SILESIAN UNIVERSITY OF TECHNOLOGY

SCIENTIFIC PAPERS

POLITECHNIKA ŚLĄSKA

ZESZYTY NAUKOWE

ORGANIZATION AND MANAGEMENT

Scientific paper no. 161

ORGANIZACJA I ZARZĄDZANIE

Zeszyt Naukowy nr 161

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GLIWICE 2022

Wydano za zgodą
Rektora Politechniki Śląskiej

ISSN 1641-3466
ISSN 2720-751X

WYDAWNICTWO POLITECHNIKI ŚLĄSKIEJ
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Nakł. 10 + 44 Ark. wyd. 30 Ark. druk. 24 Papier offset 70x100, 80 g

Zam. 115/22

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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 authors from Poland. The number consists of 24 papers.

The papers presented in the number concentrate on many topics connected with organization and management. There are in the number papers about: project management; resources management; tourism management; logistic; quality management; public management; small and medium enterprises management; information management; human resource management; Smart City, Industry 4.0; environment management; impact of COVID-19 pandemic on management; Corporate Social responsibility, and service management.

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

SELECTED METHODS OF PROJECT AND DATA ANALYSIS

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Purpose: Presentation of selected methods of project and data analysis – describes how data on ongoing projects should be collected, so that it can be used later, by applying the appropriate methodology.
Design/methodology/approach: Literature research of the subject was carried out.
Finding: Having a methodology for data collection leads, in the long term, to the implementation of a system that allows the use of this methodology. The system should provide information to help make better decisions, reducing or eliminating the risk of project failure.
Practical implications: Development of a methodology of data collection and analysis on this basis.
Originality/value: The implemented projects are comparable with each other and, on this basis, it can be argued that identifying the risks that have occurred in the past, during the implementation of various stages of projects, can contribute to more effective risk management during the implementation of current and future projects.

Keywords: company management, data analysis methods, project risk.

Category of the paper: General review.

1. Introduction

The basis for the operation of automotive production companies is the implementation of successive projects. Extensive engineering centres, working closely with manufacturing companies, are responsible for developing existing, as well as completely new product concepts. This continues until the developed solutions are implemented in production. When a project involves cooperation with a key business partner or aims to implement very important strategic objectives of the company, the success or failure of the project may determine whether the company remains competitive in the market in relation to other companies.

Regardless of the market segment a company is involved in, the implementation of its projects is always accompanied by numerous challenges, the nature and complexity of which are extremely varied. Nevertheless, the common feature that connects the encountered difficulties, is the fact that each of them brings with it a risk to the project. It can jeopardize the planned implementation of a project or even lead to its complete failure. In order to avoid failure, people – such as project managers, operations managers or leaders of individual functional teams – use methods that support the management of a wide range of risks. The purpose of such action is to prepare for the occurrence of a given negative risk, called a threat. This is done in order to be able to react appropriately when the danger occurs, thus eliminating – or at least reducing – its undesirable effects. The concept of risk is also associated with the possibility of events, whose nature may lead to positive consequences, in which case the risk is called an opportunity (PMBOK Guide, 2012). The role of the person responsible for the stage of the project affected should be to make it happen.

In the case of companies, whose operation is closely based on the successful implementation of projects, it is very important to pay attention to various aspects of the tasks performed. The aim is to improve the efficiency of operations, reduce unplanned costs and, above all, to achieve the intended objectives in accordance with the plan. In such a situation, it is therefore important to draw appropriate conclusions after the completion of each project, as well as throughout its duration, to draw the appropriate conclusions. This should include, but not be limited to: task management, cooperation with sub-suppliers and the quality of work performed by the various functional groups. Information on these issues can be useful for future risk management, as awareness of past threats or opportunities, combined with knowledge of how to deal with such situations, can contribute to the rapid implementation of an appropriate response to the relevant risks.

However, the reality is that once a project has been completed, there is not enough time to analyse it and draw valuable conclusions from it, as another project is started very quickly. In such a situation, sharing the knowledge gained during the project with other employees of the company, let alone cataloguing it correctly, may be impossible, and certainly very difficult. Therefore, it would be very useful to have a tool supporting quick archiving of the possessed information and knowledge, as well as, to some extent, enabling to make conclusions on the basis of the possessed data.

An obstacle to the practical use of such a tool is the fact that each of the implemented projects is – to some extent – innovative and unique, so their comparative analysis will not always make sense. However, if a group of projects – that are twinned in certain respects – is examined, comparing them can provide useful information and lead to conclusions that can help with risk management of similar projects, that will be carried out by the company in the future.

Such a situation occurs in the case of companies associated with the automotive industry, which carry out many programmes, consisting of similar projects, for individual clients. An example can be a company that carries out projects involving the design and implementation for production of many types of exhaust systems that are structurally similar to each other, based on components supplied by specific suppliers and are designed and developed through the work of permanent functional groups, cooperating with each other within the organisational structure of the company. This means that the implemented projects are comparable with each other and, on this basis, it is possible to argue that identifying the risks that have occurred in the past, during the implementation of different stages of projects, can contribute to more effective risk management during the implementation of current and future projects (Gembalska-Kwiecień, 2017).

2. Project analysis methods

The more complex the projects, the more analysis they can undergo. When preparing for them, it is good to first define – as precisely as possible – the purpose of the conducted application and the way, in which the information will be obtained.

It should be remembered that the expectations with regard to the implementation of projects, as well as the manner of their analysis, may differ for various projects. A project, whose scope was twinned to many similar projects carried out in the past, and an innovative project, unique to a large extent, cannot be measured in the same way. In the first case, even a slight budget overrun may or may not mean a failure, if previous undertakings have been successful within the given financial scope. On the other hand, even a significant cost overrun of an innovative project may result from an unrealistic initial estimation, and therefore does not have to be the same as a lack of expected success. The danger of misclassifying a project as a failure can lead to inappropriate conclusions, so that project analysis should always take into account whether the demands placed on it were common sense (Atkinson, Crawford and Ward, 2006).

R. Atkinson – giving the definition of project management according to the BS6079 British Standard of 1996, saying about achieving project objectives in the assumed time, at defined costs and ensuring the required quality of its delivery and implementation – points out that the analysis of a project to determine whether it has been successful or unsuccessful can be done from the perspective of the "iron triangle", which is depicted in Figure 1 of the project constraints (Atkinson, 1999).

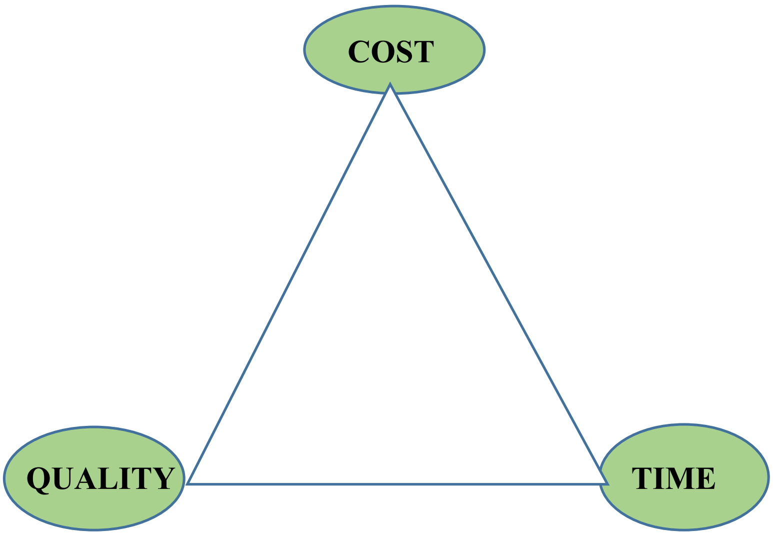

Figure 1. The iron triangle of project constraints
Source: Atkinson, R.: Project management: cost, time and quality, two best guesses and a phenomenon, it's time to accept other success criteria (Atkinson, 1999).

This means that the successful completion of a project is the same as the fulfilment of the assumptions given in the definition quoted above. Atkinson, however, draws attention to the necessity of analysing the project in terms of other criteria – defining time, cost and quality as insufficient to make a proper evaluation. He also draws attention to the possibility of tracking the progress of a project temporarily, throughout its duration, in order to assess whether it is going according to the plan, for example, through the earned value method. Progress determined in this way does not necessarily translate into success or moving in the right direction. Atkinson also draws attention to the basic question – who should define the criteria, by which the project and its realisation will be measured? He mentions key stakeholders, such as the project manager, the company's management board, the client and the project group, as well as other stakeholders, who are less directly involved in the project, but who may be influenced by it, e.g., potential clients. In relation to IT projects, Atkinson proposes four perspectives, from which a project should be analysed, to determine whether it has been successful:

1. the iron triangle perspective, whose success criteria are the aforementioned time, cost and quality,
2. the perspective of an IT system, the design of which should make it maintainable, provide good-quality information and enable effective use, while the system itself should be reliable and valid,
3. the perspective of achieving benefits for the organisation, which should improve its productivity and operational efficiency, increase profits, achieve strategic goals and learn,
4. the perspective of achieving benefits for the stakeholder community – the users should be satisfied, the impact on the environment and society should be positive, the information system should provide opportunities for personal and professional development, as well as profits for contractors.

Another way of analysis is proposed by Raz and Michael. They suggest that the evaluation of project management, including the analysis of the project itself, can be done by answering the question – how well does the project fit into the following characteristics (Raz and Michael, 2001):

- satisfies the client,
- satisfies the stakeholders involved,
- requires emergency, urgent meetings,
- has a high project management performance ratio,
- requires changes to the product after delivery to the client,
- has a low value – assuming that the objectives are achieved – of the ratio of the effort put into the project to the effort that was originally required to deliver the project/task,
- required changes in the plan.

Another important aspect of project analysis, especially when projects end in failure, is to focus on the proper cause of the events that occurred. This topic is taken up by R.J. Sauser, R.R. Reilly and A.J. Shenhar in their work on the analysis of a failed NASA project to send a space probe to collect data on the weather conditions on Mars. These authors argue that the reasons for failure are often rooted in poor project management and not, as it may seem, in technical problems (Sauser, Reilly and Shenhar, 2009). Their proposed approach to analysing twinned projects is based on determining to what extent they are similar. Then, determining how this translates into choosing the right approach to managing the project at the beginning of the project and even when the project is not going as expected. Sauser, Reilly and Shenhar suggest using various contingency theory structures to conduct a retrospective analysis of successful or unsuccessful projects.

It can be concluded from these examples, that a proper project analysis can be a very difficult task, but one that leads to finding answers to questions that are crucial in the context of future projects. In order for them to be successful, it is important to understand not only how to conduct an analysis, but also how to understand project success and what factors lead to it.

3. Factors determining the success of projects

The implementation of a risk management process aims to ensure the successful outcome of a project. For a project to end successfully, it is not only necessary to define how success is to be interpreted, but it is also reasonable to determine which factors lead to success. The aim is for the risk analysis to be carried out in a way, that is focused on the opportunities and threats associated with these factors.

T. Cooke-Davies answers the question of what are the key factors for project success. In his opinion, the factors that lead to success – when considered in the context of project management – which influence not exceeding the timeframe, are as follows (Cooke-Davies, 2002):

- the adequacy of company education on risk management,
- the maturity of organisational processes for assigning responsibility for risks,
- the adequacy, with which the visible risk register is maintained,
- the adequacy of current risk management plan,
- the adequacy of documentation on project responsibility allocation,
- ensuring that projects – or phases thereof – do not exceed three years in duration, whenever possible, and ideally do not exceed one year in duration.

Another group of factors, that Cooke-Davies mentions, are those that affect not exceeding cost tolerances:

- allowing changes to the scope of the project only through the scope change control process,
- maintaining the integrity of the base used to measure performance.

However, Cooke-Davies points out, that a distinction must be made between the concepts of success, considered in the context of project management, and understood in terms of the successful outcome of a project. This means that a project, carried out in accordance with the time plan and the assumed costs, does not necessarily lead to the achievement of the organisation's objectives and, therefore, it cannot be said to have been successful. The key factor for an individual project is the existence of processes in the organisation that involve mutual cooperation between project managers and operational managers. The purpose of implementing these processes is to effectively achieve the benefits of projects (Cooke-Davies, 2002).

The last group of factors Cooke-Davies highlights are those leading to successful project delivery, what he refers to as corporate success. The practices leading to it are:

- managing in terms of project portfolios and programmes, enabling the company to provide the necessary resources to a group of projects, whose implementation aligns with the company's strategy and business objectives;
- having appropriate project, programme and portfolio monitoring methodologies, that provide direct insight into the day-to-day aspects of performance, as well as the ability to track whether completed projects, programmes and portfolios are delivering the intended strategic benefits;
- the company's commitment to continuous development and effective learning from the experience gained through the implementation of projects.

Practices related to this should include the involvement of employees of the organisation in the development of processes related to project management, through the utilisation of knowledge and skills acquired by them.

Project success may also be considered from another perspective. J. Turner, based on the works of J. Wateridge and R. Muller, presents four conditions necessary to ensure project success (Turner, 2004):

- The criteria determining the success of a project should be established with the participation of stakeholders before the project begins. These criteria should be reviewed and updated during the project,
- the project owner and the project manager should work together and see their working relationship and the project as a partnership,
- the project manager should have enough authority to decide how to deal with the encountered circumstances, while the project owner should communicate how they think the project should be carried out,
- the project owner should take an interest in the project.

The conditions presented above are very important in the context of a successful project, because, if the first one is not fulfilled, a situation may arise, in which some project stakeholders do not share a common vision of what the purpose of the project is. In such a situation, they may perceive the results as a failure. Another reason is the need to define, from the very beginning, a clear direction, in which the project should be carried out – taking into account, among others, the time and expenses incurred – so that the activities of the project team are carried out in accordance with the defined direction. Otherwise, different perceptions of how individual tasks should be carried out can lead to project results, that are significantly different from those assumed before the project started.

A. Jaafari, on the other hand, lists the following activities as key factors for managing a project in a way, that will lead to its success (Jaafari, 2001):

- recognition and proactive management of complexity – depends on the ability to manage in real time the variables and their impact on the strategic objectives,
- decision-making processes based on the chosen strategy,
- integration of project phases, so that the focus on achieving business objectives occurs at each stage of the project,
- consideration of environmental variables, such as the perception of the project by the surrounding community, safety during project implementation, environmental impact, delivery of the project in compliance with legal requirements.

Significant work has also been done by W. Belassi and O.I. Tukel in identifying factors determining the success of the project. Defining an unambiguous way to measure the degree of success – or failure – of a project is not easy, because the various stakeholders involved in the implemented project perceive these issues in different ways – a project completed with success, perceived from the perspective of the client, may be considered a complete disaster from the point of view of the management of the organisation that implemented it (Belassi and Tukel, 2001).

Such a situation may occur when the project objective required by the client has been achieved, but the financial outlays incurred were so high, that, as a consequence, the project has lost the business case underlying the decision to proceed with it.

Achieving ultimate project success is also difficult because the factors leading to it change as the project progresses. Belassi and Tukel emphasise that the outcome of any project will depend, to varying degrees, on an individual combination of many factors – however, skilfully identifying a group of those that are critical to a particular project will allow for a better assessment of the project and an understanding of what aspects of the project may be key to achieving the desired outcome. Belassi and Tukel categorise these factors into four groups described below (Belassi and Tukel, 2001). The first group consists in factors directly related to the scope of the project, meaning that they will vary according to the nature of the project:

- size and value of the project,
- the uniqueness of the activities carried out,
- the project life cycle,
- urgency of implementation of the project.

Factors related to the project manager (the first six listed below) and members of their team (the last four factors listed):

- the ability to delegate authority,
- the ability to compromise,
- the ability to coordinate activities,
- perception of their role and responsibilities,
- competences,
- commitment,
- technical experience/knowledge,
- communication skills,
- problem solving,
- commitment.

Factors relating to the organisation, within which the project is implemented:

- senior management support,
- the organisational structure of the project,
- support of functional managers,
- project leader.

Factors relating to the external environment (in which the project is implemented):

- political environment,
- economic environment,
- social environment,
- technological environment,
- natural environment,
- clients,
- competitors,
- sub-suppliers.

Based on the information presented – showing the effect of research carried out on the identification of key factors influencing the success or failure of a project – and professional experience, it was concluded that the key factors for automotive projects are primarily:

- availability of resources to carry out the intended activities,
- support of senior management, especially in conflict situations,
- consultation with the client and ensuring good relations between the client and the project manager,
- the fulfilment of responsibilities by the project manager, but also by the members of the project group.

4. Data analysis methods

In order to develop a project analysis methodology, for which it will be possible to implement it in the form of a spreadsheet-based tool, it is helpful to be familiar with data exploration issues. An extensive study on this subject is a publication by D. Handa, H. Mannila and P. Smyth, which presents the most important aspects of data analysis and drawing conclusions based on it.

The following methods of analysing and presenting data are described below:

- statistical method, based on the analysis of the probability of occurrence of given risks. The applicability of the method is based on the information available on the implementation of past projects;
- the method of graphical visualisation of data, which is described using examples that help to understand the functioning of the prepared tool using the methodology developed in this work.

The method should be used in the spreadsheet development process, as it can provide additional opportunities for the user to draw conclusions by observing the graphical presentation of data (Hand, Mannila and Smyth, 2006).

The method of statistical data analysis involves analysing the data held on past projects and their various stages individually, in a way that allows the statistical probability of the risks involved to be determined (Larose, 2006).

To illustrate these words, if, in the case of fourteen out of fifteen completed projects, in the first stage – which in each case was, for example, the initial preparation of the product concept – there was an extension of time for this stage due to the need to implement unplanned design changes, it is possible to determine the statistical probability of this occurrence, which is 93%. This means that, when conducting the next project, the project manager should look carefully at the reasons why this situation occurred in the past. If there have been no significant changes since the completion of the projects under consideration, the statistical probability that this stage will also be prolonged in the current project is high. Taking into account the costs of constructors' work, the scope of which usually exceeds the planned and budgeted level at this point, it becomes realistic to state that, in such a situation, the level of risk for the project may be high.

Another method is graphical visualisation of data. It allows people to analyse the data through the organ of sight, and thus provides a chance to see a pattern in the data, that would be difficult to identify through algorithmic analysis by a computer (Hand, Mannila and Smyth, 2006).

The prepared spreadsheet, when developed, should also be able to visualise the entered data to provide the user with this opportunity.

However, it should be borne in mind that, before the selected method can be used, it is necessary to determine the way of collecting data concerning the implemented projects – recommendations for collecting these data are described in the following section.

5. Recommendations for the collection of project data

In order to make use of the data provided during the implementation of projects, it is essential to have a methodology for collecting it. Using Bechtel Oil, Gas and Chemicals as an example, J. Musgrove concisely describes how the company collected data on completed projects in the past, and how it introduced and is currently developing its Central Metrics Database (CMD), which contains historical information on completed projects (Musgrove, 2008). Musgrove clearly indicates that the company has suffered from the problems associated with the departure of experienced staff, so that knowledge of project implementation, as well as performance information, against which current projects can be compared, has been lost to some extent. He also draws attention to the need to ensure limited access to the collected data, as they contain confidential business information, very important for the company.

The characteristics that a system that enables data collection should have are as follows (Musgrove, 2008):

- costs, resources and individual activities should have their own categories,
- the system should be able to store data on assumed and actual costs, as well as used resources,
- the system should provide the ability to categorise projects, so that the data held can be sorted in a way that enables it to be used.

The data collected included:

- project profit and cost
- the type of work that was carried out;
- the execution of construction works;
- the execution of special works;
- the project schedule;
- specific costs;
- project summary.

Musgrove also points out that data entered into the system may be entered incorrectly or, depending on the role within the company of the user entering it, false data may be entered. One possible solution is to appoint a controlling manager for each project, who will be responsible for validating the data and approving its completeness and accuracy. In the case of the described company, this solution led to the following benefits: the accuracy of the data was no longer questioned, as once it was approved by the controlling manager, it could not be changed and was considered valid.

As further points of development of the CMD system, the possibility of collecting data on specific characteristics of the projects concerned, e.g., cost ratios for materials, was identified, as well as the realisation of the need to be able to treat large projects as a set of smaller projects, so that they could be compared with each other.

T. Pickett and B. Elliot suggest that the use of historical project data can assist in strategic decision making and provide a competitive advantage over other companies in the market (Pickett and Elliot, 2007). This data helps in deciding, which projects should be carried out in the future and which should be discontinued.

However, in order to apply the data in its possession, a company should have an appropriate methodology and follow procedures defined for this purpose. In this situation, having a system that provides the ability to work with historical data provides an opportunity to increase the efficiency of project delivery and support the estimation, planning and control of future projects. The authors point out that it is necessary to analyse completed projects in order to improve the performance of current and future projects. The development of systems to support this process is hindered by the vision of the necessary financial outlays to be incurred in this connection. This makes it all the more important to have the commitment and support of the company's management board, who should first recognise and understand the need for historical data. The benefit of using historical data is that it allows comparisons to be made, as well as plans and estimates of costs and activity times to be evaluated.

The first questions that arise are:

- how to collect all the important data?
- where to store the collected data?
- how to use the data you have to give you a competitive advantage?

In response to these questions, Pickett and Elliot highlight the following aspects:

- staff – the commitment and understanding of the data collection process by staff, both at senior management level and at the level of those directly entering data into the system, is essential for data collection to deliver the expected benefits,
- infrastructure – when thinking about collecting data using an IT system, consideration should be given to aspects, such as access to hardware and software, but also to where the data will be stored – on the company's server or perhaps in the cloud – and how it will be secured and backed up,
- categorisation – data collection should be carried out in a way that enables the data to be assigned to appropriate categories, so that it can be later segregated and searched,
- cost control system – necessary for the collected data to have real meaning for the company. The possibility of assigning categories to given costs finds its justification in the operation of this system, because, in this way, it is possible to not only monitor costs, but also compare them, thus estimating them with greater accuracy,
- project classification – necessary, so that the data held can be identified and organised in the required manner. By doing so, it is possible to avoid the danger that the projects being compared are so different from each other, that they should not be analysed together.

Pickett and Elliot draw attention to practical aspects of using the system (Pickett and Elliot, 2007). One of these aspects is the need for data standardisation – it reduces ambiguities and anomalies in the collected data. The first step in data normalisation is identified as the selection of projects that may provide unusable data. Reasons that may lead to data not having the required value can be considered:

- errors made in accounting or during project audits that translated into having inaccurate data,
- the size of the project significantly deviating from other projects of the same type – in such a situation, the data provided on the basis of the implementation of a project may be irrelevant if its scale was, for example, much smaller than that of other projects,

- projects implemented at a non-standard level – it is possible that the project implementation will be carried out in a completely different way than for the standard projects of this type, so the comparison of the data concerning them with the information about other projects will not make sense.

The course of normalisation for cost data is as follows:

- converting data to be in one common unit (e.g., currency),
- adoption of a common time frame,
- estimating missing cost data, if possible,
- ensuring that costs not incurred are not taken into account,
- classifying projects and their phases, if appropriate.

Once it has been identified which projects should provide useful information and the existing data has been normalised, it is necessary to move on to the issue of data collection. For this purpose, it is recommended to implement an information system in the company (Musgrove, 2008; Pickett and Elliot, 2007).

Once the company has the infrastructure in place to make use of the historical data, the question that needs to be answered is: How can the collected data be used to maximum advantage?

Examples of use are formulated as follows (Pickett and Elliot, 2007):

- ensuring the possibility of data comparison – having a database, it is possible to estimate on its basis, as well as to evaluate the created project plan and adopted indicators,
- calibration of the database – where, for example, the cost of materials fluctuates widely, it should be possible to consider it in such a way, as to determine when an increasing or decreasing price is a trend and when it is a more random fluctuation, dictated by non-standard situations and market conditions,
- pre-estimation of costs and lead times – the system should be able to perform calculations to determine costs and lead times based on the available data. Such information can be very helpful, as it is based on up-to-date information, so that the values generated can represent – with satisfactory probability – what costs the project will generate and what time will be needed for its implementation,
- strategic project planning – lessons learned from successful or unsuccessful projects can be of key importance for planning future projects, their implementation strategies and choosing which projects should be implemented by the company.

Pickett and Elliot cite the possibility of development and improvement of the functioning of a company using this system as the main objective of using a system for collecting and analysing historical data on completed projects.

6. Summary

Having a methodology for data collection leads, in the long term, to the implementation of a system that allows the use of this methodology. The system should provide information that helps to make a more accurate decision than if the company did not have this tool (Office of Government Commerce, 2010).

J. Rutkowski presents methods for portfolio analysis and their application in the evaluation of product innovation projects (Rutkowski, 2013). Before starting a new product project, the basic issue is how to effectively allocate the resources at one's disposal, so that the implementation of the project will bring the intended goal. It is also necessary to estimate the costs of project implementation, so that – in the long term – through their juxtaposition with the list of potential benefits, it is possible to assess whether the project has a business justification and to apply the presented methods of portfolio analysis. Rutkowski also points out that innovative companies usually have a smaller number of new product projects than non-innovative companies, but with a higher value. In this situation, having a system that allows the use of accumulated data on past projects can assist management in deciding which projects should be implemented and which should be cancelled, so that more resources can be used for selected projects.

Cost estimation and good planning skills are crucial for the successful delivery of projects (Corvellec, 2009; Pritchard, 2002; Smith and Fischbacher, 2009).

D. Dvir, T. Raz and A. Shenhar, on the basis of an analysis of more than one hundred R&D projects implemented in Israel, conducted an empirical analysis of the correlation occurring between aspects of project planning (e.g., requirements definition) and its success, considered from the perspective of, among others, the project beneficiary (Dvir, Raz and Shenhar, 2003). The results of their analysis confirmed that certain aspects of project planning can positively influence project implementation, and thus the success of a project. It was proven that, in the case of the analysed projects, taking time during planning to define project requirements positively influenced the outcome.

