firms, Cao et al. find evidence that firms in high-religiosity areas receive more trade credit than those in low-religiosity areas. Importantly, this influence is not the same for all religions but applies to Buddhism, Christianity, and Taoism (but not Islam). Cao et al. also show that the positive effect of religiosity on trade credit use is particularly evident in regions with weak formal institutions or limited access to formal finance. In addition, Cao et al. demonstrate that religiosity can improve borrowers' payment discipline, as it tends to reduce overdue trade credit.

Results from interviews conducted by Amoako, Akwei, and Damoah (2021) with Ghanaian entrepreneurs also underline the significance of religious matters in contract enforcement under weak legal institutions. They find that religious norms are among the informal trust-related institutions entrepreneurs use to enforce trade credit agreements with counterparties in domestic and West African markets.

The results of the study by Li and Zhu (2021), which also touches on the problem under consideration, correspond to the results of Cao et al. (2019). For a sample of Chinese listed firms, Li and Zhu show a positive effect of religious culture on trade credit received, an effect that is particularly pronounced for firms in areas with lower social trust. Within the context of signaling theory, they conclude that a stronger religious culture increases the level of obtained trade credit by alleviating agency problems and mitigating information asymmetry.

The studies conducted by Cao et al. (2019) and Li and Zhu (2021) track the importance of religious issues in trade credit usage from the perspective of trade credit recipients. Chen et al. (2020), on the other hand, refer to the accounts receivable category, thus focusing on providing trade credit. Based on firm-level data from 53 countries, Chen et al. reveal that firms in more religious countries tend to provide more trade credit to their customers. This positive effect of religiosity on trade credit use is further strengthened by high social trust and creditor rights protection in a country. The study by Chen et al. shows that religiosity, as an additional extra-legal institution, promotes the diffusion of trade credit among firms that may encounter barriers in formal financing.

Previous research on the role of religion in the use of trade credit also includes the study of Mättö and Niskanen (2019). Their study focuses on two groups of countries: Catholic-dominated and Protestant-dominated. In particular, Mättö and Niskanen report higher levels of trade credit use by firms (this applies to both sides of the balance sheet, i.e., the accounts receivable and accounts payable levels) in Catholic countries compared to Protestant ones. Furthermore, they find a positive effect of peoples' religiosity (measured by the percentage of people who believe in God) on the use of trade credit in Catholic countries.

### **4.3. Trade credit and national culture**

As Barro and McCleary (2003) note, culture is widely seen as impacting economic outcomes by influencing personal traits such as honesty and work ethic. Breuer and Quinten (2009) highlight the twofold impact of culture within an economic framework. First, cultural values can indirectly shape the economic behavior of individuals through their expression in the formal institutions of society, such as a particular financial system. Second, they can directly affect the economic behavior of individuals via their influence on decision-makers' preferences (Breuer, Quinten, 2009).

The relationship between trade credit and national culture is discussed by, among others, El Ghouli and Zheng (2016). Using Hofstede's four cultural dimensions (collectivism/individualism, power distance, uncertainty avoidance, and masculinity/femininity) as proxies for national culture and data from 49 countries between 1993 and 2013, El Ghouli and Zheng find that firms located in more collectivist, high power distance, greater uncertainty avoidance, and more masculine countries provide more trade credit to their customers.

The above issue is also addressed by Hoang et al. (2023). Focusing on a sample of manufacturing SMEs from 37 countries from 1998 to 2018, they identify the positive impact of collectivism and uncertainty avoidance on trade credit granting. Hoang et al. also shed additional light on their findings by alluding to the financial, operational, and commercial motives for trade credit provision. They identify that in countries with high degrees of collectivism and uncertainty avoidance, the increase in trade credit granting is more apparent for firms facing unstable demand, representing low reputations, or having relatively easy access to financial markets.

The work of Moro, Belghitar, and Mateus (2021) also complements this strand of research by raising the issue of the impact of a country's culture on the use of trade credit but it focuses on the perspective of the trade credit recipient. Drawing on data from manufacturing firms from 16 Western European countries between 2003 and 2013, Moro, Belghitar, and Mateus find that the degree of information asymmetry rooted in a country's culture is reflected in the short-term financing strategies of SMEs. In particular, they show that firms in countries characterized by high levels of power distance, individualism, masculinity, and uncertainty avoidance are more likely to resort to trade credit as a source of financing. These cultural conditions, which breed



information asymmetry in the firm-bank relationship and consequently limit the availability of bank credit to firms, contribute to the SMEs' greater reliance on trade credit.