In this case, it is desirable to be able to use an information system based on historical data, speeding up the planning process and increasing the accuracy of estimating the values of variables that characterise projects (Ward and Chapman, 2003; Dowie, 1999; Gardiner, Stewart, 2010; Gembalska-Kwiecień, 2020).

In the future, while continuing the work on the topic addressed in this paper, it is recommended that the developed methodology of data collection and analysis is implemented in the form of a computer application (Office of Government Commerce, 2010; Project Management Association Poland, 2009; Perminova, Gustafsson and Wikstrom, 2008; Gembalska-Kwiecień, 2021).

Acknowledgements

This article was created as part of statutory work 13/010/BK_22/0065 conducted at the Institute of Economics and Informatics at the Faculty of Organization and Management of the Silesian University of Technology.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

TOURISTS' MOTIVATIONS FOR USING SOCIAL MEDIA

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Purpose: The main objective of the paper is to determine whether latent variables (constructs) regarding tourists' motivations can be found in the studied social media use behaviour of tourists.
Design/methodology/approach: The study was carried out via an on-line survey questionnaire. Responses to questions were measured on a nominal or ordinal scale. Factor analysis was used in the data analysis. The subject of the study involves the use of social media by tourists and analyses their motivation.
Findings: Tourists' motivators for using social media were identified and these are: 1) Visibility in the crowd, 2) Obtaining information about nearby events, 3) Building relationships with the local community, 4) Relying on the opinions of others.
Research limitations/implications: The study was carried out only in one country. There are plans to expand the study area in the future in order to make international comparisons. Moreover, motivators were not identified by age group, which is planned in future studies.
Practical implications: Identification of tourists' motivation to use social media enables city managers, tourism organisations and tourism facility managers to have a targeted impact on tourist behaviour. These activities can result in the desired objectives being achieved, e.g. relations between tourists and the local community will be built. This will also enable the identification of people who are motivated to be visible in the crowd and offer them cooperation in the promotion of tourist destinations or attractions.
Social implications: Identification of tourists' motivators will make it possible to influence tourists in such a way that they will participate in solving problems of the local community or provide information on situations requiring intervention in the area of tourist attractions.
Originality/value: New insights on latent variables concerning tourists' motivation when using social media have been provided. The paper is addressed to city managers, tourism organisations and tourism facility managers what will help them to improve the quality of provided services.

Keywords: motivations, tourists, social media, smart city.

Category of the paper: Research paper.

1. Introduction

Modern information and communication technologies play a crucial role in the development of every area of life, including the functioning of cities and urbanisation processes. Implementation of intelligent solutions known from the smart city concept can help develop the competitiveness of cities. The smart city concept involves the use of networked infrastructure to improve the economic and political efficiency of resources and enable the smart and sustainable development of urban areas (Jonek-Kowalska and Kaźmierczak, 2020). Efficient city management requires the collection of a large amount of data and different types of information, especially from tourists. Cities for which tourism is a basis for functioning try to be more and more competitive in the tourism services market. However, it is important for city planners to have constant information sources. Tourists can be an important source of information because they visit places that are new for them and thus can share their views on the city's problems.

Currently, the most popular form of communication and channel for tourists to share information is social media. This is why, in order to increase the number of social media users, it is crucial to know the factors/motivators that make tourists use social media in a particular way. Research to date only looks at the motivation for tourist information sharing activities but does not explain the important motives for sharing experiences both during and after the trip (Ghaisani et al., 2017; Hysa et al., 2020). Motivation for information sharing activities is important as it can support city managers in the proper presentation of relevant information in terms of content and display. Having this in mind, it is important to learn about tourists' motivation for social media use during travels. This is why the main objective of the paper is to determine whether latent variables (constructs) regarding tourists' motivations can be found in the studied social media use behaviour of tourists. Thus a research question was formed: what motivates tourists to use social media during tourist trips?

The paper consists of 4 parts including introduction, literature review, analysis of data, discussion and conclusion.

2. Literature review

Nowadays we can observe a dynamic growth in the number of modern IT solutions offered both by public and private entities. Internet development enabled the creation of mobile applications (Druć et al., 2021) and social reality (Zawierucha, 2021), among other things. The offered solutions have gained the approval of the public, who use them to achieve both professional and personal goals. In January 2022, Poland had 32.86 million Internet users, which constitutes 87% of the total population (Dataportal, 2022). Among the used IT solutions, the use of social media is noteworthy. In Poland, there were 27.2 million active social media users, which shows an increase of 5% in comparison with the previous year (Dataportal, 2022). The possibilities of social media use are diverse (Akram and Kumar, 2017), which makes it possible to use them both at work and in their free time (Mader et al., 2019; Zoonen et al., 2017).

In order to meet the challenges posed by residents and tourists, cities try to implement new IT solutions that support city management. This is why more and more cities become smart cities. L.G. Anthopoulos indicates that a smart city can be considered from different perspectives, but most respondents point to such measures as urban economy, mobility, environment, living, people and governance (Anthopoulos, 2015). The concept of a smart city focuses on many innovative activities that can significantly improve the lives of the local community (Sułkowska, 2021). Thanks to the implementation of these IT solutions it is possible to obtain information, inform about events, urban planning and management.

Local authorities use diverse communication channels to obtain information from residents and tourists. Among digital communication channels, we can distinguish, among others: a website dedicated to expressing opinions, suggestions, commenting, social media, urban mobile applications and digital information boards (Rożałowska, 2021). Moreover, in their information activities cities are increasingly using social media (Woźnikowski, 2021) which enable them to reach a huge number of potential customers effectively and directly (Śledzińska and Włoch, 2020). Among several classifications of social media, the most popular is the one that classifies them according to two groups of factors such as: social presence/ media richness and self-presentation and self-disclosure (Kaplan and Haenlein, 2010).

The multitude of functionalities available on social media leads to them being used by diverse stakeholders to achieve their objectives. Social media can be used by cities for urban management (Gao et. al., 2020), sites promotion (Aftab and Khan, 2019), behaviour analysis (Chua et. al., 2021), adjustment of the offer to various age groups (Hysa et al., 2021), as well as sustainable tourism recovery (Hysa et al., 2022).

Social media users have an important meaning for their functioning. The value of services in social media and Internet instant messengers increases with the increase of the number of users (Śledzińska and Włoch, 2020). This is due to the fact that they are both information recipients and content suppliers. It is, therefore, crucial to know users' motivations for using this medium. Motivation is the force and direction of behaviour and the factors that make people behave in a certain way (Armstrong and Taylor, 2015). This is why, in order to increase the number of social media users, it is crucial to know the factors/motivators that make them use social media in a particular way. It has been found that employees use social media more often if their needs in terms of autonomy, competence and connections are met (Oksa et al., 2021). Research results show that there are differences in the motivation for using social media between women and men (Dedeoglu, 2018). Interestingly, motivation to disclose information in social media can have interpersonal nature, which involves relational maintenance and social validation, and intra-personal nature, which involves self-expression/relief and the need for identity clarification (Luo and Hancock, 2020). In view of the diverse factors that can influence motivation, it is useful to identify the activities undertaken on social media by users.

Being active in social media ensures unprecedented levels of visibility (Uldam, 2018). Users of social media make self-disclosure, which allows for building loose relations as well as following each other's cues (Shane-Simpson, 2018). It has been observed that members of a social network participate in the development by sharing different opinions. Additionally, they are unconsciously motivated to create a homogeneous opinion, which is promoted by everyone as an opinion leader (Shareef et al., 2019). This indicates that activity in social media can influence opinion-shaping, behaviour and have a significant impact on decision making. What is interesting is that individuals are likely to be influenced by their peers in the use of Facebook apps but that their intention to use these apps declines as privacy concerns increase (Van der Schyff, 2020).

Tourism is an important market segment. In 2019 there were 1464 million international tourist arrivals (UNWTO, 2019). In 2021 there were 415 million international tourist arrivals, where 67% took place in Europe (UNWTO, 2021). Social media play an important role in tourism, as an information source and communication channel (AARP Research, 2020). It has been observed that social media are used by tourists to obtain information (Hu et al., 2017), share experiences (Graziano and Albanese, 2020) and plan journeys (Constantoglou and Trihas, 2020). Additionally, thanks to social media the users build relations with local communities (Oltra González, 2021), thanks to which it is possible to obtain information or solve local problems together. Social media are also used to plan a journey, during and after the journey (Hysa et al., 2021). However, diversification in motivation to share tourism experience has been observed (Munar et al., 2014), as well as in motivation to travel (Naidoo et al., 2015). This indicates a situation in which factors that make tourists use social media are diversified.

However, the literature lacks comprehensive research that would provide an analysis of motivation for the use of social media by tourists.

3. Analysis of research findings

The objective of the analysis is to determine whether latent variables (constructs) regarding tourists' motivations can be found in the studied social media use behaviour of tourists. Research on the use of social media (SM) in tourism was conducted in Poland in the last quarter of 2019 and supplemented in 2020.

3.1. Methods and data collection

The research was conducted with the use of an on-line questionnaire with seven questions. The first three questions concerned the characteristics of the respondents' general behaviour in social media. Respondents were asked about the time and frequency of SM use as well as about SM profile settings. Responses to these questions were measured on a nominal or ordinal scale. The four remaining questions had an extensive structure, including the study of respondents' agreement with the opinions on the use of social media in tourism. Responses to these questions were measured using the Likert scale.

After the initial selection of collected questionnaires, 397 respondents were qualified for further analysis, which exceeded the minimum random sample size estimated at 386 questionnaires (for the assumed maximum statistical error rate of the sample of ±5% and the confidence level p = 0.95). Table 1 contains detailed information on the respondents participating in the survey.

Table 1.
Structure of respondents

Gender of respondents [%]	
Female	59.4%
Male	40.6%
Length of using SM [%]	
Under 6 years	78.84%
From 4 to 6 years	8.06%
From 2 to 4 years	2.52%
Up to 2 years	2.27%
I don't remember	8.31%
Never used	0%

Source: Based on own study.

To answer the research question regarding tourists' motivations for using social media during tourism trips, factor analysis was performed. For the purpose of the analysis, 3 questions from the survey questionnaire were selected (questions 4, 5 and 6) in order to find latent variables. While all variables from question 7 were treated as a separate construct called "Motivation for activities in SM". Question no. 7 was not considered in the factor analysis as it had a slightly different nature. While questions 4, 5 and 6 involved behaviours and the use of SM in terms of tourism, question no. 7 included direct statements on the motives and motivations for using SM in relation to tourism. Thus it was assumed that question no. 7 will be a separate construct (it was called Motivation for activities in SM). Then all the constructs (both those obtained from the factor analysis and the construct of Motivation for activities in SM) were analysed for validity and reliability. Questions covered by the analysis are in table 2.

Table 2.
Analyzed questions

Item	Description
4_1	4. [Negative opinions and comments in social media make me resign from a holiday]
4_2	4. [I use social media to plan a trip]
4_3	4. [I check opinions / stories on places I want to visit on social media]
4_4	4. [I use social media to learn about the history and culture of tourist places]
4_5	4. [In social media, I am looking for information about hindrances and problems that may arise in the places I intend to visit]
4_6	4. [I use short term apartment rentals (e.g. Airbnb)]
4_7	4. [I use social media to establish relationships with the local community]
4_8	4. [Positive opinions and comments in social media encourage me to go on holiday]
5_1	5. [I use social media ongoing planning of further stages of a trip]
5_2	5. [I use social media obtaining information about the place of stay]
5_3	5. [I use social media commenting on events taking place in the place of stay]
5_4	5. [I use social media making contact with the local community]
5_5	5. [I use social media obtaining information about current events (cultural, entertainment, etc.)]
5_6	5. [I use social media current sharing experiences from a tourist trip]
5_7	5. [I use social media making contact with other tourists]
5_8	5. [I use social media obtaining information about current difficulties (e.g. traffic jams, accidents)]
6_1	6. [I am sending email/text messages from a travel trip]
6_2	6. [I share the experience of a travel trip by photo/video album for friends (e.g. Facebook)]
6_3	6. [I use social media to share the experience of a travel trip by public photo/video album]
6_4	6. [I use social media writing reviews (e.g. TripAdvisor, Booking.com)]
6_5	6. [I use social media posting statements and photos in social groups/ forums]
6_6	6. [I use social media posting on blogs]
7_1	7. [I use social media because I want to help others in making a decision regarding a planned tourist trip]
7_2	7.[I use social media because I want to protect others from bad choices during a tourist trip]
7_3	7. [I use social media because I want to participate in the creation of pages that turned out to be useful for me]
7_4	7. [I use social media because I want to maintain social contacts and friendships]
7_5	7. [I use social media because I like to share my impressions on the Internet]
7_6	7. [I use social media because I want to be more recognizable by publishing my experiences]

Source: Based on own study.

Data analysis involved two stages. At the first stage, a factor analysis was used, which enabled the identification of latent variables (constructs). At the second stage, the validity and reliability of constructs identified through the factor analysis and the preconceived construct *Motivation for activities in SM* were studied. In order to ensure an adequate level of validity and reliability of the studied constructs, criteria included in table 3 were used.

Table 3.
Criteria for assessment of validity and reliability of constructs

Reliability and Validity Indicators	Criteria
Indicator Reliability	item loadnings > 0,708
Internal Consistency Reliability	Composite Realibility and Cronbach's alpha > 0,7 and < 0,95
Convergent Validity	Average Variance Extracted (AVE) > 0,5
Discriminant Validity	Fornell- Larcker criterion
Indicator Reliability	item loadnings > 0,708
Internal Consistency Reliability	Composite Realibility and Cronbach's alpha > 0,7 and < 0,95

Source: Hair, 2011.

3.2. Results of research

Stage 1: Factor analysis for questions 4, 5, 6

To see if there was a basis for doing a factor analysis Bartlett's Test of Sphericity and the KMO test were performed. The obtained results confirmed the validity of the factor analysis (Table 4).

Table 4.
Results of tests to check the validity of use of the factor analysis

Alfa Cronbacha	0.88
Barlett sphericity test	Chi kw 3395,399 df210 p=0,0000
KMO test	General criterion KMO 0,872

Source: Own study.

Then eigenvalues were calculated to decide on the number of factors. With the use of Kaiser criteria, it was determined that these will be four factors that together explain 56.6% of data variability (table 5).

Table 5.
Statistics of eigenvalue

Value	Eigenvalue	% of total variance	Cumulative eigenvalue	Cumulative % of variance
1	6.515702	31.02715	6.51570	31.02715
2	2.903380	13.82562	9.41908	44.85277
3	1.296737	6.17494	10.71582	51.02771
4	1.176229	5.60109	11.89205	56.62880

Source: Based on own study.

When conducting the factor analysis, the Principal Components method was used as a method of distinguishing factors and Varimax rotation were applied. This way, the assignment of the variables under study to the four assumed factors was obtained. The results can be found in Table 6.

Table 6.
Factor analysis results

Variables	Loadings			
	f 1	**f 2**	**f 3**	**f 4**
4. Negative opinions and comments in social media make me resign from a holiday	-0.0026	0.0276	-0.1895	0.6995
4. I use social media to plan a trip	0.0803	0.2653	0.2084	0.7149
4. I check opinions /stories on places I want to visit on social media	0.0790	0.2917	0.0831	0.7514
4. I use social media to learn about the history and culture of tourist places	0.1888	0.4472	0.2233	0.4153
4. In social media, I am looking for information about hindrances and problems that may arise in the places I intend to visit	0.0185	0.4613	0.2323	0.4683
4. I use short term apartment rentals (e.g. Airbnb)	-0.0338	0.1021	0.7363	0.2125
4. I use social media to establish relationships with the local community	0.2962	0.1107	0.7063	-0.0092

Cont. table 6.

4. Positive opinions and comments in social media encourage me to go on holiday	0.1487	0.3590	0.0143	0.5595
5. I use social media ongoing planning of further stages of a trip	0.0894	0.6774	0.2347	0.2994
5. I use social media obtaining information about the place of stay	0.0585	0.7742	0.0862	0.2857
5. I use social media commenting on events taking place in the place of stay	0.6393	0.1727	0.3515	0.0227
5. I use social media making contact with the local community	0.4355	0.2785	0.6356	-0.1243
5. I use social media obtaining information about current events (cultural, entertainment, etc.)	0.1206	0.7306	0.1144	0.0908
5. I use social media current sharing experiences from a tourist trip	0.7512	0.2460	0.0982	0.0301
5. I use social media making contact with other tourists	0.5623	0.1752	0.5458	0.0078
5. I use social media obtaining information about current difficulties (e.g. traffic jams, accidents)	0.1684	0.7125	0.0077	0.1064
6. I am sending email/text messages from a travel trip	0.7541	0.0735	-0.0223	0.0887
6. I share the experience of a travel trip by photo/video album for friends (e.g. Facebook)	0.6886	-0.0624	0.1255	0.0780
6. I use social media to share the experience of a travel trip by public photo/video album	0.2752	-0.0418	0.5214	0.3028
6. I use social media writing reviews (e.g. TripAdvisor, Booking.com)	0.6344	0.1261	0.2340	0.1932
6. I use social media posting statements and photos in social groups/forums	0.6380	-0.0302	0.2648	0.0630

Source: Own study.

Based on the conducted factor analysis names of four constructs were identified. They are presented in Table 7.

Table 7.
Names of constructs identified in the factor analysis

No	Construct
cz1	Visibility in the crowd
cz2	Obtaining information about nearby events
cz3	Building relations with the local community
cz4	Relying on the opinions of others

Source: Own study.

Stage 2: Study of constructs' validity and reliability

Then the 4 obtained constructs (cz1, cz2, cz3, cz4) together with a preconceived construct about the motivation for activity (cz5) were analysed for validity and reliability. Satisfactory levels of indicators were not obtained. In order to obtain constructs' validity and reliability at the desired level, variables with the lowest loading were removed. Thus satisfactory levels of validity and reliability were obtained (Table 8).

Table 8.
Construct together with variables and statistics

Construct	Item	Loadings	AVE	CR	CA
Visibility in the crowd (cz1)	5_3	0.754	0.580	0.873	0.819
	5_6	0.810			
	5_7	0.743			
	6_2	0.753			
	6_5	0.747			
Obtaining information about nearby events (cz2)	4_4	0.746	0.609	0.861	0.768
	5_1	0.843			
	5_2	0.817			
	5_5	0.708			
Building relations with local community (cz3)	4_7	0.890	0.817	0.899	0.777
	5_4	0.917			
Relying on the opinions of others (cz4)	4_2	0.790	0.654	0.850	0.740
	4_3	0.818			
	4_8	0.818			
Motivation for activities in SM (cz5)	7_3	0.749	0.661	0.886	0.828
	7_4	0.863			
	7_5	0.858			
	7_6	0.776			

Source: own study.

In order to study the Discriminant Validity, Fornell-Lacker criterion was used. The highest scores on the main diagonal indicate a good level of Discriminant Validity (Table 9).

Table 9.
Fornell-Lacker ctiretion

	(cz2).	(cz3).	(cz4).	(cz1).	(cz5).
(cz2).	0.780				
(cz3).	0.350	0.904			
(cz4).	0.596	0.237	0.809		
(cz1).	0.400	0.620	0.324	0.762	
(cz5).	0.303	0.520	0.248	0.717	0.813

Source: Based on own study.

Summary of results

When answering the research question posed in the paper it has been found that tourists' behaviour in social media is related to the following latent variables concerning the use of SM: 1) Visibility in the crowd, 2) Obtaining information about nearby events, 3) Building relationships with the local community, 4) Relying on the opinions of others. Moreover, for the found constructs to have an adequate level of validity and reliability, these constructs should be defined by the following variables:

- construct 1 consists of the following variables: *I use social media to*: *comment on events taking place where I am, share experiences from the tourist trip on an ongoing basis, make contact with other tourists, keep a photo/video album on the Internet for friends (e.g. Facebook), post statements and photo reports in social groups/forums e.g. Facebook;*

- construct 2 consists of the following variables: *I use social media to*: *learn about the history and culture of tourist destinations, plan the next stages of my journey on an ongoing basis, to stay informed about the place I am in, get information about current events (cultural, entertainment, etc.);*
- construct 3 consists of the following variables: *I use social media to*: *build relationships with the local community, make contact with the local community;*
- construct 4 consists of the following variables: *I use social media to*: *plan the trip, check opinions/reports on social media about the places I want to visit, Positive reviews and comments on social media encourage me to travel.*

The analysis of validity and reliability has confirmed the accuracy of the preconceived construct 5 *Motivation for activities in SM* (statistical measures related to validity and reliability had satisfactory levels).

- construct 5 consists of the following variables: *I use social media to: help others make a decision about a planned tourist trip, warn others about bad choices on a tourist trip, participate in the creation of websites that have proved useful to me, maintain social contacts and friendships, share my experiences on the Internet, be more recognizable by publishing my experiences*.

4. Conclusion

Modern technologies support efficient city management, which is influenced by the implementation of IT solutions that facilitate tourism management. This is due to the possibility of extracting information from large data sets and the implementation of smart city solutions. The possibility of social media use allows for achieving assumed goals both by the city authorities and the users. Due to the significant importance of the amount of data that are necessary for smooth city management, it is worth knowing the motivation of social media users.

The research conducted indicates the direction of behaviour of tourists who use social media. Based on the analysis of social media usage by tourists, four motivators of their behaviour were identified. They result from factor analysis of latent variables and they are: 1) Visibility in the crowd, 2) Obtaining information about nearby events, 3) Building relationships with the local community, 4) Relying on the opinions of others. Moreover, the analysis has shown a correctly preconceived construct concerning Motivation for activities in SM.

This paper has filled a research gap in the field of tourism management, smart city and the use of modern technologies. A proprietary research questionnaire was used in the study. Moreover, new insights were provided concerning motivators and behaviours of tourists when using social media. This information can be used by city managers, tourism organisations, tourism facility managers. Thanks to identifying motivators for using social media by tourists, it is possible to take multi-faceted measures aimed at influencing tourist behaviour. These measures can result in the desired objectives being achieved, e.g. relations between tourists and the local community will be built. This will also enable the identification of people who are motivated to be visible in the crowd and offer them cooperation in the promotion of tourist destinations or attractions.

The paper's limitation is the fact that the research was conducted only in Poland. In the future, it is planned to conduct the research also in other countries in order to make international comparisons. Moreover, there is no identification of motivators in particular age groups. Therefore, an in-depth research is planned for the future, which would be directed at studying the intensity of individual motivators in particular age groups.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

THE USAGE OF RENEWABLE ENERGY SOURCES BY COUNTRIES IN THE VISEGRÁD GROUP. DIAGNOSIS AND ENVIRONMENTAL EFFECTS

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Purpose: The goal of this article is evaluation and comparative analysis of the usage of renewable energy sources in the countries of the Visegrád Group in the years 2000-2020, in context of the current environmental situation in the European Union, concerning the reduction of CO_2 emissions.
Design/methodology/approach: The data regarding the creation of renewable energy used in this article is divided into: solar energy, wind energy, biomass and hydroenergy the division, in order to evaluate their usage in the energy mix of the Visegrád Group nations. Furthermore, in the research, the data on CO_2 emissions in those countries has been used to measure the effects of the European Union's environment policy. This analysis used: average annual rate of change, trend function, as well as dependency analysis using the Pearson correlation coefficient.
Findings: The results of the study suggest, that all of the countries belonging to the Visegrád Group take systemic measures to increase the share of renewable sources in the energy mix (most intensively in Poland). Nonetheless, the countries that reduce CO_2 emissions the fastest are the Czech Republic and Slovakia. A smaller amount of success in this area is noted by Hungary. The CO_2 emission rate per capita in Poland is maintained on a constant level, which shows ineffectiveness of the actions taken as part of the environmental policy.
Research limitations/implications: The main limitation of the study is the usage of simple analytical methods of evaluation, that result from poor quality of available data and the restriction of the environmental effect assessment, which only identifies the correlation of linear relationships between CO_2 emissions and the involvement of renewable sources in the energy mix of the studied countries.
Practical implications: The results represent a foundation for recommendations to address the energetic policies of the studied countries. They may also serve as an example of the energy mix transformation in growing economies.
Social implications: The results point to a low usage of renewable energy in the Visegrád Group and also partly (Poland, Hungary) a small range of the reduction of CO_2 emissions per capita, which suggests the need to intensify actions for more efficient energy mix transformations, as well as sustainable development in the studied countries.

Originality/value: The authenticity of the study results stems from a comparative analysis of the Visegrád Group's countries energy resource mix. Another advantage of this analysis is its embedding in the context of CO_2 emission results.

Keywords: renewable energy sources; energy policy; resource economics; energy mix analysis.

Category of the paper: research article.

1. Introduction

In the current conditions of growing economies, great importance is attached to environmental protection, as well as sustainable growth, which guarantees maintenance and/or improvement of the quality of life for current and future generations. These priorities are of great importance, particularly for the European Union, which has been realizing its deeply regulated environmental policy, focused on minimizing the usage of non-renewable energy sources, along with reducing CO_2 emissions. This finds confirmation in a few key, systematically implemented documents, that regulate the functioning of energetic policy in all of the states making up the European community. Currently it is stated, that by 2030 (https://www.europarl.europa.eu/factsheets/pl/sheet/68/polityka-energetyczna-zasady-ogolne):

- at least 40% of greenhouse gas emissions will be reduced in comparison to the levels from 1990,
- there will be an increase up to 32% of the share of renewable energy in all sources of energy,
- the energetic efficiency will improve by 32,5%,
- at least 15% of EU electrical power systems will be interconnected.

In context of such ambitious intentions, it is very important to monitor the environmental effects of energy strategies adopted by various European Union countries, especially those encountering problems in the process of executing European climate policy.

Having in mind the circumstances stated above, the goal of this article is evaluation and comparative analysis of the usage of renewable energy sources in the countries of the Visegrád Group in the years 2000-2020, in context of the current environmental situation in the European Union, concerning the reduction of CO_2 emissions. Additionally, the article attempts to answer the following research problems:

- What is and how does the usage of renewable energy sources change throughout time in the energy mix of Visegrád Group countries since the intensification of EU's environmental policy incorporated in the years 2000-2020?

- Which renewable energy sources are used by countries belonging to the Visegrád Group?
- How does the CO_2 emission rate per capita change in the Visegrád Group countries in reference to the scope of renewable sources used in order to satisfy energetic needs?

During the research process, the data from *BP Statistical Review of World Energy* and *Eurostat* were used. Several techniques used to conduct research were: literature studies, dynamic and structural analysis, trend analysis and the identification of dependence, that was realized with the help of the Pearson correlation coefficient.

2. Literature overview

As mentioned above, the key goal of the European Union's environmental policy is the reduction of CO_2 emissions, which is related directly with the energy industry, responsible for about 2/3 of emissions. With regard to the Union's concept, such a goal should be realized primarily by expanding the scope of renewable energy source usage in the energy mix of the Union's Member States. The existing results, stemming from executed analyses, experiments and studies, show that the achievement of this goal is complicated and often ineffective, due to a few factors.

The first factor being the need of deep and often prolonged overhaul of energetic infrastructure. This, in turn, requires a substantial amount of capital, as well as well-planned, effective energetic policies, realized in a consistent manner (Zhang and Wang, 2022; Vérez et al., 2022).

The second factor deals with the cost of renewable energy. Existing studies and experiments show, that renewable energy sources are in need of subsidizing (Al-Refaie and Lepkova, 2022; Dolores et al., 2022; Lee and Xydis, 2022), which, in turn, is related to additional costs for local and national budgets.

The third factor is linked to political circumstances. Political terms do not favor consistent execution of given energetic policies. Oftentimes, once defined directions of development of renewable energy sources are negated and changed, this, on one hand, prevents grounding the effects of the taken actions and, on the other, creates uncertainty and reluctance to take initiatives in the future.

The fourth factor is akin to the environmental awareness of households and corporations in a given country (Janik et al., 2021; Ober and Karwot, 2022). The lesser it is, the worse are the effects of energetic transformation, in which all participants of socio-economic life must comply. In this case, another barrier is the income, which often limits environmental actions, despite higher ecological awareness of citizens.

As a result, the achievement of environmental policy goals set by the EU is most effective in well-developed Western European countries, backed by free market and democratic traditions. According to current study results, the countries, which are handling ecological challenges best, are the Scandinavian countries, Germany, Great Britain and France (Trotta, 2020; Goh and Ang, 2018; Saidi and Omri, 2020; Li et al., 2016). The economies of Central and Eastern Europe encounter many barriers, that deeply complicate and slow down energetic transformation. As a result, this group of countries shows poor environmental effects in the form of insignificant CO_2 emission reduction (Grosse, 2011; Ptak, 2009, 2014; Maśloch, 2009). The only countries, which are efficient in lowering greenhouse gas emissions in this region are the Czech Republic and Slovenia. The rest of the countries in this group are known to be less effective in taking on the EU's environmental policies.

This is known to be a typical case for emerging and developing economies, which is confirmed in studies conducted worldwide. Regions such as Asia, Africa and Central America deal with similar problems (Dokas et al., 2022; Esquivias et al., 2022; Lee and Yoo, 2016). This primarily results from those countries' heavy usage of cheaper and easier to access non-renewable materials, as well as problems in maintaining consistence in working to reach ecological goals. It is important to note that these regions do not display common ground in environmental policies, which impose radical changes in the energy mix. The absence of formal regulations and financial restrictions connected to CO_2 emissions – as shown in current studies – does not support effective prevention of degradation of the natural environment (Wolde-Rufael and Weldemeskel, 2020; Guo and Wang, 2022; Beal and King, 2022).

3. Research method

The data regarding the creation of renewable energy used in this article is divided into: solar energy, wind energy, biomass and hydroenergy the division, in order to evaluate their usage in the energy mix of the Visegrád Group nations. Furthermore, in the research, the data on CO_2 emissions in those countries has been used to measure the effects of the European Union's environment policy. This analysis used: average annual rate of change, trend function, as well as dependency analysis using the Pearson correlation coefficient.

The methods stated above were used to solve the following problems:

- What is and how does the usage of renewable energy sources change throughout time in the energy mix of Visegrád Group countries since the intensification of EU's environmental policy incorporated in the years 2000-2020?

- Which renewable energy sources are used by countries belonging to the Visegrád Group?
- How does the CO_2 emission rate per capita change in the Visegrád Group countries in reference to the scope of renewable sources used in order to satisfy energetic needs?

The studies and description of results have been divided into two stages. During the first stage, the usage of renewable energy sources in energy mixes, as well as their structure were analyzed. The second stage concentrated on the environmental effects of climate policy in the form of CO_2 emission reduction in the studied countries.

4. Research results

4.1. The analysis of the share of renewable sources in energy mixes

The first step was the analysis of the change in the share of renewable sources in the energy mixes of the studied countries, as well as pointing to their development tendencies. The sum of used solar, hydro- and biomass energy was considered. The results are shown in Figures 1-2.

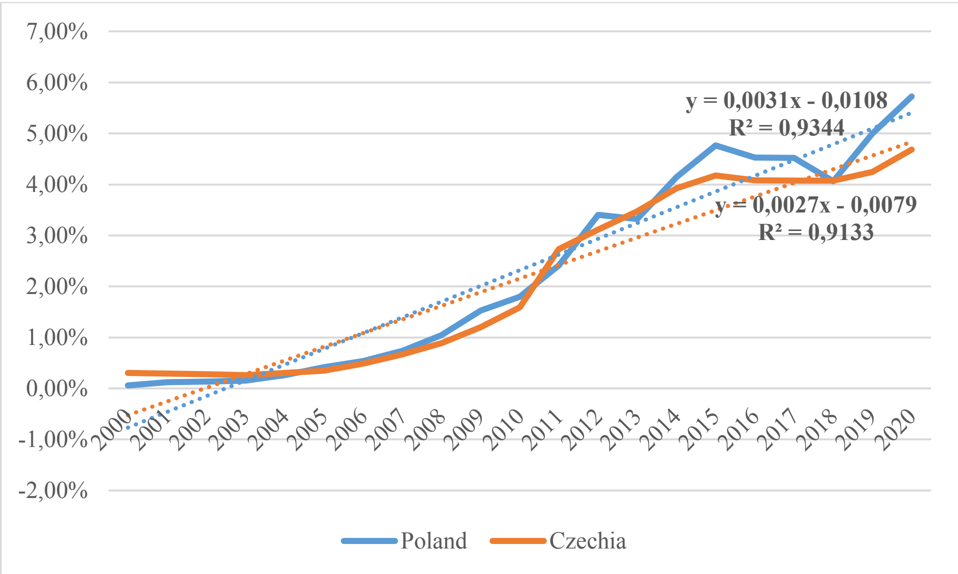

Figure 1. The share of non-renewable sources in the energy mixes of Poland and Czech Republic in the years 2000-2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

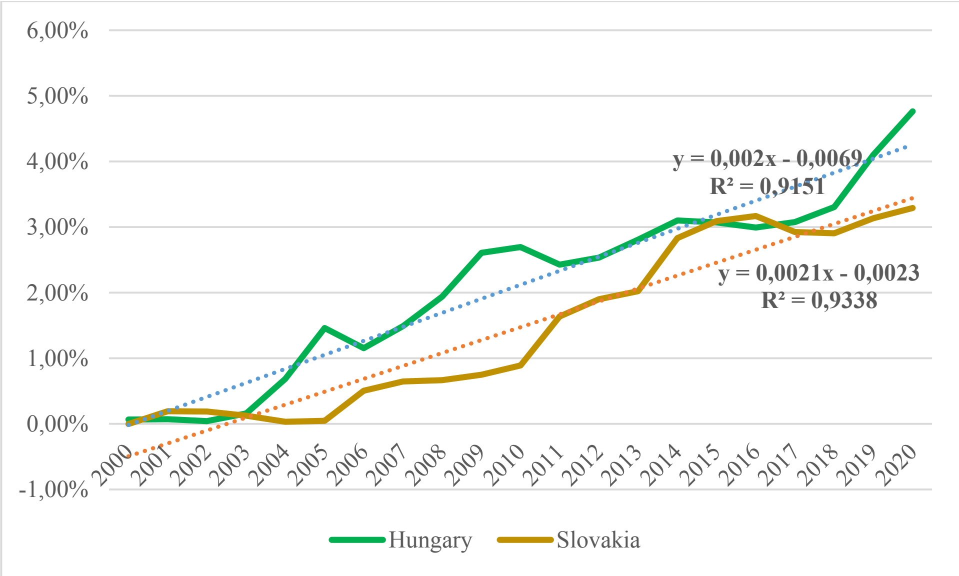

Figure 2. The share of non-renewable sources in the energy mixes of Hungary and Slovakia in the years 2000-2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

And yes, the total share of renewable sources in energy mixes in the studies countries has passed 6% only in Poland. In the Czech Republic and Hungary, the share came close to 5%, however the lowest level was noted in Slovakia (not much higher than 3%). All of the studied countries note upward trends, which shows that countries are putting a great effort into trying to achieve the goals set by the EU's environmental policy and they systematically increase the usage of solar, hydro- and biomass energy. All of these trends are well-suited, which may suggest a high probability of further growth and increase in share of renewable energy sources, in order to satisfy energetic needs in the studied countries. It also confirms their slow, but sure energetic transformation. It is important to note that the interpretation of the coefficient of the trend's linear function leads to the conclusion that the share of non-renewable sources had its quickest growth in the energy mix of Poland (0.31% annually) and the Czech Republic (0.27% annually). Smaller, but similar growth could be observed in Hungary (0.2% annually) and Slovakia (0.21%). In the last three years of analysis, the growth rate increased extensively in Poland and Hungary. Initial observations show that Poland and the Czech Republic are the most efficient in achieving the environmental goals of the European Union, Hungary being the country to follow and Slovakia having the slowest growth rate.

The conclusions stated above are confirmed by the statistics of the share of renewable sources in energy mixes of Visegrád Group countries shown in Figure 3. Poland and the Czech Republic were characterized by the greatest average share during the study. The share in these countries also changed most intensively, which was a result of an acceleration in energetic transformation after 2010.

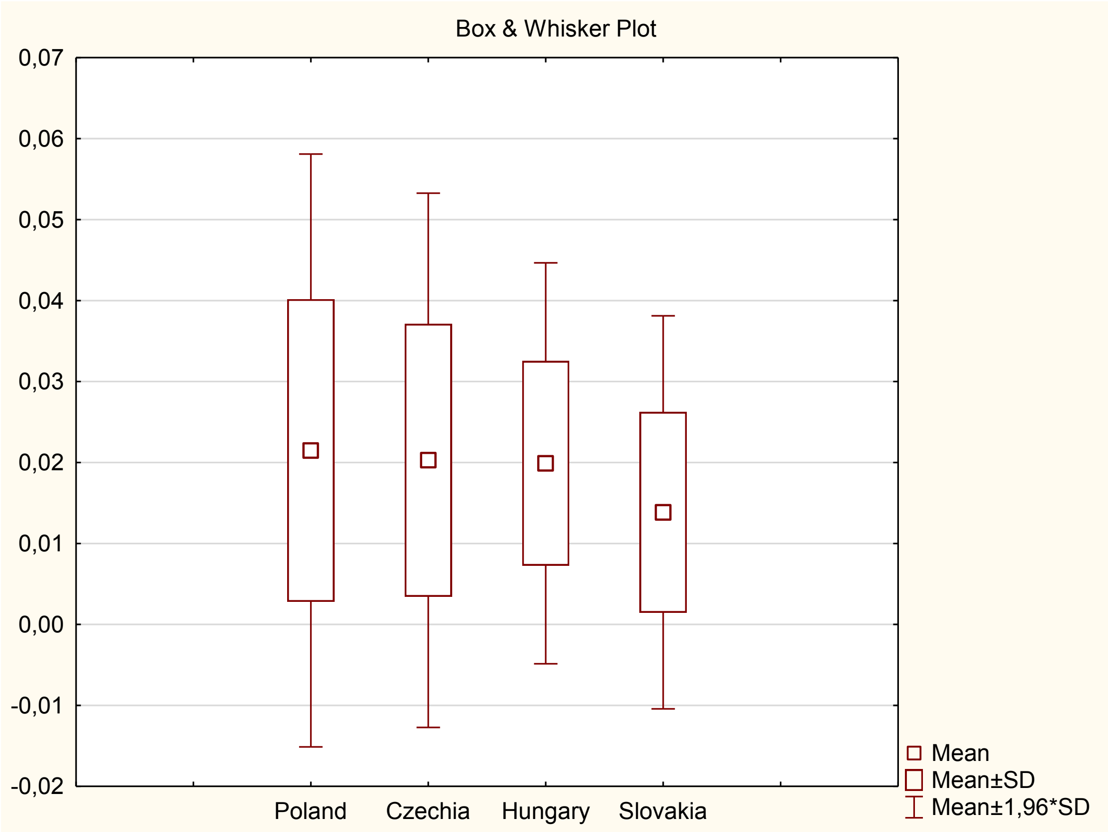

Figure 3. The box plots show the share of renewable sources in the energy mixes of the studied countries in the years 2000-2020. Source: own work.

In line with the previous conclusions, Poland and the Czech Republic are characterized by a similar development path of renewable energy sources in the years 2000-2020. This is also confirmed by Pearson's linear correlation coefficients between the shares of renewable sources in the energy mixes of the analyzed countries presented in Table 1. All values included in the table are statistically significant and indicate that the scale of changes made in the analyzed period in Poland, the Czech Republic and Slovakia were almost identical. On the contrary, the least similarity concerned Hungary, where the identified correlations were the weakest.

Table 1.
Correlation matrix for the share of renewable sources in the energy mixes of the studied countries for years 2020-2021

Country	Correlation coefficients			
	Poland	**Czech Republic**	**Hungary**	**Slovakia**
Poland	1.0000	0.9911*	0.9220*	0.9891*
Czech Republic	0.9911*	1.0000	0.8973*	0.9898*
Hungary	0.9220*	0.8973*	1.000	0.8862*
Slovakia	0.9891*	0.9898*	0.8862*	1.0000

$p < 0.001$*
Source: own work.

In the next part, an analysis of the structure of the use of individual non-renewable sources was performed on the example of 2020 – the most recent in the studied time series. The results for individual countries are presented in Figures 4-7.

And yes, in Poland (Figure 4) the most popular was wind energy, followed by biomass. Solar energy was used to a small extent, but it should be noted that currently the energy policy of Poland actively supports the acquisition of solar energy, which may lead to an increase in the share of this source in meeting the national energy needs.

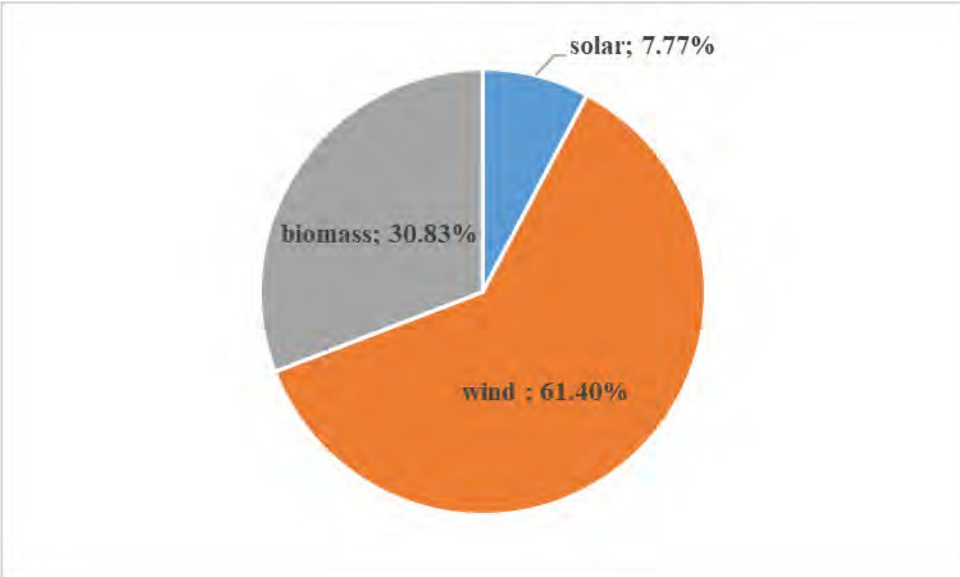

Figure 4. The structure of the use of renewable sources in Poland in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

The Czech Republic (Figure 5), on the other hand, had biomass as the largest share in renewable sources, constituting approx. 2/3 of the total use of these sources. The second most important source was solar energy. Meanwhile, wind energy was used to a small extent. Thus, despite the similarity in the development tendencies and the level of use of renewable sources, the mixes of these sources for the Czech Republic and Poland differ significantly, which results both from the chosen directions of energy policy development and from climatic and geographical conditions (e.g., the possibility of creating wind farms in Poland near the sea, not available in the Czech Republic).

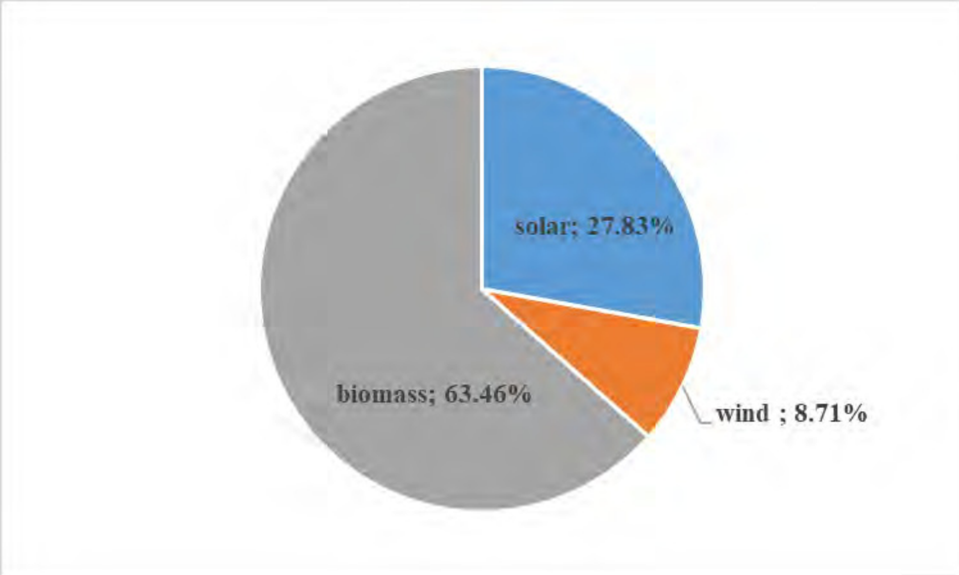

Figure 5. The structure of the use of renewable sources in the Czech Republic in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

Hungary displays a similar mix of renewable sources. It is dominated, similarly, by solar and biomass energy (Figure 6). Wind energy was only a minor supplement to renewable sources.

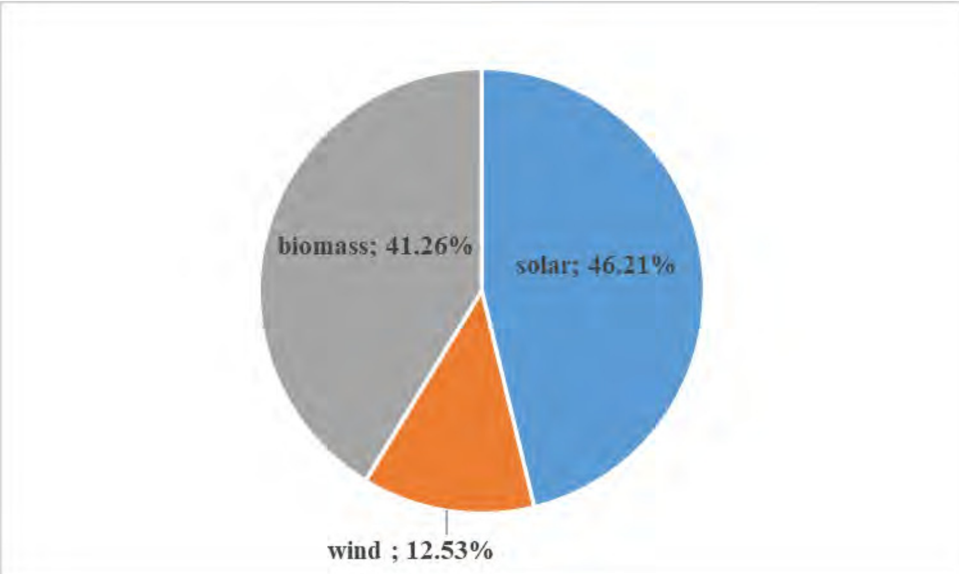

Figure 6. The structure of the use of renewable sources in Hungary in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

In turn, in the Slovak mix, biomass was primarily used, which was supplemented with solar energy. The use of wind energy was marginal. Therefore, despite the geographical proximity of the countries making up the Visegrád Group, each of them used different proportions of renewable energy sources.

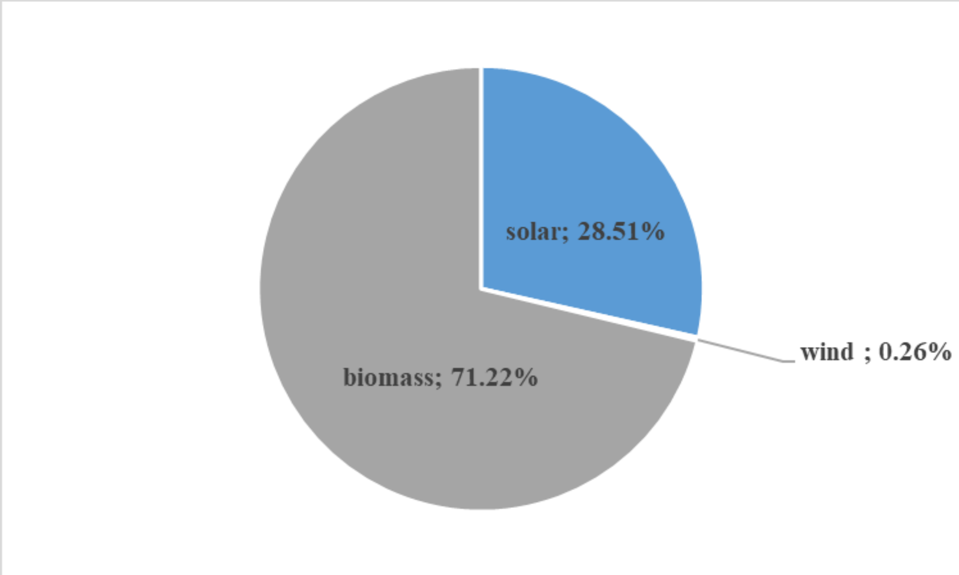

Figure 7. The structure of the use of renewable sources in Slovakia in 2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

As mentioned in the introduction, hydroenergy is also included among low-emission and renewable energy sources. Its share in the energy mix of the studied countries is shown in Figure 8. The data presented there shows that this source was used to the greatest extent in Slovakia (3-9%). In other countries, the share of hydroenergy in satisfying energy needs did not exceed 2%. It can, therefore, be concluded that Slovakia chose a different direction of energy transformation than the other 3 countries, choosing hydroenergy to a greater extent than classic renewable sources (solar, wind or biomass energy).

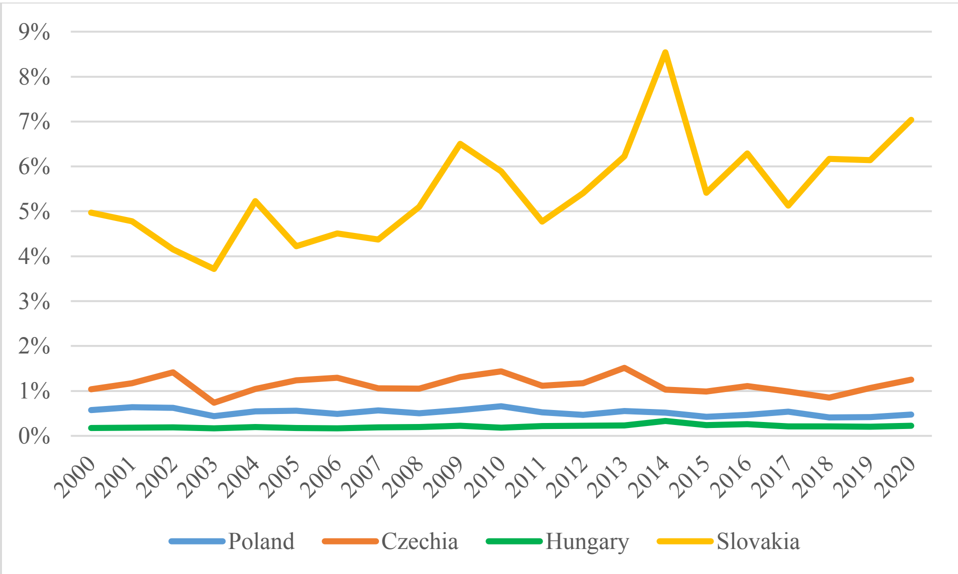

Figure 8. The share of hydroenergy in the energy mix of the studied countries in the years 2000-2020. Source: own study based on the data of the *BP Statistical Review of World Energy*, 2021.