The question of the role of the cultural environment in the use of trade credit also arises in the study by Mättö and Niskanen (2019), which differs from the studies mentioned above by analyzing trade credit on both sides of the balance sheet. In this study, Mättö and Niskanen refer to five cultural variables - three of Hofstede's national culture dimensions, such as power distance, individualism, and uncertainty avoidance, and two of Schwartz's cultural orientation scores, such as embeddedness/conservatism and intellectual autonomy, and divide religions into two categories: Catholics and Protestants. For a sample of SMEs from 35 European countries, Mättö and Niskanen find mixed results on the impact of cultural values on trade credit, suggesting that it may vary depending on religion and/or the legal and financial environment. In particular, they obtain an unambiguous result for individualism, showing its positive relationship with the level of accounts payable.

## **5. Discussion and conclusions**

Trade credit is a well-established financial instrument that has been studied extensively. Despite the considerable knowledge about its use, research on the cultural factors associated with trade credit has been relatively limited. This literature review explores the cultural influences on trade credit use. It consolidates and analyzes current, fragmented research on the cultural nuances inherent in trade credit decision-making.

An examination of publications on trade credit in search of a cultural element has identified three prominent strands of discussion. These include issues of trust, religion, and national culture in the use of trade credit. The literature review confirms the importance of these cultural aspects both for granting and receiving trade credit, thereby supporting the research hypothesis. More specifically, the literature review yields the following conclusions regarding the issues at hand.

Trust is a crucial element in transactions that involve deferred payments. This paper indicates that trust can explain why firms employ trade credit. The reviewed studies highlight the significance of a favorable social climate for business activities. Trust plays a vital role in alleviating difficulties that firms face in financing their activities during distinct scenarios, including systemic banking crises and pandemics. Additionally, the role of this informal institution appears to be particularly important in the context of economic policy uncertainty and weak legal systems.

Limited research exists on the influence of religious issues on trade credit decisions, but the available results confirm their importance in understanding such decisions. Existing studies suggest that religiosity positively influences the use of trade credit. They highlight the

supportive role of a religious setting in promoting the prevalence of trade credit for businesses that confront limitations in obtaining formal financing. The research findings show that religiosity has a positive effect on timely payment. However, additional investigation is needed in this area.

There is little research on the use of trade credit within the context of national culture, similar to the discussion of religious issues and trade credit. However, investigation in this area highlights the significance of various national cultural dimensions in determining trade credit decisions. These findings shed light on the factors accounting for cross-country variations in the provision and use of trade credit as a source of financing.

Overall, the review results suggest that informal institutions play a vital role in explaining the cross-regional and cross-country differences in the use of trade credit. These findings enhance our understanding of the determinants of trade credit and its cultural underpinnings, establishing theoretical and practical implications. The results indicate that cultural issues affect firms' trade credit decisions and highlight the need for a more interdisciplinary view of this financial instrument. Without a perspective that properly considers the human component, our understanding of trade credit will remain insufficient. Therefore, future research on trade credit should adopt a broader perspective that extends beyond a purely financial focus and considers the role of informal institutions. Due to the crucial significance of trade credit in corporate operations, a comprehensive approach to trade credit is required for scholars and practitioners, indicating which issues should be given special attention when making trade credit decisions. Awareness of the multiple determinants of trade credit from both a demand and a supply perspective can significantly aid firms in making sound financial decisions.

While the cultural aspects are becoming more prevalent in research on trade credit, some issues should be more prominent in publications. The review suggests several opportunities for future research in the subject matter.

Firstly, due to the risk of late payment or non-payment of trade credit, it would be advisable to deepen research on the above phenomenon with a cultural component. Although some studies show an interest in this subject, the topicality of the problem of late payments and payment bottlenecks and the seriousness of their multiple consequences call for further and more comprehensive research. Secondly, given the specific nature of small businesses, these entities, especially micro-enterprises, are a particularly appealing area for research that combines trade credit with cultural dimension. As the functioning of these entities is closely tied to the person of the owner, who is often single-handedly responsible for different areas of the business, research conducted on such samples could be particularly fruitful in terms of conclusions. Finally, the recent COVID-19 pandemic has created new challenges for businesses, and more research is needed to understand its impact on the use of trade credit, including the cultural dimension. The above issues appear to be attractive and promising areas for future research.

This review has some limitations. The article focuses on the use of trade credit in the context of trust, religion, and national culture. As the notion of culture is broad, this review does not cover every possible cultural issue that may affect the use of trade credit. Further studies could, therefore, focus on exploring additional cultural aspects of trade credit. Moreover, the review is restricted by the limited amount of research conducted in this field. Additionally, there is a limitation in this review due to the heterogeneity of the analyzed studies. The differences in objectives, questions, environmental settings, and the range of variables considered make it challenging to compare studies.

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