4.2. Evaluation of effectiveness of changes made to the energy mix in the context of CO_2 emissions

In the second stage of the study, the impact of changes in the share of renewable sources in the energy mix on the reduction of CO_2 emissions was analyzed. The reduction of CO_2 – in terms of the assumptions of the EU energy policy – is to be the main effect of the pro-environmental energy transformation. The degree of reduction achieved by the studied countries of the Visegrád Group in absolute terms is shown in Figure 5.

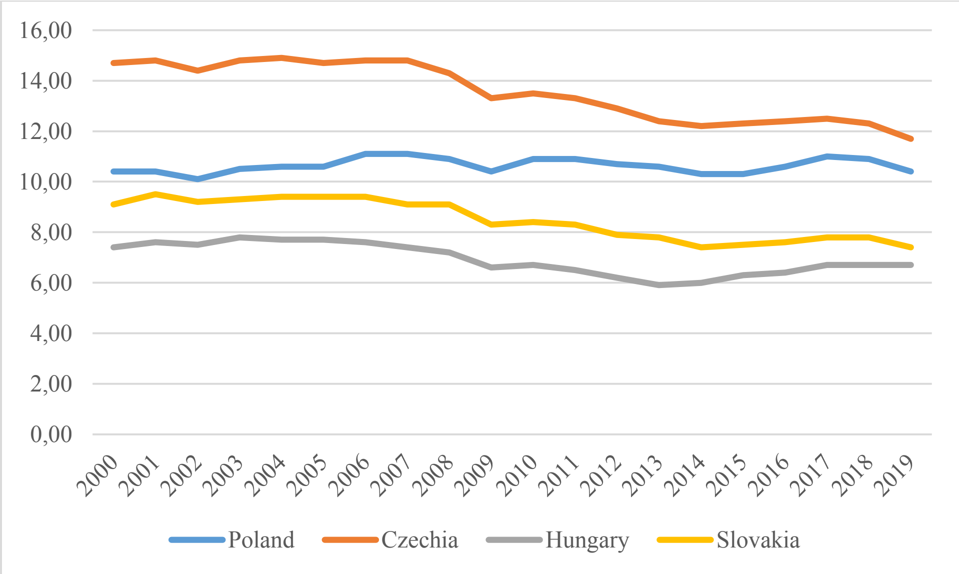

Figure 5. CO_2 emissions per capita in the studied countries in the years 2000-2020 [ton per citizen]. Source: own work.

Starting from 2009, CO_2 emissions in the Czech Republic, Slovakia and Hungary have been systematically decreasing. Poland was not able to maintain the same rate of reduction. The chart clearly shows two periods, in which the emission of CO_2 in Poland increased. Its highest level was characteristic for the Czech Republic and Poland – this situation did not change until the end of the analyzed period.

The lack of effective CO_2 reduction in Poland is confirmed by the correlation coefficient between the share of renewable sources in the energy mix and the level of CO_2 emissions (Table 2). It is the only country in the study, where no statistically significant correlations were found between increasing the share of renewable sources in the energy mix and reducing CO_2 emissions. For instance, there is a strong correlation in the Czech Republic and Slovakia. Hungary displays a weaker one, but still clearly indicative of the mutual negative correlation of the described variables.

The observations above are also confirmed by the average annual rate of change in CO_2 emissions and the level of its reduction in the twenty-one-year research period. In Poland, both the first and the second parameter were 0.00%, while in the leading Czech Republic, CO_2 emissions were reduced annually by approx. 1.19%, which allowed to reduce it by over 1/5 in the years 2000-2020. Slovakia achieved a similar effectiveness in reducing CO_2. Even in

Hungary, which showed significantly worse results, CO_2 emissions decreased annually by 0.52% and, finally, in 2020 it was reduced by 9.46% compared to 2000.

Table 2.
Pearson linear correlation coefficients for the share of renewable sources in energy mixes and CO_2 emissions, as well as the average annual rate of change in CO_2 and the total change in CO_2 emissions in 2000-2020

Country	Statistical parameters		
	Correlation coefficient	Average annual rate of change	Changes throughout 2000-2021
Poland	-0.0016	0.00%	0.00%
Czech Republic	-0.9691*	-1.19%	-20.41%
Hungary	-0.8188*	-0.52%	-9.46%
Slovakia	-0.9475*	-1.08%	-18.68%

$p < 0.001$*

Source: own work.

5. Discussion

The results of the analyses confirm the observations described in the literature on the subject. Emerging economies struggle to increase the share of renewable sources in their energy mix. In the studied group – as in other described countries with a similar degree of economic development – non-renewable sources are predominantly used to meet energy needs. This is difficult to change, especially in the context of a large economic gap separating the countries of the Visegrád group from the leaders of the EU economy.

As a result, the environmental effects in the form of reducing CO_2 emissions in the studied regions are not impressive. Although it is worth emphasizing the achievements of the Czech Republic, which not only systematically increases the share of renewable energy sources in the mix, but also effectively and quickly reduces CO_2 emissions per capita. The success of the Czech energy sector in this area is also confirmed by previous analyzes, pointing to the country as an example of the effective implementation of environmental goals, also in developing economies. It is worth adding that the Czech Republic has given up hard coal mining and its use in the energy sector, and is systematically using nuclear energy, which certainly also has a positive effect on the scope of greenhouse gas emissions.

In the context of the statements and observations above, the recommendations for the studied economies should primarily include the intensification of actions to increase the share of renewable sources in the energy mix, because, in the light of the research results, the EU intention to increase this share to 35% in 2030 seems unrealistic. According to the guidelines of theory and practice, the following may be helpful in this respect: consistent and unchanging energy policy, subsidizing renewable energy sources and spreading ecological awareness in the society.

6. Summary

The results of the study suggest, that all of the countries belonging to the Visegrád Group take measures to increase the share of renewable sources in the energy mix. Nevertheless, the rate of change and the comparison of the surveyed countries with the leaders of the European energy transformation, such as Germany or the Scandinavian countries, testify to a very slow annual growth and the level of the total share of renewable sources in meeting energy needs in the surveyed regions. In these terms, the leader is Poland, with Slovakia being the weakest in taking these measures.

The energy mixes of renewable sources of the studied Visegrád Group countries differ in the proportions of the use of these sources, which indicates that the paths of energy transformation are individualized, despite their geographical proximity. There are, however, similarities between Slovakia, the Czech Republic and Hungary, which mainly use biomass and solar energy, while Poland focuses on wind and biomass. Common to all mixes is the significant use of biomass. It is also worth noting that Slovakia – apart from solar, wind and biomass energy – also uses hydroenergy to a large extent, which is treated as a low-emission source of energy, enriching its energy mix and diversifying the risk associated with suppliers of energy carriers.

In the conducted analysis, attention was also paid to the result of the adopted energy policies, assessed in the context of reducing CO_2 emissions. In this category, the best results are achieved by the Czech Republic and Slovakia, which show the highest rate and level of overall emission reduction. Hungary is characterized by a lower dynamic of changes, but the overall observed trends also prove the effectiveness of the implementation of environmental objectives, although they are implemented to a lesser extent. For Poland, both the rate of change and the level of CO_2 reduction equals 0.00%, which proves the ineffectiveness of the pro-environmental energy policy.

The main limitation of these analyses is the usage of simple statistical methods of evaluation, that result from poor quality of available data and the restriction of the environmental effect assessment, which only identifies the correlation of linear relationships between CO_2 emissions and the involvement of renewable sources in the energy mix of the studied countries.

Therefore, further research should be focused on an in-depth analysis of the initially identified relationships between the use of renewable sources in the studied countries and the effects of the implementation of the EU climate policy. It would also be worth identifying the reasons for the low effectiveness of actions taken for the benefit of sustainable energy.

Acknowledgments

The research was financed from a research grant awarded to the Department of Economy and Informatics (Faculty of Organization and Management of the Silesian University of Technology) no. 13/010/BK_22/0065.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

POSSIBILITIES OF USING HYDROGEN BUSES IN URBAN TRANSPORT

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Purpose: The aim of this paper is to present the possibilities of using hydrogen buses in urban transport taking into account technological, economic and environmental conditions.
Design/methodology/approach: Analysis of international literature, Polish literature and reports related to the development of alternative energy sources in vehicles and urban transport development.
Findings: The Polish government to achieve the environmental requirements of the European Union obliges local government units to ensure the share of zero-emission buses in the fleet of vehicles in use. On the basis of the conducted analysis we can say that a significant advantage of hydrogen vehicles is the total lack of emissions, a long range of up to 350-400 km and short charging times. However, a significant problem is insufficient infrastructure – not enough hydrogen stations. Despite this difficulty, more and more manufacturers are interested in producing hydrogen vehicles, and investors are seriously considering the costs and benefits of zero-emission buses. Unfortunately, none of the economic analyses that have been commissioned by Polish companies providing transport services have shown the viability of using hydrogen buses.
Originality/value: The paper shows the global trends in the development of city buses with particular attention to hydrogen buses.

Keywords: bus, hydrogen propellant, zero-emission vehicles.

Category of the paper: general review.

1. Introduction

Electricity is one of the fastest growing alternative energy sources in urban transport vehicles. However, as with conventional energy sources such as oil and coal, electricity is not the primary source of energy. A fully charged battery carries only energy from other, often conventional, sources. Electric vehicles with batteries (BEV) are very efficient in converting energy from the grid into motive power. They can also recover energy while driving by using regenerative braking. One of the major disadvantages of BEVs is that they tend to be limited in range due to the size and cost of the batteries needed to power the vehicle and the energy requirement. Charging the battery systems can take several hours, not a few minutes as in a conventionally powered vehicle (CV). In order to make use of the advantages of both electric and conventional vehicles and to bridge the gap between CV and BEV, an alternative is being considered which could be a hydrogen fuel cell electric vehicle (FCEV). Hydrogen is a chemical energy carrier capable of generating electricity up to 39.39 kWh / kg, which exceeds the energy density of most batteries. A fuel cell (FC fuel cell) works in a similar way to an ICE internal combustion engine. The ICE converts the chemical energy of the fuel supplied to the engine to produce mechanical energy used to propel the vehicle. FC works in a similar way to ICE in that the chemical energy is directly converted into electricity in FC, but in an environmentally friendly process. Unlike a battery, which depletes when it is used to power electrical components, internal combustion engines and fuel cells act as continuously operating energy sources as long as they are supplied with fuel. Therefore, it is anticipated that a hydrogen fuel cell could overcome the disadvantages of BEV, making hydrogen the transport fuel of the future. Hydrogen produces zero harmful emissions, which is one of the most significant benefits of using FC (Manoharan et al., 2019).

A fuel cell (FC) is an electrochemical reactor that converts the chemical energy of the fuel and oxidant directly into electricity. The term fuel cell is used almost exclusively to describe a reactor that uses hydrogen as the main source of energy (Rosen and Koohi-Fayegh, 2016). Hydrogen and oxygen are supplied to the fuel cell separately (Fig. 1). The electrodes are separated by an electrolyte. The hydrogen molecules first enter the hydrogen electrode (called the anode) of the fuel cell. The hydrogen molecules then react with the anode-coating catalyst to release electrons to form a positively charged hydrogen ion. These ions pass through the electrolyte and reach oxygen in a second electrode called the cathode. The electrons 'flow' into the electric circuit, generating the current of the fuel cell system. At the cathode, the catalyst causes hydrogen ions and electrons to combine with oxygen from the air, creating water vapor, which is the only by-product of the process (Deloitte and Ballard, 2020).

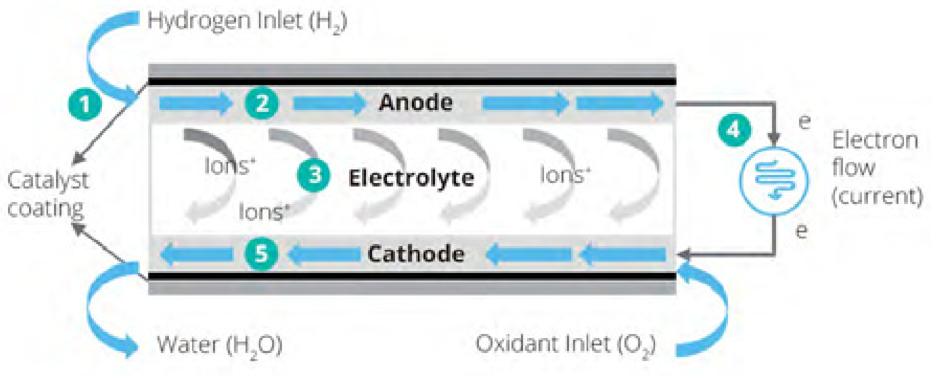

Figure 1. Principle of operation of a fuel cell. Adopted from Deloitte and Ballard, 2020.

The disadvantage of hydrogen fuel is its production cost, which today is about three times higher than the refining of crude oil (Rosen and Koohi-Fayegh, 2016; Chakraborty, 2019). According to the International Energy Agency (IEA, 2015), the structure of global hydrogen production consists of about 48% hydrogen produced from natural gas, 30% from crude oil and 18% from coal. The remaining 4% is produced by electrolysis of water. (Szałek et al., 2021). However, with the recent industrial-scale concept of producing green hydrogen offshore by deploying electrolyser systems on rebuilt oil rigs, this structure may change. Offshore wind farms are an inexhaustible renewable resource, but remote locations pose challenges in terms of connection to the electricity grid and irregular supply. Another issue is energy storage and the limited possibility of feeding electricity into the grid during peak production periods. Offshore hydrogen production will solve this problem by ensuring that electricity is received in the immediate vicinity of wind farms. It also aims to use existing platforms, pipelines, terminal infrastructure and maritime facilities (using existing infrastructure) to reduce costs. The hydrogen produced by these installations will also act as an energy reservoir during peak production periods.

As the hydrogen production technology by wind farms develops and "surplus" electricity from renewable sources is converted on a large-scale using electrolysers, it is electrolysis that will be the dominant future process in the production of renewable hydrogen. As a result of the electrolysis of water, hydrogen and oxygen are produced with a very high purity, above 99.999%. This is used when refueling hydrogen into fuel cell vehicles – no further purification is required. However, to obtain such pure hydrogen, the water must be pre-treated, which reduces the energy efficiency of hydrogen production from renewable sources. The current energy efficiency of hydrogen production by electrolysis is around 75%. Due to the dynamic development of renewable hydrogen production and the expected decrease in its production cost, it is justified to claim that fuel cells can be used in passenger cars, vans, trucks, buses and other means of transport (Szałek et al., 2021). The advantages of fuel cells as a means of transport include also high engine efficiency (65% for fuel cells compared to 35% for an internal combustion engine), better fuel efficiency and constant engine torque. In addition, fuel cells eliminate vibrations and noise associated with energy production. It is also worth mentioning that there are positive aspects influencing the quality of life of the society and the state of the environment, including the lack of fuel combustion when parked (Turoń, 2020; Granovskii et al. 2006).

2. Using hydrogen propellant in means of public transport

Buses are the most popular means of public transport in the world. They are used in virtually all conditions in which public transport operates. This is due to the great flexibility of this transport system. It does not require the construction of a special and costly transport infrastructure, except for stops and the infrastructure necessary to operate buses. They enable the easy creation and launch of new routes, have a large capacity and allow you to quickly respond to changes in the flow of passenger flows.

The analyzes of the works (Uhl, 2020; Sharma and Strezov, 2017; Onat et al., 2016) clearly show that the global trends in the development of city buses are moving towards the use of electric buses powered by fuel cells. This is confirmed by available reports of global consulting companies (McKinsey & Company, 2017), which indicate that in the near future heavy urban transport will be dominated by means of transport powered by hydrogen propulsion based on fuel cells and electric motors. This mainly applies to vehicles operated in an urbanized area, where the frequency of vehicle movement on the roads is high. Therefore, we are on the threshold of changes in the operated fleets from vehicles powered by internal combustion of fuels to electric vehicles, including hydrogen-powered vehicles, where electrochemical reactions are used to store or generate electricity.

The European Union plans to reduce pollution emitted by transport by 60% by 2050 compared to 1990. In addition, local government units in Poland are required to ensure the share of zero-emission buses in the fleet of vehicles in use, in the amount of at least 30% until 2028 (ZDR TOR, 2020; Dz.U. 2018 poz. 317).

In 2003, 3 Mercedes-Benz buses powered by hydrogen fuel cells were tested for the first time in Beijing. In 2017, the first commercially operated line of fuel cell buses in China was launched in Foshan Yunfu by Feichi Bus. As of 2018, more than 200 FCEBs operate in cities such as Shanghai, Foshan, Zhangjiakou and Chengdu. In 2018, Toyota Motor Corporation unveiled its first FCEB, the Sora (Figure 2), and then put more than 100 buses in service in the Tokyo metropolitan area in 2020 (Kane, 2018).

Figure 2. First hydrogen bus produced by Toyota Motor Corporation. Adopted from Kane, 2018.

2.1. Development of hydrogen fueled buses in Poland

The Polish bus manufacturer Solaris signed contracts for the delivery of Urbino 12 hydrogen buses (Figure 3) with urban transport operators in Germany, the Netherlands, Italy, Sweden, Spain, Romania, the Czech Republic and Austria.

Solaris has already delivered buses with hydrogen fuel cells to the public transport fleet in Cologne, Germany, Stockholm, Sweden and Bolzano, Italy. The first public transport operator in Poland to add a hydrogen bus to its fleet will be MZK in Konin. The contract signed with Solaris Bus & Coach provides for a four-year lease of the Urbino 12 hydrogen bus powered by hydrogen energy. The vehicle will be delivered to Konin in 2022 (Solaris A car Group Company, 2020). Three more cities, Poznań, Włocławek and Chełm, submitted applications for financing hydrogen vehicles under the Green Public Transport program, implemented by the National Fund for Environmental Protection and Water Management.

Figure 3. Urbino 12 Hydrogen bus. Adopted from Solaris A car Group Company, 2020.

Gdynia and Gdańsk were the first to conduct hydrogen tests of the Solaris Trollino 18 hydrogen trolleybuses in 2017 - it is a trolleybus equipped with fuel cells enabling the vehicle to operate beyond the reach of the traction line (Trollino). Currently, the Tri-City is applying for hydrogen trolleybuses under the same program. Warsaw is planning to purchase 10 hydrogen buses, while the Municipal Communication Plant in Bielsko-Biała has announced a tender to develop a concept for introducing hydrogen propulsion into the city's fleet.

In the plants of AUTOSAN sp. Z o.o. the first hydrogen-powered bus has also been built. It complements the family of vehicles intended for public transport under the common name of SANCITY. The zero-emission SANCITY 12LFH shown in Figure 4 is a low-floor bus with a length of 12 meters. It was designed on the basis of an electric bus. The bus has an electric motor with a fuel cell power module. The official premiere of the newest emission-free AUTOSAN SANCITY 12LFH bus with a hydrogen drive took place on October 27-29, 2021 during the 15th edition of the TRANSEXPO International Public Transport Fair in Kielce.

One of the main limitations in the development of hydrogen propulsion in Poland is the lack of hydrogen charging stations. PKN Orlen, which has hydrogen refueling stations in Europe, reports that it should launch similar points in Poland this year. The first Polish city with such a station is to be Poznań. Orlen is building a hydrogen hub in Włocławek, and another one in Płock. It is planned that such stations will be able to be serviced not only by buses, but also by passenger vehicles (Świat OZE, 2021).

Figure 4. A zero-emission hydrogen-powered bus SANCITY 12LFH. Adopted from Trans Expo Kielce 2021: Solaris displays four zero-emission buses.

Last year, the Ministry of Climate and Environment, informing about the commencement of public consultations of the Polish Hydrogen Strategy, announced that in 2025, 500 domestic hydrogen-powered buses are to be operated in Poland. In 2030, there will be four times more. Transport – according to the ministry – is to be one of the key sectors of the economy that uses hydrogen.

Fuel cell electric buses (FCEBs) are one of the main applications of fuel cells today. Buses usually have regular, predictable routes that do not require a large number of refueling stations. In addition, the performance of bus operators is significantly influenced by the emissions requirement imposed by public authorities, the use of hydrogen powered buses (FCEB) has become a very visible, green public transport initiative (Rosen and Koohi-Fayegh, 2016, Eudy and Post, 2018; FCH JU, 2018).

2.2. Buses used in the London public transport

Transport for London ("TfL") is the integrated transport body responsible for the day-to-day operation of the city's public transport network, including buses, underground, light rail, taxis, etc. (Transportation for London. What we do). In December 2003, TfL began testing the first generation of fuel cell buses in London to reduce air pollution in the city. The tests were part of the HyFleet: CUTE project, which brought together 31 industry and government partners from across Europe to accelerate the development of hydrogen-based transport systems in Europe. This project was funded by the European Union and the UK government. In 2010, as part of the Clean Hydrogen Cities ("CHIC") project, TfL purchased 5 next-generation hydrogen fuel cell buses and put them into service on the popular RV1 tourist route between Covent Garden and Tower Gateway. For the first time in the UK, the entire route was fully served by hydrogen-powered buses. In 2013, TfL purchased three more hydrogen fuel cell buses and expanded the fleet to eight buses (Ballard, 2016). Subsequently, in 2015, TfL again added 2 more fuel cell buses to its fleet (Van Hool). In May 2019, Transport for London ordered other 20 double-decker hydrogen fuel cell buses to expand its zero-emission bus fleet. 20 hydrogen fuel cell buses were put into service in 2020 on Routes 245, 7 and N7 213. It is planned that all buses used in London's urban traffic will be zero emission by 2030.

Currently, TfL uses 3 types of buses (Rosen, 2016):

- FCEV (StreetDeck Fuel Cell Electric Vehicle (FCEV) premiered at Euro Bus Expo): electric motor power: 200 kW; loading capacity: 85 passengers; range: average 350 km, up to 500 km; charging time 5-10 minutes.
- BEV: electric motor power: 200 kW; battery capacity: 382 kWh; loading capacity: 84 passengers; range: ~ 250 km; 4-5h charging time.
- ICEV: ICE engine power: 320 kW; loading capacity: 120 passengers; range > 300 km; charging time approx. 5 minutes (Ezzat and Dincer, 2018, Turoń, 2020).

3. Cost analysis of the use of hydrogen fueled buses

The subject of financial analysis for any investor is the actual cash inflows and outflows associated with the investment. The decision to purchase a bus fleet should take into account the following financial costs (Eko-Efekt Sp. z o.o., 2019; Gromadzki, 2021; Mroskowiak and Witosz, 2021):

- investment costs for rolling stock and for the technical infrastructure of operation and supply,
- fuel and electricity purchase costs, resulting from the planned work of transport for particular types of vehicles,
- vehicle maintenance costs,
- costs for external emissions such as pollutants, greenhouse gases and noise,
- vehicle insurance costs.

Cost-benefit analyses of the use of zero-emission buses carried out by transport companies have shown that the purchase of hydrogen buses may be possible, but there is currently no infrastructure for hydrogen vehicles in Poland (Gromadzki, 2021; Mroskowiak and Witosz, 2021). The market price of hydrogen is EUR 9.50. It is approximately PLN 40-45 per kg. A public transport bus uses about 8 kg of hydrogen per 100 km, so the cost of driving 100 km would currently be 320 PLN. The cost of purchasing the bus is about 4 million PLN, and the cost of building a hydrogen station is estimated at 4-6 million PLN (Mroskowiak and Witosz, 2021).

Figure 5 presents the TCO (total cost of ownership) breakdown for the three types of buses operated by TfL (Rosen and Koohi-Fayegh, 2016). The TCO value includes both the purchase cost and the operating costs of individual types of buses. As can be seen from the table below, purchase cost and fuel cost are the main components of the TCO of fuel cell buses. This is due to the high purchase prices of buses as well as the high price of hydrogen (higher than for ICEV buses with conventional drive and BEV – electric drives). The costs of insuring fuel cell buses are also high. However, it is estimated (Rosen and Koohi-Fayegh, 2016) that these costs will soon fall as the prices of fuel cell systems and hydrogen fall. An additional element is road tax, the amount of which depends on exhaust emissions. All three types of buses pay road taxes, but for ICE vehicles, these are much higher due to their high emissions.

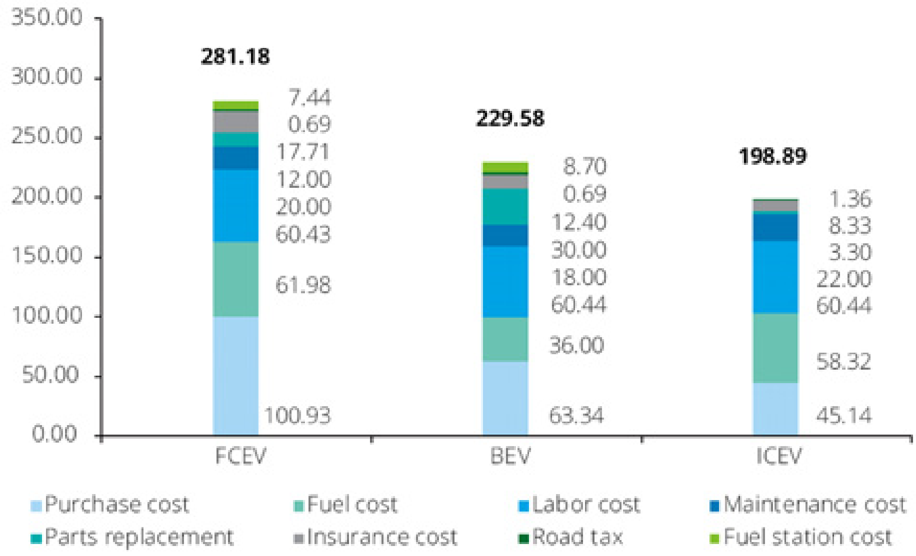

Figure 5. Summary of TCO (Total Cost of Ownership) for the three types of buses operated by TfL. Adopted from Rosen and Koohi-Fayegh, 2016.

Figure 6 shows the estimated total cost of ownership (TCO) of fuel cell buses over the next 10 years. It is estimated that the total cost of ownership of fuel cell buses will be lower than that of battery buses and ICE buses from 2024 (Rosen and Koohi-Fayegh, 2016).

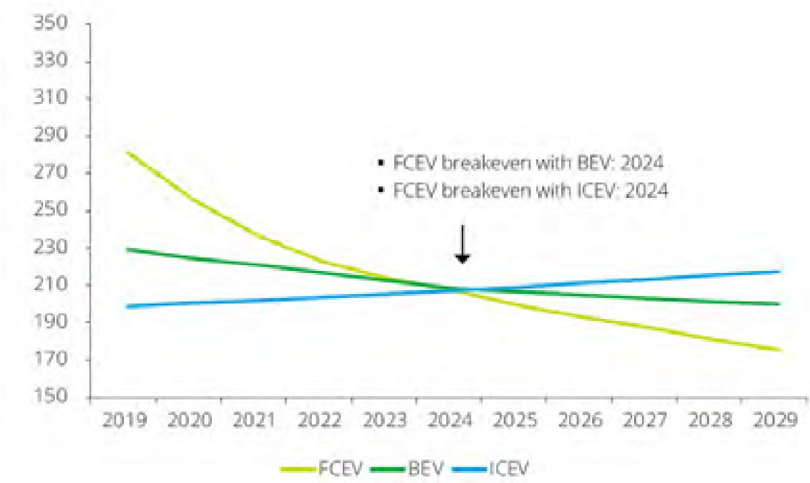

Figure 6. Estimated Total Cost of Ownership (TCO) of FCEV buses over the next 10 years. Adopted from Rosen and Koohi-Fayegh, 2016.

4. Conclusions

Although the total cost of ownership of fuel cell buses (FCEV) today is higher than that of electrically powered buses (BEV) and conventionally powered buses (ICE), there are intangible benefits to using fuel cell technology in city transit. First, the fuel cell buses meet the London Council's emission standards. In April 2019, London began implementing an "Ultra Low Emission Zone" ("ULEZ"). Vehicles exceeding the emission standard are charged an additional ULEZ fee. The zone is expected to be expanded to include larger vehicles such as buses, coaches and trucks. The introduction of ULEZ is one of the steps to meet the goals of reducing carbon dioxide emissions in London. In the foreseeable future, city authorities will introduce increasingly stringent restrictions on emissions from public transport vehicles, which will make the total cost of ownership of conventional ICE vehicles much higher, and green vehicles such as BEV and FCEV will become the standard in public transport.

Acknowledgements

This paper was financed from the resources of the Silesian University of Technology, project no. 13/010/BK_22/0065.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

DEMAND SIDE RESPOND IN THE CONTEXT OF RENEWABLE ENERGY PROSUMERS

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Purpose: The aim of this paper is to show the problem of adaptation of Demand Side Respond programs to the new market of renewable energy prosumers and to indicate the possibilities and proposals for these adaptations taking into account the current legislation and available solutions such as energy consumption monitoring, energy storage and control of energy consumption with Smart Home solutions.
Design/methodology/approach: The aim of the paper was achieved by analyzing the literature on Demand Side Respond, analyzing the current legislation and analyzing the specifics of prosumer behavior.
Findings: As a result of the analysis, problems related to the adaptation of Demand Side Respond programs for prosumers of energy from renewable sources (especially from PV installations) were indicated and possible solutions were proposed.
Research limitations/implications: Future research will address the development of a set of recommendations for prosumers to optimize their behavior and ultimately contribute to the proper management of energy from PV installations.
Originality/value: The article presents an important issue in the growing renewable energy market resulting from the new prosumer billing system that came into effect on April 1, 2022.

Keywords: Demand Side Respond, prosumer, renewable energy market, prosumer behavior optimization.

Category of the paper: Research paper.

1. Introduction

The demand for electricity in the world is constantly growing. The economic development visible in most countries of the world, including Poland, requires continuous expansion of generating capacity. At the same time, a number of actions resulting from EU regulations, including in particular the RED II Directive (Directive of the European Parliament and of the

Council (EU) 2018/2001 on the promotion of the use of energy from renewable sources) and the EMD Directive (Directive of the European Parliament and of the Council (EU) 2019/944 of June 5, 2019 on common rules for the internal market in electricity) affect the development of renewable energy sources. At the beginning of 2022, the installed capacity of energy from renewable sources in Poland has already reached 17GW, or nearly 30 percent of the total installed capacity. Distributed energy plays and will play an increasingly important role in the country's power system. Renewable energy generation is playing an increasingly important role in the power system due to efforts to reduce dependence on imported fossil fuels as well as to reduce greenhouse gas emissions (Qadrdan et al., 2017). It is important to note that renewable energy production is dependent on weather conditions and therefore does not provide a constant generation capacity. The electricity demand of consumers is also not constant, but varies according to the season, days of the week and hours of the day, etc. The overlap between the variability of consumer demand and the variability of renewable generation further increases the imbalance in the power system.

Differences in supply and demand for electricity result in changes of prices on the energy market. Prices of the electricity available on the Polish Power Exchange are determined separately for each hour. Market mechanisms, based on the forecasted demand-supply relation, decide about the energy price for the current and the next day. The ratio of hourly prices during the day varies from several dozen to several hundred percentage points.

Traditionally, energy demand-side management programs are primarily for industrial customers and involve reducing energy demand during peak hours. Renewable energy prosumers are typically residential customers. This raises the issue of optimizing energy use in this case. The answer to balancing electricity supply and demand as indicated by Antonopoulos et al., (2020), may be provided by Demand Side Respond (DSR). The DSR service is part of a broader Demand Side Management (DSM) program, the role of which is to control demand for power and electricity in such a way as to minimize the costs of developing and operating the power system. Most of the actions are targeted at inducing consumers to rationalize their energy consumption. The effect of these actions is usually the release of peak capacity in the system and avoidance of investment on the part of the generation system and transmission infrastructure.

It should be noted, however, that currently little use is made of the capacity of small distributed consumers to perform DSR and DSM tasks (Cardoso et al., 2020; Marwan et al., 2014; Palensky et al., 2011). The activities of energy companies in this regard are not very lively. This does not mean, however, that small consumers have no technical possibilities and economic potential for such activities. A particularly interesting market segment will be customers with their own renewable sources of electricity generation, i.e., prosumers.

On April 1, 2022, Poland saw a new prosumer billing system come into force, which is completely different from the previous one. The new net-billing system is based on settlements based on the value of energy injected into the grid by the prosumer and not on the quantity of energy injected as before. As of July 1, 2024, the price of energy introduced to the grid by prosumers will be determined for individual hours. This means introducing a wide range of individual consumers to participate in the energy market, giving them the opportunity to take advantage of the benefits of the energy transformation by managing their energy consumption, which will enable them to save money and contribute to an overall reduction in energy consumption. At the same time, it will become necessary to utilize innovative technologies both in the area of energy intensity reduction, energy storage and proper management of owned energy. This paper attempts to outline the issue of optimizing the electricity use of prosumers participating in Demand Side Respond programs.

2. Demand Side Respond

Demand Side Response (DSR) is the service of reducing or shifting the demand for electricity by the end customer in response to changes in electricity prices or at the direction of the transmission system operator. In general, DSR programs can be divided into two categories: price-based and incentive-based programs. The first type includes time-of-use, critical peak price, and real-time price (O'Connell et al., 2014). The second type targets encouraging consumers to reduce their electricity consumption, for example through interruptible tariffs and direct load control (Palensky et al., 2011). Importantly, all these programs can contribute to maintaining stability in the National Power System in case of a difficult balancing situation, especially during peak electricity demand hours. In Poland, the transmission grid operator has so far launched DSR programs for industrial customers. The operator sends a notification and the customer reduces its consumption for a certain period of time and receives remuneration for this operation. The customers participating in the DSR programs can apply one or several mechanisms:

- Temporary limiting of energy consumption.
- Shifting power consumption to other times.
- Switching on the in-house power supply.
- Accumulating energy in or using storage capacity.

The mass installation of smart meters allows looking for opportunities to implement DSR service also for distributed, small-scale electricity consumers. In practice, however, this is extremely difficult to achieve for individual electricity consumers. Simulations by Bućko and Stahl (2020) show a relatively small decrease in peak load despite a noticeable reduction in overall energy demand for the group of consumers in question.

The reason for this is the need for daily use of energy-consuming appliances during the morning and afternoon/evening peak hours such as kettle, electric plate or water heater. This leaves appliances that can be used at other times such as air conditioners, televisions, computers and routers. However, the power consumption of these appliances is generally not significant and, moreover, requires residents to be consistent in shifting their usage hours. In practice, a change of consumption profile requires a change of customer habits which is extremely difficult to achieve, especially for large populations.

One of the more effective methods of engaging consumers in DSR programs is the use of dynamic tariffs. A dynamic price contract is a contract for the sale of electricity that reflects current energy price fluctuations in the markets. However, without appropriate support from innovative technologies, customers would have to continuously control the operation of its receivers and manually adjust their operation to current energy prices. Technological support for the consumer enabling proper use of dynamic tariffs to reduce the energy bill should become one of the key tasks in the era of soaring energy prices.

DSR programs based on dynamic tariffs will be increasingly considered as a way to reduce energy costs, especially for consumers with their own renewable energy sources (RES), i.e., prosumers. New legal regulations require the use of dynamic tariffs in the process of accounting for energy surpluses introduced to the grid from own RES installations.

3. Prosumers

A prosumer is a specific market actor who is engaged in production for personal use (Rupnik, 2010). Prosumption can also include the production of exchangeable goods and services (Toffler, 2006). In the case of the energy sector, with the development of electricity metering technology and Smart Grid technology, a consumer has emerged who is beginning to have an impact on the operation of the energy market. This new consumer called prosumer through actions and reactions to increase its personal benefits or group benefits starts to be an important player in the energy market (Bremdal, 2011). As reported by Heinisch et al., (2019), two factors have been identified to influence the rapid growth of prosumers in the energy market. One factor is economic aspects, such as the increase in retail electricity prices and the reduced prices of PV installations. The second factor is behavioral aspects such as environmental awareness and the desire for greater sufficiency. These factors have influenced the development of the photovoltaic sector also in Poland. The increase in electricity prices and subsidy mechanisms for own generation sources led a significant part of the population to install photovoltaic panels connected to the general power grid. Throughout 2021, 396,514 new photovoltaic installations with a total capacity of 3,774.71 MW were built. The total number of photovoltaic installations is approximately 850,000 units.

The main purpose of the state's promotion of installing its own individual generation sources was to relieve the strain on the country's electricity system by self-consuming its own consumer-generated energy. However, it should be noted that the energy consumption and generation profiles of photovoltaic panels do not match, as shown in Figure 1. A typical generation profile on a sunny day has a peak in its output during the midday hours. This is due to the most common southern orientation of PV panels. In contrast, peak residential power consumption occurs during the morning and afternoon/evening hours.

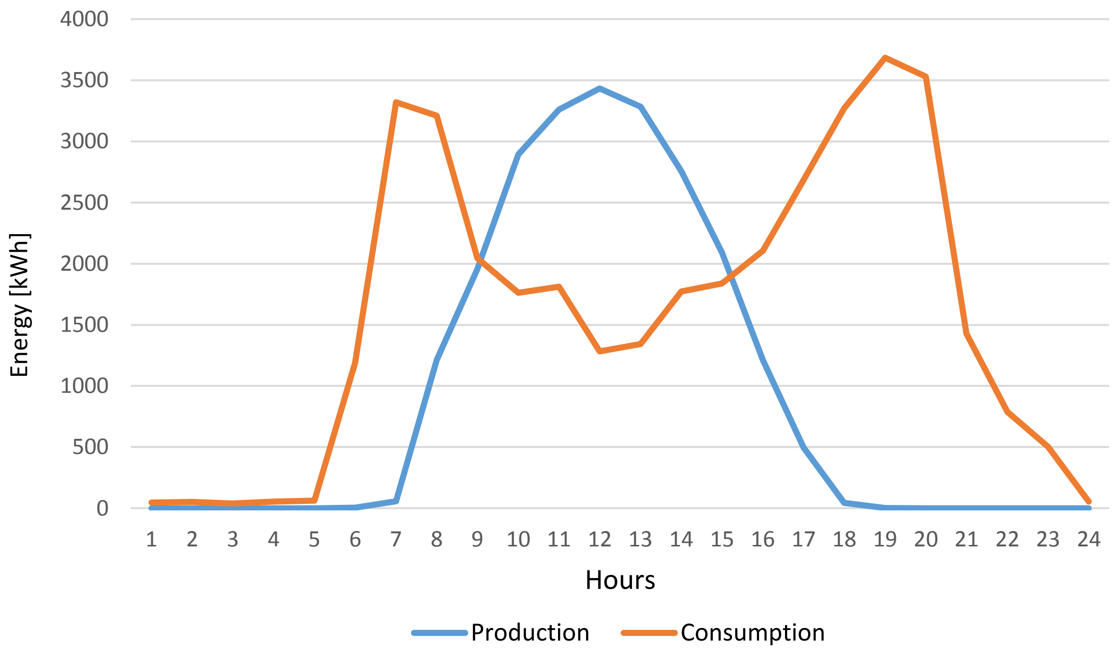

Figure 1. Daily amount of energy generated from the photovoltaic installation and its consumption for the household. Source: own study.

For the typical case of a photovoltaic installation, the problem arises of excess energy during the midday hours. The excess energy from the installation is returned to the grid and can be used by other energy consumers. According to the current provisions of the RES Act applicable to prosumers who concluded an agreement with a seller before April 1, 2022, energy injected into the grid can be returned to the prosumer by the seller at no charge, up to 70 or 80 percent of the energy injected into the grid. This means that the prosumer can treat the grid as an energy storage facility, incurring costs of 20 or 30 percent of the energy it has injected. The prosumer only has to pay for the missing energy from the grid in accordance with the applicable tariff. A slightly oversized photovoltaic installation enables the prosumer to cover its energy requirements in full, eliminating the need to pay any usage charges. However, this is at the expense of the seller, who must pay fees associated with the distribution of energy supplied to the customer. A typical energy input and energy return to the grid per year for a photovoltaic network is shown in Figure 2. As can be seen, the energy input to the grid is much higher than in the months from spring to autumn, which are characterized by higher insolation.

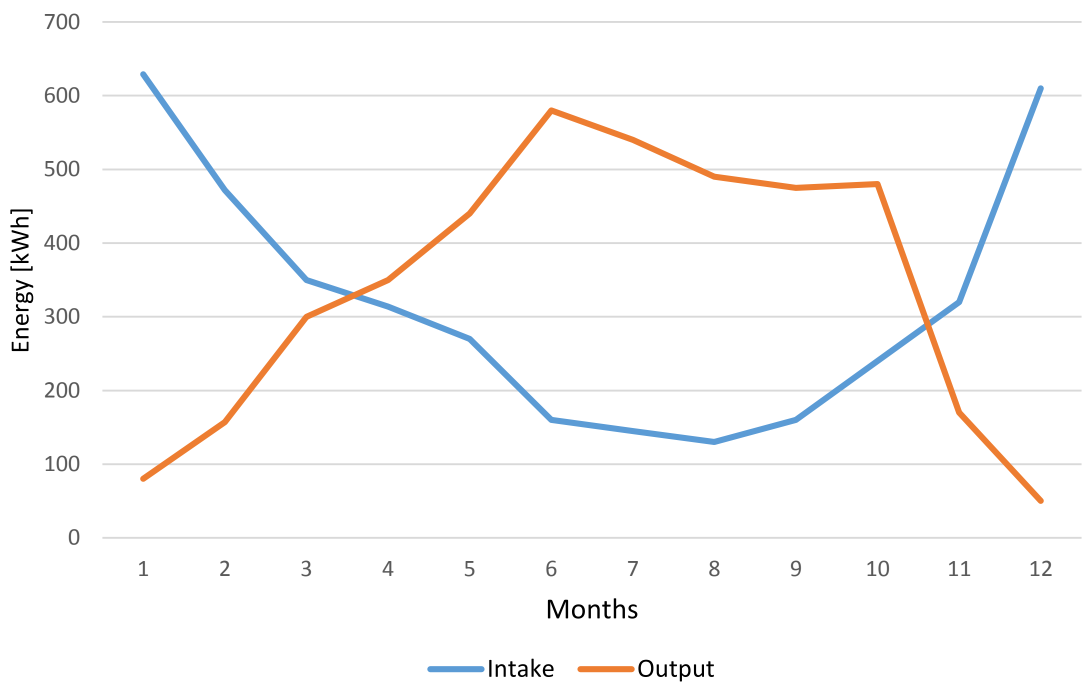

Figure 2. Annual intake and output energy to the grid for the household. Source: own study.

Summarizing the legal *status quo*, prosumers have not been motivated in any way to adjust their consumption to current market signals. Relatively low charges for treating the grid as an energy storage facility do not encourage prosumers to increase self-consumption so that the grid can actually feel the reduction in energy demand especially during peak hours.

The amendment to the RES Act is intended to reverse this unfavorable trend and encourage prosumers to manage the energy they produce much more rationally. The change involves the introduction of a net-billing system consisting in the sale of energy surpluses to the seller. The purchase of energy needed by the prosumer will take place in accordance with market rules applicable to energy consumers, including distribution fees. This is a major difference for the prosumer, as the prosumer receives the equivalent of the energy itself for introducing the energy into the grid, while the consumption of the energy is charged with distribution fees in addition to the purchase. This change has very serious consequences, because investment in one's own photovoltaic system may prove to be not beneficial.

The amended Renewable Energy Sources Act should change the way we use our own energy. As of July 1, 2024, the value of energy injected into the grid will be settled in hourly or 15-minute price gradations. This means that the value of energy sold will be affected by two variables: the quantity and the price of energy in a given hour. Introducing dynamic energy prices means introducing market signals that can be used for energy balance management. Variable prices with skillful control of energy input and output to the grid can to some extent compensate for the need to pay distribution fees. Selling surplus energy at high-price hours and buying it at low prices should become an alternative for prosumers, thanks to which the investment in the generating installation should pay for itself within a few years.

However, the profitability of photovoltaic installations based on new legal regulations requires additional actions, without which it will be difficult to achieve proper management of energy resources and thus profitability of one's own photovoltaic installation.

4. DSR programs for prosumers

In the current legal situation, DSR programs are of particular importance; their introduction may improve the situation of prosumers of photovoltaic energy. It should be noted, however, that such programs make sense when energy consumers are able to recognize their characteristics of energy input and output to the grid. Without this basic knowledge, signal response actions will be chaotic and consequently lead to higher energy usage costs (Heinisch et al., 2019).

This paper proposes Demand Side Response, price-based as well as incentive-based programs to monitor energy consumption, energy storage and control energy consumption using Smart Home solutions.

4.1. Energy consumption monitoring

For an energy consumer, control of energy consumption requires periodic checking of the meter. Then, based on the difference in readings, the consumption for the period is calculated, and knowing the price of the energy makes it easy to calculate the value of the energy consumed. For a prosumer, the situation is much more complicated because the meter shows two values, i.e., energy input and output, and it is very difficult to calculate the amount of energy consumed. This situation raises a fundamental problem related to the need to control energy management, which can be solved by smart metering. Directive 2019/944 on common rules for the internal market in electricity defines "smart metering" as an electronic system by means of which the amount of electricity injected into the grid or the consumption of electricity can be measured, obtaining more information than for a conventional meter, and transmitting and receiving data for information, monitoring and control objectives, using electronic communications. AMI (Advanced Metering Infrastructure) is such a smart metering system. In Poland, classical energy meters are gradually being replaced by AMI meters. These meters have two very important features: they can record the energy consumption for short intervals, e.g., 15 minutes or one hour, and they continuously transmit the current readings to the relevant distributor via a communication module. Some distributors provide their customers with an application through which they can continuously monitor their consumption, but unfortunately not the energy charges. The lack of such functionality results from the principle of "unbundling" of energy distribution and sale, which means that the distributor cannot be informed about the energy price for the customer.

Alternative solutions for AMI are meter overlays or energy monitors installed in the input circuits of the electrical system. The advantages of monitors are unquestionable because in addition to checking the consistency of energy consumption readings by the distributor's meter and energy monitor, it is possible to use much more advanced features. Standard energy monitor collects much more information and higher resolution, e.g., one minute. The data from the monitors are collected in the computing cloud and the results can be observed using specialized applications. It is important that the applications provided with the energy monitors allow for an understanding of how energy is used in the household. Limiting the application to a set of collected data in numerical form or even a graph is clearly insufficient. Analyzing this data sometimes requires specialized knowledge of energy.

One of the important functions of the energy monitoring system is disaggregation of energy consumption for individual energy consumers. Performing disaggregation requires the use of mathematical methods, such as Hidden Markov Models. Knowing the contribution of individual appliances as a function of time and power consumed can definitely help the user make energy management decisions. An example application that facilitates disaggregation of energy consumption data of individual devices in a household is shown in Figure 3.

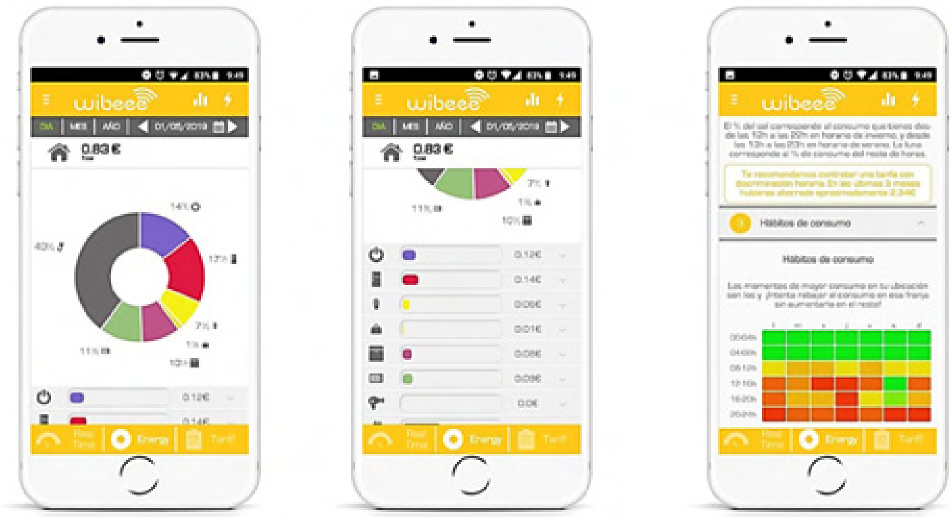

Figure 3. Wibeee application with data disaggregation function.

The analysis of the detailed consumption data and its correlation with energy knowledge, both technical and price knowledge, can lead to the creation of a system of individual recommendations for the customer. An example of such a system is Bidgely's individual customer recommendation module, which is shown in Figure 4.

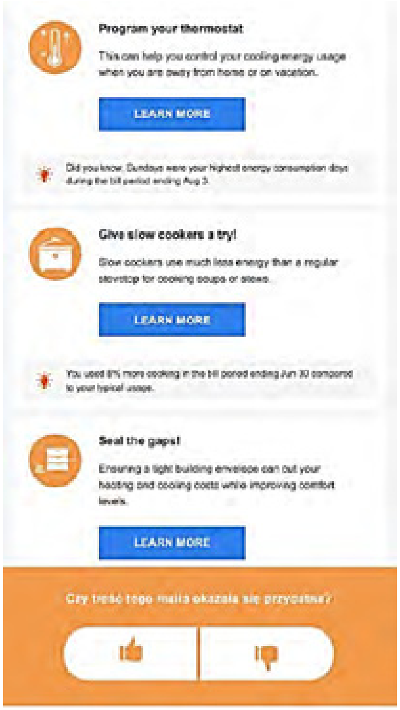

Figure 4. Module of individual recommendations for the customer based on the analysis of consumption and disaggregation of consumption profile.

4.2. Energy storage

Mulder et al. (2013) highlight that residential electricity consumers are likely to become the first available business case involving small-scale electricity storage. Furthermore, the cost of energy storage is expected to continue to decrease, giving prosumers additional opportunities to control the use of the electricity produced and to increase their own consumption of the energy produced by PV panels (Nykvist and Nilsson, 2015).

According to the provisions of the EU Directive (Directive 944/2019), "energy storage" means deferring, in the energy system, the final consumption of electricity from the moment of its generation or converting it into another form of energy that allows it to be stored and then converting such energy back into electricity or using it in the form of another energy carrier. The role of energy storage may be played by electric cars, which are charged from the photovoltaic installation during the hours of maximum energy production. It is also relatively easy and cheap to store energy in the form of heat, which is needed not only during the heating season, but also throughout the year in the form of domestic hot water. An alternative is to install heat pumps powered by photovoltaic installations.

Electricity storage is the most convenient way to store excess production from photovoltaic installations. Collected surpluses can be used at times of increased consumption. The unquestionable advantage of energy storage is the simplicity of increasing self-consumption from your own installation.

The objectives set by the European Union to increase the share of RES in energy production encourage the development and implementation of storage technology. Thus, it is becoming increasingly efficient and accessible to everyone. Energy storage is crucial for improving energy security and for the development of renewable energy. Experts agree that there can be no RES development without energy storage. Therefore, energy storage is another step on the way to transformation of the energy industry.

Despite the undoubted advantages of energy storage, one should pay attention to their limitations and costs. A typical energy storage for PV has a capacity of 3kWh to 10kWh. This means that such a storage can store the surplus from 1-3 days of self-generation. During cloudy and winter periods, the storage will not be able to store enough energy to cover normal demand. The missing energy has to be obtained from the electricity grid. An oversized PV system with energy storage that covers all electricity demand with its own production would certainly not be economically viable.

Smart energy storage control systems can manage the energy from home PV installations. The created consumption and storage scenarios allow for a much more efficient use of energy. The controlling parameters in such solutions can be the operation parameters of the main energy consumers, energy prices in particular time zones and the sunshine forecast required for PV production forecasting.

Figure 5 shows an example comparison of energy prices for the Day-Ahead Market (data from the Power Exchange) with the amount of energy produced during one day – September 14, 2021 (by hour).

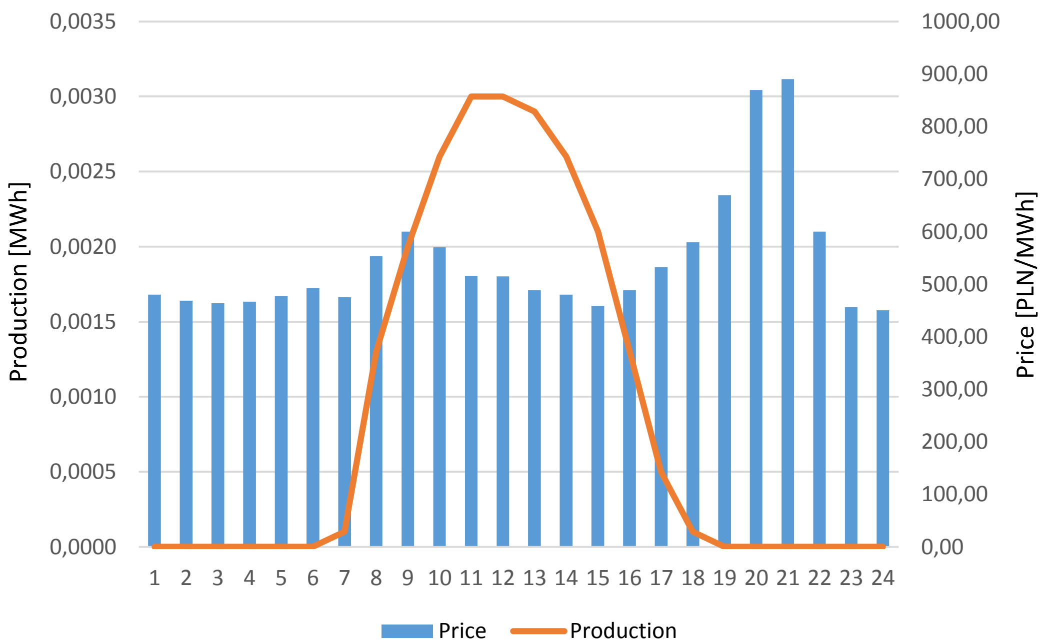

Figure 5. Comparison of Energy Prices for the Day-Ahead Market and Photovoltaic production for an exemplary household. Source: own study.

As can be seen in Figure 5, the energy production of a PV plant is highest in the daytime, between 9 AM and 4 PM, while the energy prices are highest in the evening hours (between 6 PM and 10 PM). In order to reduce the purchase costs, the prosumer should therefore sell the energy, i.e., feed it into the grid during the hours with a high price, and withdraw the energy during the hours with a low price, which can be done with energy storage.

4.3. Controlling energy consumption with Smart Home solutions

Smart Home installations increasing the comfort and safety of life, as well as due to their relatively low cost, are becoming more popular every year especially in the context of the development of energy generation based on renewable sources (Risteska Stojkoska and Trivodaliev, 2016). As emphasized by Beraldi et al. (2020), designing smart homes equipped with energy management systems is even becoming a necessity because in the new energy grid consumers no longer play a passive role but actively contribute to energy production by installing, for example, rooftop solar panels. A Smart Home installation consists of a set of connected intelligent devices (IoT) such as sensors and actuators, usually controlled from a dedicated control panel. Smart Home installation can perform specific tasks such as: switching on and off the lighting according to pre-set scenarios, maintaining room temperature adapted to the time of day and year, creating alarms based on events detected by surveillance cameras, etc.

Often underestimated function of Smart Home is the ability to reduce or change the profile of energy consumption. Apartment lighting divided into sectors and linked to motion sensors can save energy consumption. Even greater savings can be achieved when the home is heated using electric heaters equipped with remote control or connected to smart outlets. Lowering and raising the temperature in the apartment or individual rooms can be implemented on the basis of any scenarios based on, for example, detecting the presence of household members.

Despite the enormous possibilities of controlling energy-consuming devices, typical Smart Home installations very rarely implement scenarios aimed at achieving goals related to energy efficiency or even lowering energy bills. The reason for this state of affairs should be seen in the lack of broader awareness of such opportunities by investors and designers, and more importantly in the lack of motivation. Rising energy prices and the introduction of a DSR-based billing system for prosumers should definitely change this state of affairs.

5. Summary

The problems related to the development of electricity generation from renewable sources, which have been mentioned in the paper, indicate the necessity of applying Demand Side Respond for a new type of producer and consumer, i.e., the prosumer. When adapting DSR programs for prosumers, however, many challenges need to be taken into account, such as:

- Variable electricity production dependent on technical parameters of the installation, time of day, season and weather conditions.
- Variable energy consumption that depends on deterministic factors such as time of year and length of day as well as stochastic elements related to individual customer behavior.
- Variable configuration of energy consumers.
- Variable energy storage capacity, both in the form of energy storage and other forms of storage such as hot water tanks.
- Variable energy prices determined by market conditions.

With so many variables, it is extremely difficult for the prosumer to decide how to manage energy at any given time. With very high price fluctuations such as those currently observed on the Polish Power Exchange, a good strategy may be to feed-in the surplus energy into the grid during the hours with high prices. In a different system, a scenario based on maximizing the use of one's own energy might be more advantageous.

Despite the announced subsidies, the new way of accounting for energy bringing prosumers closer to participating in the energy market may be a barrier to profitability for many potential investors. Without appropriate support systems to manage their own energy, there will be no one willing to invest in building their own RES sources. Therefore, it is necessary to create solutions that will take over the functions of support for energy management by prosumers in the conditions of application of DSR/DSM systems.

Currently, there are many solutions of this type, but they are addressed mainly to industrial consumers and are limited to the implementation of specific scenarios. In this situation, there is a great need expressed by companies installing PV systems to support customers in the efficient use of energy adapted to the changed legal conditions.

In order for prosumers to effectively use their own energy under the conditions of DSR/DSM, it becomes necessary to make available on a mass scale software in the form of mobile applications, web portals or autonomous control applications that, based on the individual configuration of generation, storage, consumption, metering and control systems available at home, would supervise energy management. For example, if the prosumer has a Smart Home installation it is appropriate to enable the transmission of control signals from the control system to the Smart Home control panel. Otherwise, the prosumer should receive personalized messages with recommendations that will improve energy efficiency in their case. A prosumer with energy storage can, for a change, try a form of energy trading based on price volatility. Such operations can be performed within the prosumer's deposit or by reselling energy to an aggregator.

The changes introduced by the amended RES Act in the functioning of prosumers' settlements may slow down the extremely intensive development of own RES installations. On the other hand, the rapid increase in energy prices should encourage consumers to switch to their own energy sources. Therefore, there is an urgent need to support prosumers in order for them to skillfully use the opportunity offered by the transition from a system of fixed tariff prices to dynamic prices. The solution may be programs containing recommendations for prosumers, which will aim to optimize their behavior and, as a result, contribute to the rational use of natural resources and optimization of energy use.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

QUALITY OF LIFE ASSESSMENT IN TERMS OF RESIDENTS – EXAMPLE OF A LARGE CITY

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Purpose: The objective of the article is to present the quality of life in terms of residents in the example of a large city.
Design/methodology/approach: Research was carried out remotely using an online questionnaire. A diagnostic survey method was used with the residents. The research topics are related to the quality of life of the residents, based on the current state of life and factors influencing the quality of life.
Findings: The study found that the quality of life has a significant impact on the functioning of residents in their private and professional lives regarding living conditions in a large city. The conducted research shows that there are many problems related to the quality of life of the residents and that information on their existence may be valuable information for Municipal Office.
Social implications: Social implications of the research were indicated. Attention was paid to the benefits of research for improving the quality of life in the city.
Originality/value: The study highlights the need for comprehensive quality of life research conducted among residents. Methods of obtaining data from residents were proposed to Municipal Offices and the conditions for their use for the city's development were defined.

Keywords: Quality of life, smart city, research surveys, city residents.

Article category: Research paper.

1. Introduction

Quality of life is a concept widely understood by society, which is still an issue of a cognitive nature. Economic and social indicators regulating the quality of life let us learn about opinions, life satisfaction, and housing satisfaction, as well as aspects of functioning, financial situations and the development of both the residents and the cities in which they live. Quality of life is defined in various ways by many authors. The quality of life concept was introduced in the United States after World War II and was initially associated with material well-being (Dziurowicz-Kozłowska, 2002). The World Health Organisation (WHO) defines quality of life as ‘an individual's perception of their position in life in the context of the culture and value systems in which they live and in relation to their goals, expectations, standards and concerns’ (World Health Organisation, 1997). P. Dolan and R. Metcalfe tried to organise the aspects of a subjective assessment of the quality of life by assigning indicators used in the research (Dolan, Metcalfe, 2013). Thanks to this, they distinguished three categories of well-being, i.e.: evaluation studies, studies of personal experiences and studies of eudaemonia, i.e. rational contentment and satisfaction, of every reasonable person. Amartya Sen, in his book ‘Inequality Reexamined’, defines quality of life as follows: ‘A person's well-being can be understood in terms of their quality of life (a kind of good state of being). And life can be interpreted as a set of interrelated functions that consist of beings and actions’ (Sen, 2000, pp. 55-56). Thanks to the definitions and research carried out so far, showing the quality of life from various perspectives, one can be inspired by them and also improve them. Literature on the subject shows many studies and analyses concerning the quality of life in the city (Gliwice Municipal Office, Katowice Municipal Office, Zabrze Municipal Office). The city of Gliwice has conducted research on living conditions in the city. According to the research, the residents of Gliwice consider their city to be one of the most attractive in the region. (Information Bulletin of the Municipal Office in Gliwice, 2018). An analysis of the situation of large centres in Poland, including Katowice, was carried out in the city of Katowice. Capital research was carried out, including: institutions, infrastructure, quality of life, people, image, investments and finances (Report on major Polish cities – Katowice, 2007). The main direction of research in the city of Zabrze is customer satisfaction with the services provided by the Municipal Office. In addition, the city of Zabrze also conducted research on the development of urban space. M. Czepkiewicz and P. Jankowski present examples of spatial research on the quality of life, social, economic and geographic indicators, as well as research on residents’ satisfaction with their home surroundings (Czepkiewicz, Jankowski, 2015). In the article, Czepkiewicz and Jankowski formulated recommendations and showed how to properly conduct spatial research on quality of life in the city. Other research that makes it possible to assess quality of life are studies conducted by municipal offices, which check the city's potential in a simple and general way by creating a questionnaire aimed at finding out about the opinions of the residents. Research on quality of life is carried out in various perspectives and areas, such as studies of spa towns showing the advantages of a city for tourists. Such research was carried out in Ciechocinek, where the hierarchy of features according to the respondents influencing the quality was shown. As can be noticed, the context and the area of research have many possibilities of perceiving the quality of life. There are many reports in literature on the subject of a smart city and the role of the quality of life research at the city level (Albino et al., 2015; Caragliu et al., 2011; Desdemoustier et al., 2019; Papachristou and Rosas-Casals, 2019). For example, in 2015, research was carried out in European cities to determine the level of quality of life and the residents satisfaction with life (Publications Office of the European

Union, 2016). In Poland, various studies on the quality of life at the city level were carried out (Ranking of the quality of life in province cities, 2021). As already mentioned, research on the quality of life targets various social groups, including children and adolescents. Such research was carried out in Poland in 2021 by the Ombudsman for Children, aimed at assessing the quality of life of children and adolescents in Poland (Pawlak, 2021). Research carried out by the Ombudsman for Children focused on the dimension of the school environment and the author solely focused on this. The tool used for the study was the KIDSCREEN questionnaire (Ravens-Sieberer & Kidscreen Group Europe, 2016). Research was carried out on three levels of education: nursery, primary and secondary education. 5,800 students from different schools at different levels participated in the study. The aim of the study was to determine the level of education and then to determine how to help with low scores. It is worth emphasising that the research was carried out during the pandemic which meant remote learning difficulties for students.

This study aims to assess the living conditions of residents and their satisfaction, as well as to diagnose problems in a large city. Research aimed at city residents should make it possible to assess the city's potential, its needs, strengths and weaknesses. Opinions of residents are one of the most valuable comments that can be made by changes in cities. Only residents of a given area know what they need, what they want to change, so that they can live better in their city. For the purposes of the research, the following research questions were formulated:

1. How does a city resident perceive quality of life?
2. How does the resident assess the various aspects affecting quality of life?
3. What problems does a resident notice about their city?

2. Methods

The study was conducted in a city with a population of over 100,000 residents located in the south of Poland. The research sample was 1,000 people – one research questionnaire was sent to each of them. The study was aimed at assessing the quality of life within a selected city. Research was conducted in the period of March – June 2021. 186 responses were obtained from the conducted research. Research was conducted using a questionnaire created in Google Forms. A questionnaire was chosen for this due to the possibility of quantifying the results of the research. Quantitative research makes it possible to compare questions and answers using the cross method as well as to better visualise research results. As a research tool, the questionnaire enables the research to be carried out on a large number of respondents. This tool is convenient and easy for both parties, both for the sender and recipient of the questionnaire. There is also a Web survey platform in Poland. It is a tool that makes it possible to create a questionnaire that will let you examine the quality of life and send it to a defined group of respondent email addresses. Thanks to the ability to collect and analyse large amounts of information, it is even possible to quickly explore numerous communities. Quality of life research can also be conducted by means of an interview, i.e. one to one contact between the consultant and the respondent. This is a more difficult method to carry out because of the interview and face-to-face time with the consultant. In 2009, Piotr Rogala from the Wrocław University of Economics presented a report on the implementation of works on the design and testing of a system for measuring the quality of life in communes (Rogala, 2019). In the report, he defined the order of conducting the research and indicated the stages which is known as a 'road map' of researching the quality of life in the commune. It is a presentation of the key stages that should be taken into account when examining the quality of life in the commune.

Due to the pandemic and a greater selection of recipients, electronic means of contact was chosen. Using electronic means, including city and social portals, groups of activists, social groups and groups of seniors, helped with accessibility to the recipient. Using electronic means was also a direct and convenient way of contacting the public. Questions in the research survey covered various aspects, therefore sections were created in the questionnaire indicating the issue to which the authors wanted to be answered and to know the opinion of the residents. Sections of the study were selected in such a way that research results could indicate positive and negative opinions of residents in the largest possible area in which they live. The respondent's opinion in several areas allows for a broader view and assessment of quality of life in a given city. It also makes it possible to assess the existing situation and the level at which the residents live in a given area. The questionnaire contained 30 questions, some of them had a rating scale from 0 to 5. The questionnaire contained closed questions – questions to assess the aspect, i.e. quality of life in the city, safety, education, housing economy, social infrastructure, business development, employment market, public transport, health service, culture, citizen (participatory) budget, administration, quality of life for elderly in the city and an information table on age, gender and education, as well as a question about the length of residence in the city. The survey made it possible to get to know opinions of the residents, their attitude, expectations and satisfaction with living in a large city. The research shows what problems large, modern cities have and what they can boast about. Researching quality of life with the use of a questionnaire allows for a broad look at the situation of the city and its residents.

3. Results

186 people took part in the conducted research on quality of life in the city. Thanks to answers provided by the respondents, it was possible to assess individual aspects that were included and to determine the impact of key factors on quality of life in the city. At the beginning of the survey, respondents were asked about quality of life, what it is associated with and what it is for the respondents. Respondents were also asked about the standard of living in the city and the assessment of individual aspects in the area of quality of

life. The study covers the following aspects: quality of life in the city, safety, education, housing economy, social infrastructure, business development, employment market, public transport, health care, culture, citizen (participatory) budget, administration, quality of life for the elderly.

For the first question, respondents were asked to answer what, in their opinion, quality of life is related to (Figure 1).

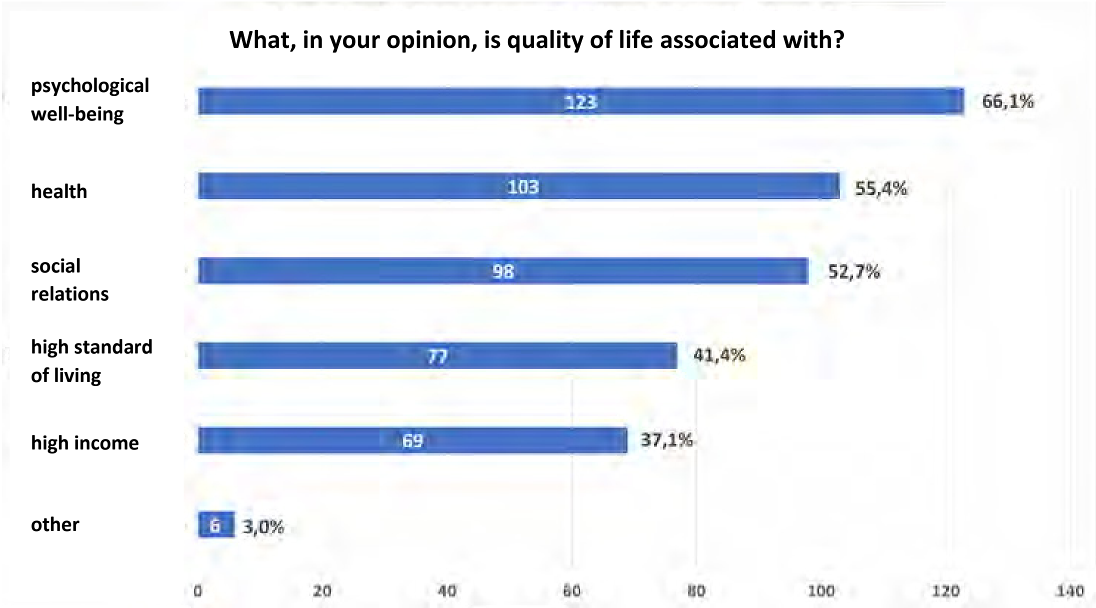

Figure 1. Summary of answers to the question: What, in your opinion, is quality of life associated with?

In the five areas given, respondents provided most answers relating to the sphere of life, mental well-being. As many as 66.1% of respondents pay special attention to mental well-being, i.e. the comfort in which they can live peacefully, implement their plans and intentions, take action both in the professional area and in a very important area of family life. Nevertheless, health and social relations are also important for the respondents, where more than half of the respondents in both cases answered in favour of the significance and, in their opinion, connection with quality of life in the city. Health in times of a pandemic and social relations that have been limited are for people a valuable aspect in the proper functioning in today's world. Lack of contact and relationship with another person can have a negative impact on quality of life. Thanks to the answers to health, it can be concluded that it is thanks to health, good mental and physical being that a person increases their ideas about quality of life and which constantly strives to achieve a level according to their own quality expectations. According to the respondents, to a lesser extent, quality of life is associated with a high standard of living and high income. Such a reaction may be caused by the situation we find ourselves in, i.e. the high impact of the pandemic and its changing priorities.

Another question and issue raised in the questionnaire was the standard of living in the city (Figure 2).

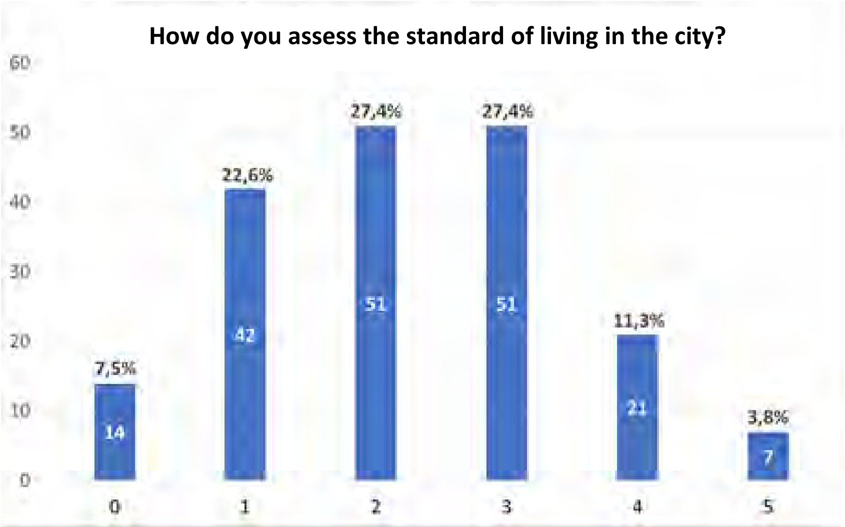

Figure 2. Summary of answers to the question: How do you assess the standard of living in the city?

The standard of living in the city has been rated moderately, which may be influenced by many factors, such as the housing economy, employment market or the surrounding social infrastructure. Many of the respondents rated the level at 1, which is not a favourable rating but shows the probable direction for improving quality of life in the city. Thanks to this question, residents showed that living conditions should be improved by referring to and analysing each aspect of life in turn. The city also received a rating of 4 and 5, but it was by a small group of respondents. Rating of the standard of living may depend on the length of residency or social class, but also on the preferences and expectations of each resident.

The next question included in the questionnaire for respondents was to specifically show what aspects have an impact on the rating of quality of life in the city (Figure 3).

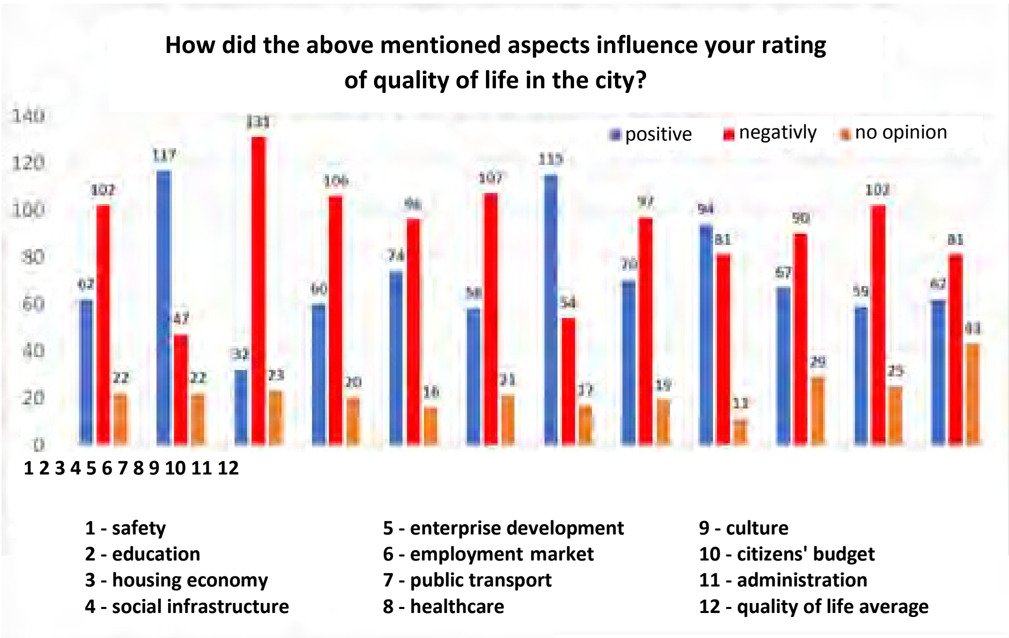

Figure 3. Summary of answers to the question: How did the above mentioned aspects influence your rating of quality of life in the city?

The following aspects were analysed: safety, education, housing economy, social infrastructure, business development, employment market, public transport, health care, culture, citizen budget, administration and quality of life of the elderly. Of all the above mentioned aspects, education was rated the best receiving 117 responses, then public transport, which was selected by 115 people, and culture by 94 people Results of these three best rated aspects may indicate that today's world trends are being followed, in which education plays one of the most important roles. Transport was also rated positively and highly, which indicates modern public transport systems, as well as accessibility related to the purchase of tickets or checking timetables. The third best rated aspect is culture, which may indicate festivities and cultural events organised by the city. The housing economy was rated the most negatively, which may indicate a low standard, investments and renovation of flats in the city, and then the employment market and social infrastructure were also negatively rated. When assessing the employment market, it is possible that respondents suggested the lack of jobs or good salaries in the city, while infrastructure is an important cultural and social element, as well as influencing the image of the city itself.

Another question posed in the survey was satisfaction with the level of education in the city, which is shown on a 0 to 5 scale (Figure 4).

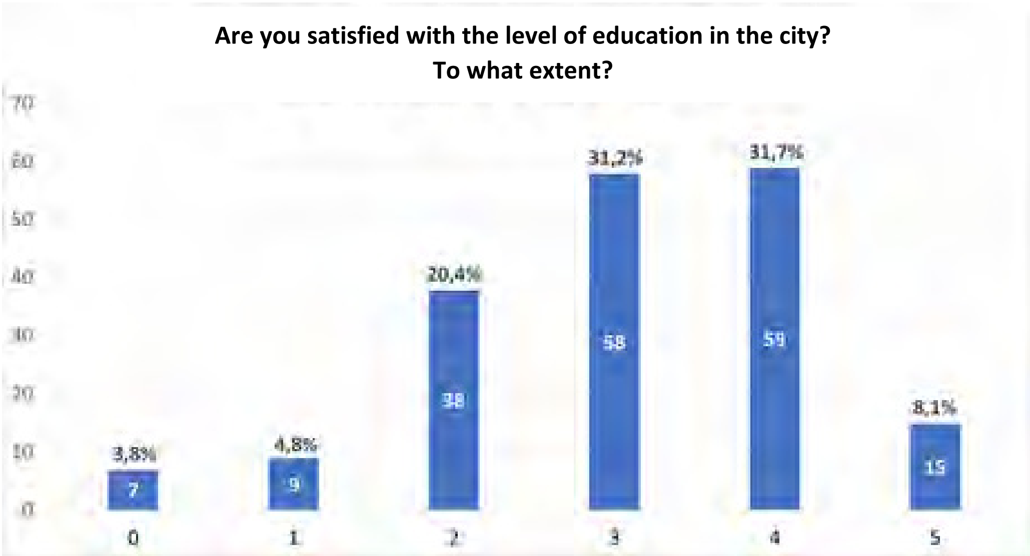

Figure 4. Summary of answers to the question: Are you satisfied with the level of education in the city? To what extent?

As shown in the previous question, education enjoys high ratings from the respondents. Most of the respondents gave a positive rating of the aspect of education. There were also people with a negative opinion, also showing that there is a problem and that poor areas should be improved. Ratings 3 and 4 were indicated by the majority of respondents. This level of satisfaction may indicate the manner, quantity and quality of knowledge provided in schools in the city. An additional aspect indicating a positive reaction to education may be schools for children with special needs, bilingual schools and those developing passions and interests of children and young people.

Another question with a high rating among the respondents concerns public transport (Figure 5).

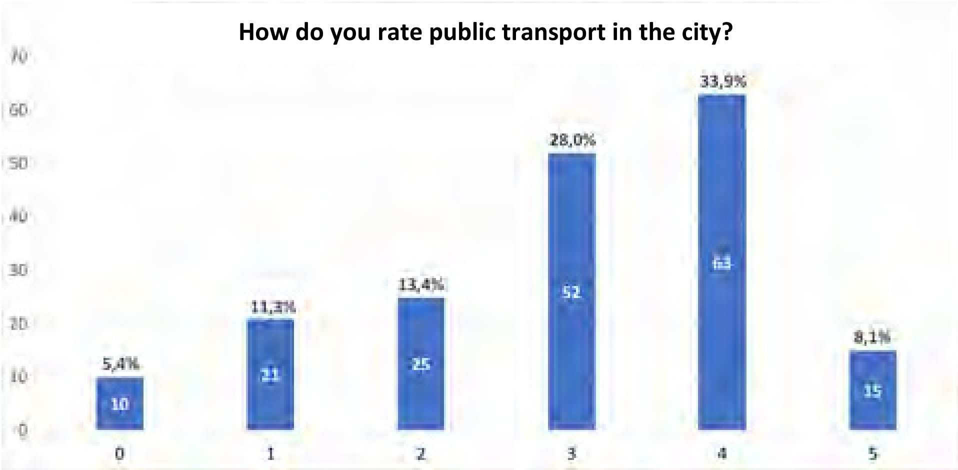

Figure 5. Summary of answers to the question: How do you rate public transport in the city?

Research has shown that city residents have a positive and high opinion of public transport. This rating may be influenced by modern transport, a payment system that lets you purchase a ticket via the Internet, digital timetables with information on when a particular means of public transport departs. Also, the comfort of travel and repairs carried out on roads and rail roads.

The respondents were also asked to answer a question on how they assess the increase in cultural potential in the city (Figure 6).

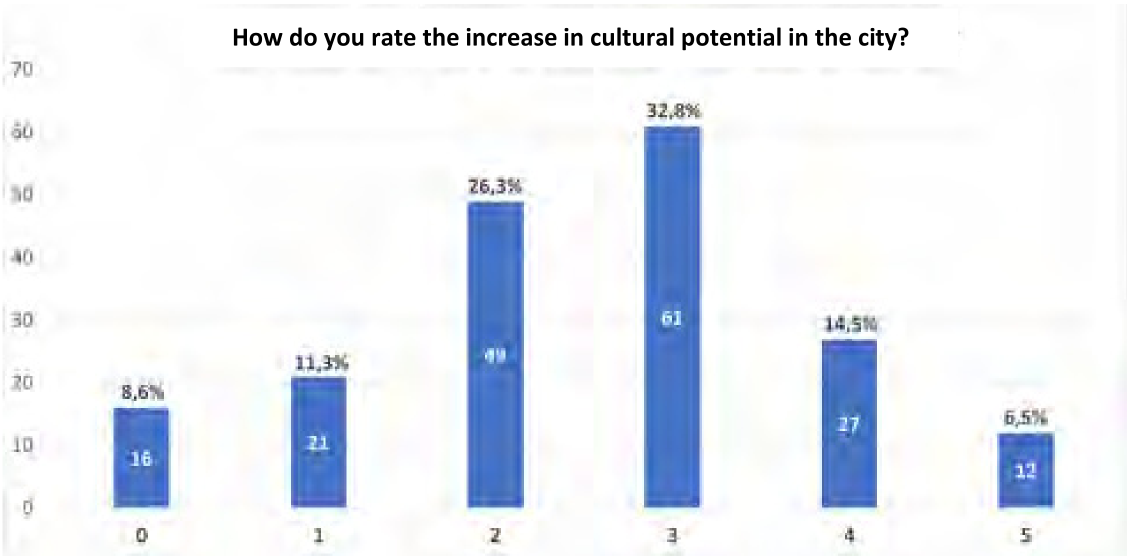

Figure 6. Summary of answers to the question: How do you rate the increase in cultural potential in the city?

Most of the respondents rated this area positively. The aspect of culture in the city is an important part of building tradition, encouraging residents to participate in city life, but also in ensuring that residents spend their free time in their city. Spending free time in your home city is a big advantage; thanks to festivities and cultural events, the city has a chance to promote its attractions and encourage people to use the services of local companies.

The next question shows the quality of available housing offered by the city (Figure 7).

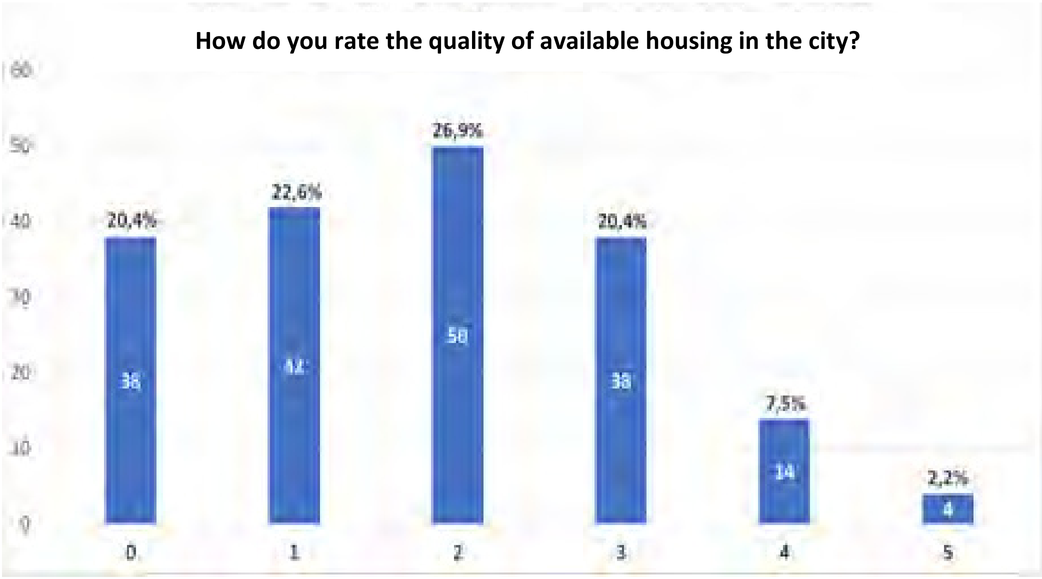

Figure 7. Summary of answers to the question: How do you rate the quality of available housing in the city?

In this question, the majority of respondents expressed a negative opinion, which is reflected in Figure 7. The respondents' opinions were very low, indicating the scale of the problem in the housing economy. Only 9.7% of responses were positive. A negative rating may indicate a low standard, small in size, not renovated or damage from previous tenants. Lack of care in the housing economy has a negative impact on the opinion of residents and their willingness to stay in the city. Negative ratings may also be reflected in the city's future, many people may move to other cities, improving their quality of life and housing.

The next question relates to the employment market and jobs in the city (Figure 8).

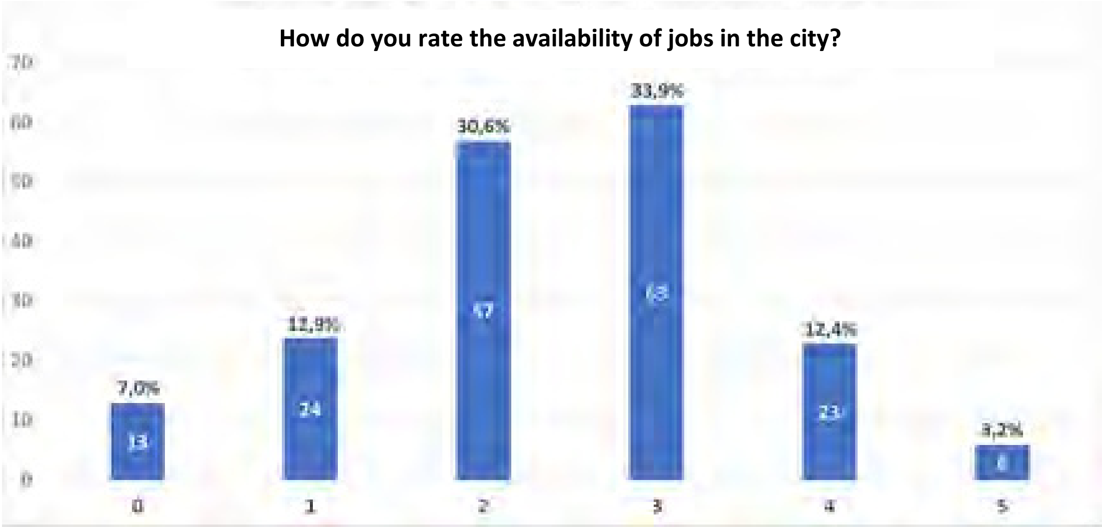

Figure 8. Summary of answers to the question: How do you rate the availability of jobs in the city?

Permanent employment and income is very important for people nowadays. In the midst of a pandemic and uncertainty in employment markets and the economy, employment is a priority for residents. The availability of jobs in the city was moderate. A rating of 2 was indicated by 30.6%, which indicates dissatisfaction with the number of jobs, while a rating of 3 was indicated by 33.9%. 15.6% of the respondents rated it positively. Research results show that the number of job positions should be increased. Positive and negative ratings of the respondents may also result from their qualifications and the lack of demand for a specific occupation, or in the case of a positive rating – the demand of the employment market in a given occupation, field of expertise.

In the next question, respondents were asked to provide answers about the state of the social infrastructure (Figure 9).

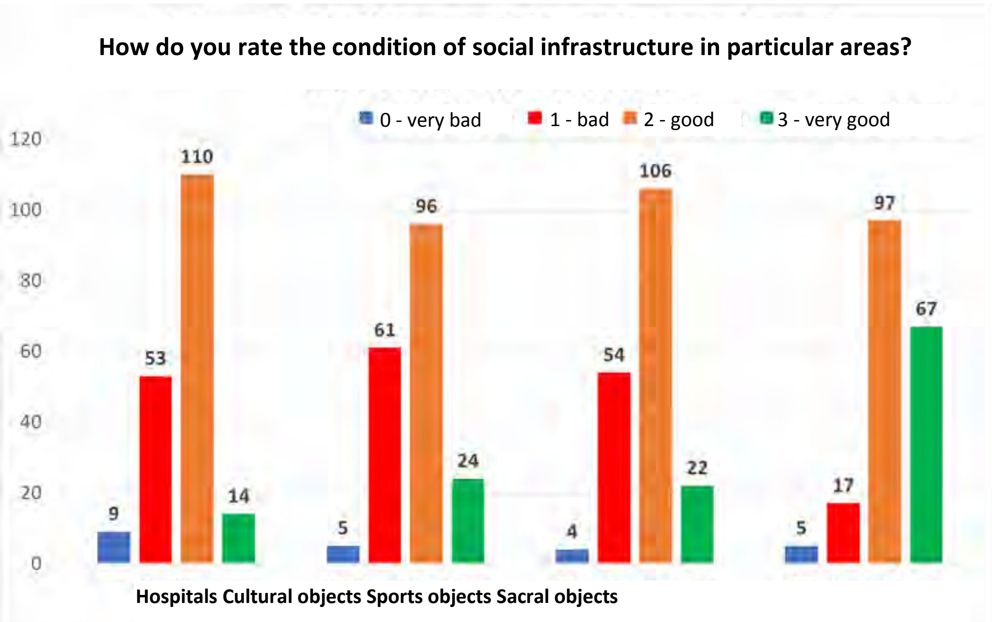

Figure 9. Summary of answers to the question: How do you rate the condition of social infrastructure in particular areas?

The listed facilities were given a good rating. The following facilities were given a good rating: hospitals were rated the best, then sports facilities, religious facilities and finally cultural facilities. There were also respondents who rated the infrastructure negatively, but only few cases. Answers to this question may indicate that the city cares about social infrastructure and thus the positive opinion of its residents.

Safety in the city is one of the most important aspects that a city should follow (Figure 10).

Figure 10. Summary of answers to the question: How do you rate safety in the city?

Residents rated the level of safety at a moderate level. In this way, they reveal that they feel moderately safe and expect greater safety in the city. It may also result from the number of interventions, the level of response by local forces or the manner of conducting interventions. Safety is an important part of the area and which the city should pay particular attention to.

In the conducted research, the aspect of public administration was analysed (Figure 11).

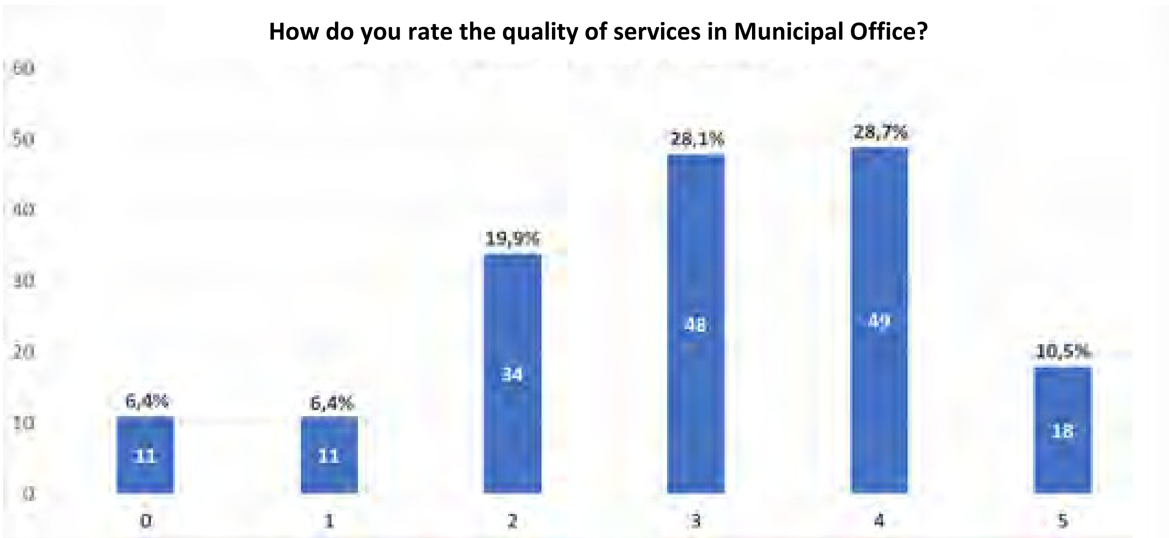

Figure 11. Summary of answers to the question: How do you rate the quality of services in Municipal Office?

Respondents were asked to rate the quality of services provided by Municipal Office. The quality of services in Municipal Office was rated as good, as shown in Figure 11 which shows the scale of responses. The residents rating on public administration is positive, which shows care for the image of the office, competences, increasing the qualifications of officials, personal culture as well as commitment to work and willingness to help in administrative matters. The city, in order to ensure the level of provided services, conducts systematic trainings and surveys among employees, as well as residents using the services.

In the survey, respondents were asked to comment on quality of life of the elderly in the city (Figure 12).

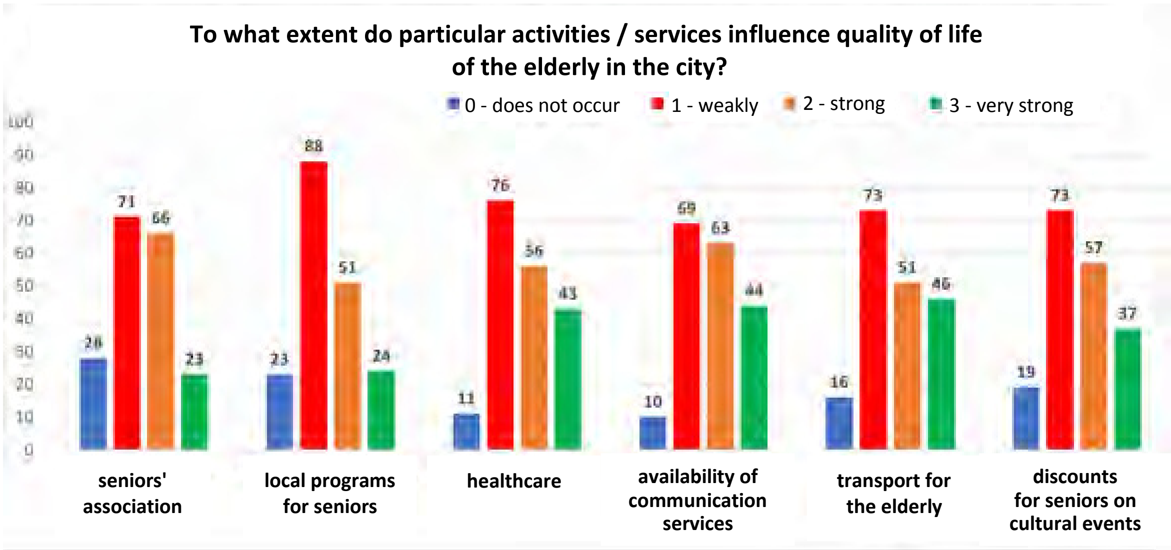

Figure 12. Summary of answers to the question: To what extent do particular activities/services influence quality of life of the elderly in the city?

The question posed in the survey was to what extent individual activities/services affect quality of life of the elderly in the city? 46 people voted ‘very strongly’, with the highest number of votes in favour of adapting transport for the elderly. Respondents believe that this has the greatest impact on quality of life of the elderly. According to respondents, social clubs in the city have the smallest impact on quality of life of the elderly.

Another question asked to the respondents was the impact of the citizen budget on quality of life in the city (Figure 13).

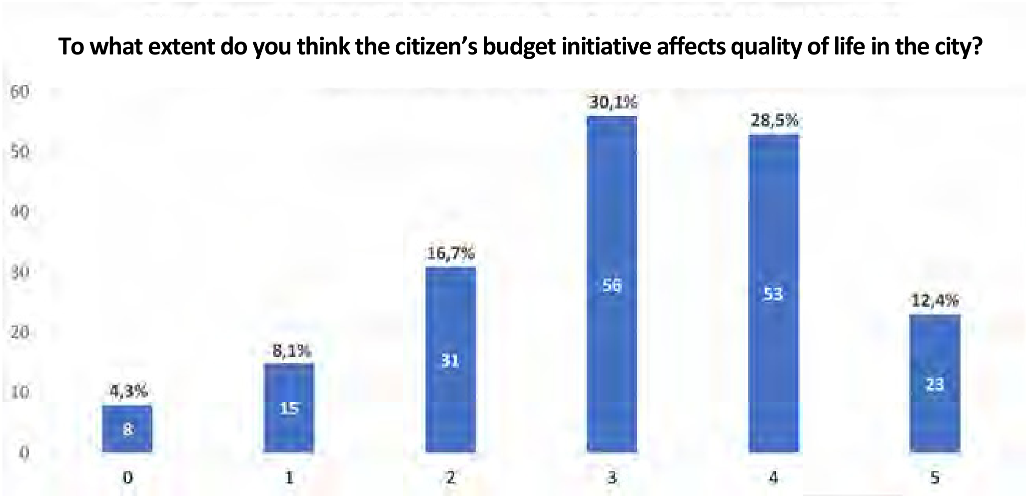

Figure 13. Summary of answers to the question: To what extent do you think the citizen's budget initiative affects quality of life in the city?

In recent years, citizen budgets have become more and more popular among residents. Thanks to the citizen's budget, residents have a real influence on the activities and initiatives undertaken in the city. They themselves can coordinate and get involved in the city's life and its development. Research results show that the majority of respondents support the idea of a citizen's budget and believe that it has an impact on quality of life in the city.

4. Discussion

Residents understand quality of life as a component of functioning in their everyday lives. The conducted research made it possible to identify factors influencing quality of life of the residents. All research questions were answered. The study identified the following factors influencing quality of life in the city: quality of life in the city, safety, education, housing economy, social infrastructure, business development, employment market, public transport, health service, culture, citizen's budget, administration, quality of life of the elderly. According to residents, the most important part of quality of life is mental well-being, i.e. mental comfort and stability. Health and social relations are also important for the residents. Some respondents believe that a high standard of living and a high income also affect quality of life. On the basis of further analysis, residents positively rated the areas of education and public transport – in their opinion, these elements function well in the city and they are satisfied with the level that the city maintains in terms of education, development and proper operation of transport. The introduction of modern solutions related to the payment system, modern transport, digital information (Radomska, 2019) on timetables, as well as renovations have had a very positive response from society. Residents rated negatively and indicated the need to strengthen the following areas: safety, housing economy, social infrastructure, employment market and administration. The negatively rated areas have a significant impact on quality of life in the city. A negative rating may result from an inappropriate approach to the problem, trivialisation, financial situation or not making the most of available solutions. Strengthening safety is a fundamental element of mental well-being highlighted in the study. Safety has a strong influence on city life and mental well-being. Each group of society should feel safe and be safe in the city. This should be influenced by the local forces (Municipal Police, Fire Brigade, Police) and, according to the research, this is what residents indicated. Another element affecting residents is the housing economy, i.e. flats and buildings in which they run their households. A negative rating may result from the standard offered by the city, the availability of flats and insufficient renovations. Long-term neglect of the housing economy may have negative effects on the number of residents, which results in migration to other cities with more favourable housing conditions. With another aspect of social infrastructure in mind, public facilities such as hospitals, schools, and religious buildings were considered, which are the image of the city for both residents and tourists. The employment market also received a negative opinion from respondents. An unfavourable opinion on the employment market may result from the lack of jobs, the lack of appropriate qualifications and the inability to raise or change qualifications if it is impossible to practice one's profession. Work in life plays one of the most important roles, ensuring our existence as well as the use of skills, accomplishment of dreams and self-fulfilment. The last element negatively rated in this study is public administration. Public administration should meet the needs of society. Residents meet with their local administration in various situations, when their matter needs to be dealt with in municipal offices. Negative assessment of this sector may result from the quality of services provided by the municipal office. In dealing with administrative matters, the competence, knowledge, commitment and personal culture of an employee and office clerk should be at a high level. The study also touched on quality of life of the elderly, where residents expressed their approval for activities undertaken by the city. The elderly are just as important a social group as any other. Residents could also express their opinion on the subject of the citizen's budget. This issue was rated positively, and residents are satisfied that they can decide for themselves and have the opportunity to participate in the development and changes taking place in their city. Comprehensive quality of life surveys carried out in municipal offices provide the opportunity to obtain information needed to create the living conditions expected by residents themselves. Often, research on quality of life is incomplete. They focus on the aspect they want to investigate and therefore have plans. Qualitative research is carried out in various cities of the Śląskie Province. In the city of Gliwice, in 2017 (CBOS research report, 2017), a survey was carried out by the Public Opinion Research Centre, in which residents were asked about living conditions in the city. The study was of a cognitive nature, residents were asked about individual areas of life, thanks to which answers were obtained in most aspects of quality of life in the city of Gliwice. In the city of Zabrze, surveys are carried out on the satisfaction of residents with quality of services and customer satisfaction. Additionally, research has been carried out in the field of spatial development under the name ‘City as a space of development’. The presented examples show that such studies are too small for large cities with over 100,000 residents. As mentioned before, comprehensive quality of life surveys should be carried out once a year, aimed at obtaining information and opinions of residents about the actual state of the city and the needs of residents, as well as proposals for intensifying activities in individual areas in cities. The quality of life survey should provide as much information as possible and give a broad view of the perception of various areas of life by residents. This data can be used to make decisions by the city on the directions of further development and activities for the future. The scope of the research should be as wide as possible, therefore the research should be conducted face-to-face and by electronic means. Not every group the sender wants to reach will be able to use the Internet communication channel, such as, for example, the elderly for whom the contact method is more convenient and easier. Two ways of conducting research result in a greater reach with recipients. An additional proposal for information gained through the survey is to create teams in municipal offices aimed at analysing the obtained responses and referring them to the relevant departments dealing with specific issues. Such a method will make it easier to diagnose the problem, solve it, and also intensify and speed up activities. By referring the matter to the relevant department in the municipal offices, the information can be quickly analysed and used for implementation.

5. Summary

The article presents the opinion of residents on quality of life, using the example of a large city. Research conducted among residents was aimed at finding out opinions on quality of life in their city. The questionnaire covered various areas of quality of life related to living conditions, satisfaction, contentment as well as problems and negative aspects taking place in a large city. Research shows that residents have divided opinions about living conditions. The areas of education and public transport were rated positively, while safety, housing economy, social infrastructure, the employment market and administration – negatively. The research is an aspiration to undertake further research related to quality of life. Results of the conducted research indicate the need for changes. A comprehensive assessment of residents' quality of life should be introduced once a year, which would give a faster response to existing problems. Before conducting research in the city, an appropriate team should be appointed to develop the survey results. This method will facilitate a good and effective analysis. The team should collect responses and then forward them to the relevant departments. This would give a faster reaction to problems. As for the method of conducting research, two methods should be used - face-to-face and by electronic means. The face-to-face method is better suited to the elderly, whose opinions are very valuable for assessing quality of life. Electronic means allows to reach every individual, the possibilities of social networking sites are endless and it is worth using them. The benefit that the city can obtain from conducting such research is the improvement of its situation and solving the problems noticed by its residents.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

HOW CITIES MEASURE QUALITY OF LIFE – CONCEPT OF THE SECOND STAGE OF THE RESEARCH

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Purpose: The aim of this article is to present the concept of the second stage of research concerning the study of quality of life at the city level and to indicate the cognitive possibilities offered by combining the two stages of research.
Design/methodology/approach: Based on the results of the first stage of research, the assumptions and methodology for the second stage were developed. A concept of a survey carried out among a sample of 84 municipal offices of cities with over 50,000 residents located in Poland is presented. Particular attention was paid to the development of the research tool and the conditions necessary to obtain a high return in the survey.
Findings: The developed concept provides an opportunity to trace the dynamics of phenomena related to the study of quality of life at the city level. It enables comparison of two groups of cities which conduct and do not conduct structured research on the quality of life. It provides information required to explain adverse phenomena related to data collection and processing and their causes.
Research limitations/implications: Limitations resulting from the specificity of the research were highlighted and directions for further research were indicated.
Practical implications: The possibility of practical use of the research results in the context of data acquisition for sustainable development of cities was highlighted.
Social implications: Social implications of the research were indicated. Proper acquisition and utilisation of information obtained from residents should affect improvement of the quality of life.
Originality/value: The article presents a completely new approach to research on the quality of life on the city level. In the first stage, the aim was to investigate whether municipal offices are able to extract data from surveys on quality of life of their residents in order to use them for sustainable development. The second stage involves investigating how the cities process these data and the extent to which they use this information in their office activities.

Keywords: Quality of life surveys, research concept, municipal office, sustainable development.

Category of the paper: Research paper.

1. Introduction

The smart city concept has developed over the years. There are three basic stages in the development of this concept (Borcuch and Piłat-Borcuch, 2016; Beck, 2018; Kubina et al., 2021). In Smart Cities 1.0, the most important was technology and the possibility of its adaptation by the city administration. In Smart Cities 2.0, a superior role was played by city authorities, which tried to implement modern technologies in order to improve the quality of life of residents. In Smart Cities 3.0, citizens are starting to play a key role in the development of cities. Residents should be involved in the city development and provide the necessary information in this regard. There are different forms of residents' involvement, both individual and collective. It is important that the city government creates the right conditions for articulating the needs, expectations, opinions, comments and evaluations of the human factor and encourages their communication at the city level. This information can be used in various areas and fields of the city's functioning. Therefore, two issues arise. The first one is the ability to acquire data; the second is the ability to process data and use them in decision making. The concept of smart city highlights the importance of skilful use of the information obtained for sustainable development. This is reflected in definitions (Caragliu et al., 2011; Albino et al., 2015) and developed models (Giffinger et al., 2007; Lombardi et al., 2011; Airaksinen et al., 2017; Jonek-Kowalska et al., 2018) concerning smart city. Several authors point to the need of obtaining diverse data (Huovila et al., 2016; Bosch et al., 2017a, 2017b; Allam and Newman, 2018; Desdemoustier et al., 2019; Camboim et al., 2019). Data can be collected during various projects carried out by the municipal office. One of many possible sources of data are surveys on the quality of life of residents, There appears to be very little literature on the possibility of collecting data based on quality of life surveys (Noori et al., 2020; Ligarski, 2021). Even fewer publications mention the possibility of using these data for sustainable development of cities (Ligarski, 2021). Thus there is a clear cognitive gap concerning both data acquisition from surveys on the quality of life and their further use for the city's sustainable development. The author has developed a concept of comprehensive research in this regard. This concept presents a completely new approach to research on the quality of life on the municipal office level. In the first stage, the aim is to investigate whether cities are able to extract data from surveys on the quality of life in order to potentially use them for the city's development. The second stage involves investigating how cities process the data and how they use them in practice. Until now, the use of surveys on the quality of life has been limited to assessing the satisfaction of residents and city authorities and, to a limited extent, to calculating certain indicators of city functioning (Inch, 2010; Macke et al., 2018). The developed research concept creates completely new cognitive possibilities. So far the first stage of the research has been implemented, which resulted in three publications (Ligarski and Wolny, 2021a, 2021b; Ligarski, 2021). In this paper, the author intends to briefly summarise the results obtained in the first stage, highlighting questions and emerging issues that require additional research. Based on this the author wants to present the concept of the second stage of the research which will complement and expand the original research. He also intends to present cognitive possibilities created by combining the two stages of research.

The aim of the paper is to refer to the assumptions and results of the first stage of the research and to present the concept of the second stage concerning the research on the quality of life at the city level and to indicate the cognitive possibilities offered by the two stages of research together.

2. Assumptions and results of the first stage of the research

The following assumptions were made when undertaking the first stage of research into how quality of life can be investigated and how this information can be used for sustainable development of cities. The research was to be nationwide and carried out on a relatively large sample of cities aspiring to introduce the concept of smart city. From among 944 Polish towns with a status of a city, ultimately 84 cities were selected for the research. All cities with more than 50,000 residents were selected, assuming that the largest cities should be interested in the smart city concept and they should have the most information about it. Research questions were formulated, which formed a basis for empirical research. It was decided that the basic research tool would be a questionnaire survey. This required development of own questionnaire. Ultimately, the questionnaire included 29 closed questions and demographics box. Such form of the questionnaire was to make results' comparison easier. In the section with questions there was also "other" option available, where respondents could give their own answer. By design, the survey was anonymous, with the demographics box asking respondents only to select one of the four size groups in which the city falls. Selection of one group to which a city can be assigned due to per capita income and indication of the province where the city is located. By undertaking the research, the aim was to achieve the highest survey return rate possible. Thus a professional organisation was chosen to conduct the survey and the minimum return rate of 80% was indicated. A tender procedure was carried out to select an organisation with relevant experience in carrying out this type of research. The survey was addressed to people in municipal offices that are responsible for conducting research on the quality of life of residents. The survey was conducted in the period from October to December 2020. The survey return rate of 90.5% was achieved. The obtained research results were compiled and statistical analyses were performed taking into account the formulated research questions.

The first surprise after obtaining the research results was to find that only 35 cities out of the group of 76 surveyed municipal offices declared that they conduct quality of life surveys. This means that only 46% of the cities surveyed conduct research on the quality of life of their residents. In turn, 54% of the cities surveyed do not carry out any structured research on their residents' perceptions of quality of life. Thus, these cities do not acquire data that could be used, upon adequate processing, for the city's development.

In the first publication presenting the research results the authors referred to the concept of research and tried to answer the question why a large number of cities do not conduct quality of life surveys (Ligarski and Wolny, 2021a). In the research questions posed, attention was paid to the knowledge and awareness of those responsible for conducting quality of life surveys at the city level and the organisation of the process. The paper shows that the vast majority of respondents see the need to study the quality of life in their cities. However, the definition of the concept of quality of life and its understanding leaves much to be desired. In some of the municipal offices surveyed, the concept of quality of life was not clearly defined. The lack of basic knowledge regarding the concept of quality of life and factors that influence it significantly limits the employees' activities. If it is not clear what quality of life is and which factors influence it, it is no surprise that the employees have problems with studying this type of phenomena. The office's management should provide and systematise knowledge on quality of life and the factors affecting it. Define the role of research on quality of life and the need to acquire data that, upon adequate processing, could be used for improvements in various areas of the office's operations. Based on the results obtained, it should be concluded that this process did not take place properly in the majority of offices. In the paper (Ligarski and Wolny, 2021a) it was also pointed out that the size of the city affects the definition of the concept of quality of life. Chi-square independence tests showed significant differences between cities qualified to different size groups. This can indicate that the largest cities have prepared their employees better for the quality of life research compared to smaller cities.

The second paper presenting the research results focused on the perception of areas that affect the quality of life (Ligarski and Wolny, 2021b). A compilation of 25 areas developed by the author that may affect the quality of life was used for the research. The paper analyses how cities understand the areas affecting the quality of life, in which areas this research is carried out and whether there is a need to extend it. The relationship between the areas influencing the quality of life, their importance, areas included in the research, and areas which should be expanded upon in the research in the respondents' opinion was also investigated. The results obtained for 35 cities that conduct structured quality of life research were subjected to statistical analyses. Based on the results it was found that cities are aware that the quality of life is affected by many areas, however, they conduct such research only in selected areas and their number is limited. The cities also find it difficult to identify areas that should be added to the current research on the residents' quality of life.

In the third paper presenting the research results the authors tried to answer the question how the cities compile the results obtained from quality of life research and what activities they undertake on this basis (Ligarski, 2021). Information was obtained on how the data are compiled and presented to the various organisational units and employees of the offices.

Who and how analyses the compiled results and what decisions and actions follow. There was also an attempt to estimate the percentage in which an office uses the obtained information and whether this depends on the size of the city. It was found that the research results do not reach all organizational units and employees. There are problems at the stage of results analysis and problems with making decisions and taking actions. Only one third out of 35 municipal offices undertake specific actions resulting from previously conducted analyses. It can be concluded that the offices do collect data; however most of them are not able to use them properly for the city's sustainable development.

3. The concept of the second stage of the research

Knowing the results of the literature research and having the knowledge and experience from the first stage of the research (Ligarski and Wolny, 2021a, 2021b; Ligarski, 2021), it is necessary to conduct further research. The observed cognitive gap regarding the use of information from the quality of life research for sustainable development of cities remains an important issue that requires obtaining information. Obtaining this kind of information should help municipal offices in better organisation of this process and inspire them to actually use the information in various areas of the city's functioning.

When developing the concept of the second stage of the research the following assumptions were made:

1. The research will be conducted on the same sample of Polish cities as in the first stage of the research.
2. The research will use the research questions posed earlier and they will be supplemented by new questions.
3. The main research tool would be a questionnaire survey.
4. The original questionnaire will be used for the research after modification.
5. The survey was intended to achieve a high return rate.
6. The research results will be statistically analysed.

The selected research sample remains the same as in the first stage. This group includes 84 cities in total. These are the largest cities in Poland in terms of number of residents, which can be divided into five size groups. Within this group, there have been slight shifts of cities assigned to the respective size groups due to a decrease in population. This concerns only a few cities and does not affect the research group significantly. Conducting the research in the same cities again also creates new cognitive possibilities. Obtaining information whether and how the perception of studied phenomena changes after one year. The first research was conducted in the period between October and December 2021 and the second is planned for December

2021 – January 2022. It should also be noted that this year was exceptional due to successive waves of coronavirus outbreaks which affected the operation of municipal offices.

As assumed, the research will use research questions developed for the first stage of the research. Additional research questions were also formulated. Answers to these questions will make it possible to compare offices that conduct quality of life research in an institutional way with offices that do not conduct such research. It will also be relevant to find out how the passing time (one calendar year) affected the perception of phenomena concerning the quality of life.

The survey conducted in the first stage of the research enabled obtaining enough information to achieve the research goals. In the second stage of the research, the survey will be the main source of data. This will enable information to be obtained from as many of the surveyed offices as possible. In the times of pandemics a survey is also a safe option for all parties involved in the process.

The research will use author's own questionnaire form in Polish, which was used in the first stage of the research. However, the form will be modified and adapted to current needs. The initial assumption is to use as many questions with answers as possible, so that the results can be compared with the results of the previous research. However, experience from the previous research edition prompts a change in the order of some of the questions. In the first stage of the research only 46% of the surveyed cities conducted structured research on the quality of life. Cities that had not conducted such research did not answer most questions because their order assumed a positive answer to the question concerning conducting research on the quality of life. After changing the questions' order, all surveyed cities will have to answer basic questions. Only the questions concerning collection, processing and use of data will be reserved for cities that conduct quality of life research. It is also intended to introduce new questions to gather information needed to clarify issues that were not investigated in the first stage of the research. The comparison of questions' order in the first and second stage of the research and introduced changes are presented in Table 1.

Table 1.
Compilation of questions' order in the first and second stage of the research, including introduced changes

No.	Numbers of questions in the first survey form	New questions and removed questions	Numbers of questions in the second survey form
1	1		1
2	2	New question 1	New question 1
3	3		2
4	4		15
5	5		16
6	6		3
7	7		4
8	8		5
9	9		6
10	10		7
11	11		8

Cont. table 1.

12	12		9
13	13		10
14	14		11
15	15		12
16	16		13
17	17		14
18	18		17
19	19	New question 2	New question 2
20	20		18
21	21	New question 3	New question 3
22	22	New question 4	New question 4
23	23		19
24	24		20
25	25		21
26	26		22
27	27	Removed question 27	23
28	28	Removed question 28	24
29	29	Removed question 29	25
30			26

Source: Own study.

The survey form used in the first stage of the research included 29 questions. The form used in the second stage of the research includes 30 questions. 26 questions used in the original survey form were implemented in the second form. Four new questions were introduced; three questions concerning office's e-services were removed, ensuring that the survey form is not too long. The original form began with questions about defining the concept of quality of life and awareness of the need to study it at city level. Then respondents were asked about the way of organising this process. The modified form will begin with questions concerning defining and understanding the concept of quality of life in a city, which will be complemented with two issues concerning areas that affect the quality of life. The author of the survey questions identified 25 areas that can affect the quality of life and enabled them to be rated on a five-point scale. Respondents also have the possibility to add another area that, in their opinion, affects the quality of life and to rate it. A summary of those areas in alphabetical order in Polish that appears in the original survey form together with the rating scale is provided in Table 2.

Table 2.
Summary of areas affecting the quality of life together with the rating scale

No.	**Areas affecting quality of life**	**Areas rating**				
		1	**2**	**3**	**4**	**5**
1	a. public administration					
2	b. public safety					
3	c. education					
4	d. waste management					
5	e. water management					
6	f. service and commercial infrastructure					
7	g. climate and geographic location					
8	h. culture and protection of national heritage					

Cont. table 2.

9	i.	housing					
10	j.	leisure opportunities					
11	k.	science					
12	l.	environmental protection					
13	m.	future perspectives					
14	n.	social assistance					
15	o.	entrepreneurship					
16	p.	civil society					
17	q.	sport and recreation					
18	r.	information technologies					
19	s.	transport and communication					
20	t.	tourism and promotion					
21	u.	technical services					
22	v.	working conditions in the city					
23	w.	living conditions in the city					
25	x.	spatial planning and architecture					
25	y.	health					
26	z.	other (additional), please specify					

Source: Own study.

The survey form includes four questions that concern the mentioned areas affecting the quality of life and enable their rating on a five-point scale. The first question asked to identify which of the listed areas affect the quality of life, the second to determine their importance (relevance). The third question asked which of these areas are included in the city's survey and the fourth asked which areas should be added to the survey. In the first stage of the research, these questions were arranged in succession and designed for offices that conduct research on quality of life. In the new form, the first two questions have been moved to the beginning. This modification will enable examining the understanding of areas affecting the quality of life also in offices that do not conduct formal research on the quality of life. These questions will also be a natural extension to the questions on the understanding of the concept of quality in the city. In the rest of the survey form the questions will remain in their original order. A new question will be introduced only after asking a question about which of the areas listed are included in the city's quality of life research. The new question "In your opinion, does the currently conducted research on the quality of life in your city cover all the important areas for the quality of life?" is intended to obtain the opinion of the person in charge of the quality of life research as to whether, in their opinion, all relevant areas have been covered in the currently conducted research in the city. The following two questions included in the second survey form concern the issue of data collection. The following questions were introduced: "When you start collecting data on quality of life, do you know for what purposes this information will be used in the future and to which organisational units it should go?" and "What do you think could be improved when collecting data on quality of life in your city?". These questions are designed to investigate the knowledge and attitude of employees in charge of research to data collection with a view to the future use of the results. This is an important issue which will be elaborated in the second stage of the research. In the rest of the survey form the questions will remain in the same order as in the original form. The three final questions concerning e-services were removed from the form as they were found to concern additional issues. This also ensured that the form is not too long and its completion does not take too much time. As in the first stage of the research, the research was conducted anonymously. The demographics box asks only to indicate one of the size groups and one of the per capita income groups to which the city can be assigned and to indicate the province where the city is located.

In order to achieve the highest possible survey return rate, a lot of attention was paid to the selection of an organisation which will directly conduct the survey in the municipal offices. A tender procedure was held to select this organisation, with requirements regarding competence and experience in conducting this type of research. The requirements also included a condition that the expected survey return rate should be at least 90%. This procedure led to the selection of a professional organisation that was able to meet the requirements.

The results of the research, once structured, will be statistically processed using IBM SPSS Statistics. The research team is competent in this area and has gathered experience by compiling the results of the first stage of research.

4. Discussion

Seeking to comprehensively investigate how cities conduct quality of life research and how they use this information for sustainable development, the concept of the second stage of the research was presented. This concept complements and extends the first stage of the research thus presenting new cognitive possibilities. After the first stage of the research, various phenomena at office level have been identified. Vast majority of offices recognise the need to investigate the quality of life of residents. However, less than half of the offices surveyed conduct a standardised quality of life research (Ligarski and Wolny, 2021a). The concept of quality of life has not been clearly defined in a large number of offices. This leads to various problems. The second stage of the research is intended to investigate the understanding of the concept of quality of life by people who are or who potentially are to be in charge of conducting such research. This is also to be achieved by examining employees' awareness of which areas affect quality of life and what their importance is. In the first stage the research was conducted on a group of employees of offices which conduct structured research on quality of life (Ligarski and Wolny, 2021b). In the second stage, the research is intended to be carried out on a group of all research participants. The second stage of the research will make it possible to explore the basic issues in two groups of offices, the first – which conducts structured quality of life research, and the second – which does not conduct this type of research. The results obtained will enable comparison of these groups. In the first stage of the research conducted on a group of offices that conduct structured quality of life research, it was found that employees of offices are aware that quality of life is influenced by many areas and are able to assess their importance. These results are in line with results of other research presented in literature (Macke et al., 2018; Papachristou and Rosas-Casals, 2019; Moeinaddini et al., 2020, Rodríguez Bolívar, 2021). However, it was noted that offices choose only some of the areas affecting the quality of live in their research. When comparing these results with research in literature (Macke et al., 2018; Rodríguez Bolívar, 2021) it seems that the offices do this deliberately. Researches on quality of life are conducted in a limited number of areas and the data thus obtained are fragmented. Obtaining incomplete data will result in lack of sufficient information that could be used for city's sustainable development. Explaining why this is the case inspired the author to introduce new additional questions to the survey form, as detailed in the previous section of the paper. The second stage of the research will seek to explain why there are disturbances at the data collection stage and what the reasons are. This is an important issue that has a significant impact on the subsequent use of information for the development of the city in various areas. If a city is not able to obtain required data, this shortage will influence all subsequent stages related to the processing and use of information. The second stage of the research, by using most of the questions from the first stage, will allow us to determine how perception regarding the quality of life research at the municipal office level changes after one year. It is assumed that it will be possible to identify the dynamics of some phenomena present at a city level. Introduction of additional questions and partial change of question order will make it possible to broaden the investigated issues and will provide an opportunity to explain the causes of the unfavourable phenomena that occur at the level of the quality of life research in cities. The practical implementation of the concept of the second stage of the research gives two possibilities. On the one hand, to trace the dynamics of the phenomena occurring in offices, on the other hand, to compare two groups of offices, conducting and not conducting structured research on the quality of life of their residents.

5. Summary

Seeking to comprehensively investigate the issue of how cities conduct quality of life research and how they use this information for sustainable development, the concept of the second stage of the research was developed. The starting point for the development of the concept was the results of the first stage of research. The paper refers to the assumptions and results of the research. Research achievements documented in three scientific publications are indicated. Moreover, questions and issues that require further elaboration were highlighted. The assumptions of the second stage of the research and the chosen research method were presented. Particular attention was paid to the changes introduced in the survey form. New questions and motives for their introduction to the form were presented. Actions taken in order to ensure high survey return rate were described.

The developed concept of the second stage of the research will enable the completion and extension of the current research. It will provide an opportunity to trace the dynamics of phenomena related to the study of quality of life at the city level. It will enable comparison of two groups of cities which conduct and do not conduct structured research on the quality of life. It should also provide information required to explain adverse phenomena that occur at different stages of data collection, processing, and use, and identify their causes. It can be assumed that the results of the first and second stage of the research will be complementary and will provide a holistic view of the phenomena occurring during quality of life research and use of this information for the city development in various areas. This should inspire municipal offices to use quality of life research as a valuable channel for obtaining data from residents which, upon adequate processing, can be used for the city's sustainable development.

When looking at the possibilities of the two stages of research as a whole, it is also important to note the limitations. The research is a questionnaire-based survey conducted in municipal offices on a group of people responsible for the quality of life research. Thus there are limitations resulting from the nature of conducting surveys. The author of the paper has planned additional case studies in selected offices. They will enable access to a larger group of employees and to records that contain evidence of the activities carried out. This should affect the verification of the obtained research results.

Acknowledgements

This work was supported by the resources of the Silesian University of Technology, project no. 13/010/BK_22/0065.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

THE IMPACT OF SELECTED COOLING SYSTEMS ON THE URBAN NATURAL ENVIRONMENT

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Purpose: The aim of the paper is to indicate the possibility of using refrigerants which do not have a harmful effect on the destruction of the Earth's ozone layer and the urban environment.
Design/methodology/approach: The environmental impact of refrigerants was characterized. Selected refrigerants and their place of application are described. The impact of selected refrigerants on the urban environment is presented.
Findings: An attempt has been made to identify the absolute environmental impact of selected stationary refrigeration systems in operation in cities, i.e. home refrigerators, individual air conditioners, heat pumps, air conditioning systems of large-format stores – shopping centers, or cold stores. Both the direct impact related to the refrigerant used in the system and the indirect one related to the energy consumption to drive the device have been considered.
Practical implications: Use of new refrigerants that do not damage the Earth's ozone layer.
Originality/value: The environmental impact of different refrigerants is presented. The paper is addressed to technical services and personnel responsible for the design and operation of refrigeration and air-conditioning equipment.

Keywords: cooling systems, refrigeration, urban environment.

Category of the paper: Viewpoint.

1. Introduction

Refrigeration, closely related to many industries, plays an important role in the modern world. It allows for creating not only a comfortable and healthy living environment, but most of all it is an indispensable means for the production, processing and storage of food. In practice, the most common are steam compressor refrigeration systems, the operation of which is based on the process of evaporation and condensation of the working medium. The operation of these systems, however, is associated with some negative impact on the natural environment, which results from the properties of working factors and CO2 emissions accompanying the process of generating energy necessary to supply the cooling system.

The depletion of the ozone layer and the impact on global warming are two major environmental problems faced by the refrigeration industry. Today it is known that CFC and HCFC refrigerants, which have been widely used in cooling systems for years, are responsible for the leakage of the ozone layer. The process of destroying the ozone layer is as follows: the CFC or HCFC factor emitted to the atmosphere in the stratospheric layer under the influence of strong UV radiation decomposes and releases a chlorine atom, which, reacting with ozone, reduces it to an oxygen molecule. The ozone depleting capacity of a substance is determined using a comparative unit known as the Ozone Depleting Potential (ODP). The discovery of the ozone hole and the identification of the substances responsible for this state were the basis for adopting the 1987 Montreal Protocol. The protocol adopted a plan for the gradual decommissioning of halogenated refrigerants (United Nations, 1987). As research and observations show, this allowed for a gradual restoration of the ozone layer (Newchurch et al., 2003). However, this is a very slow process and it is expected that only between 2040 and 2070 will it be possible to obtain the level of ozone from before the 70s of the last century. The refrigerants in use today have a zero ozone depletion potential. So it can be concluded that this problem has been solved.

Another major environmental problem is the global warming effect of refrigeration systems. It is measured by the amount of greenhouse gas emissions to the atmosphere accompanying the operation of the cooling system. It is the sum of the direct emission of the refrigerant from the installation and the emission of carbon dioxide generated during the production of energy to supply the cooling system, which is included in the TEWI index. The individual global warming potential of a refrigerant is determined by the GWP (Global Warming Potential) index. It represents the amount of infrared radiation that a substance can absorb compared to carbon dioxide (for which GWP is 1). According to reports published by IIR (Coulomb, Dupont, 2017), in 2016 refrigeration systems were responsible for 7.8% of global greenhouse gas emissions, while in 2004 this value was 1.4% (Coulomb, Dupont, 2017). This increase is mainly due to the constantly growing number of refrigerating appliances in operation. Under the 1997 Kyoto Protocol, substances with high GWPs are gradually phased out of use (Coulomb, Dupont, 2017). Thus, the direct environmental impact of the refrigerants is gradually reduced. It has been assumed that by 2030 the maximum allowable GWP of the refrigerant is to be around 450. The reduction of indirect greenhouse gas emissions by cooling systems is achieved by improving the efficiency of cooling systems and the use of low-emission or zero-emission energy sources to power them.

Currently, there are approximately 5 billion refrigeration systems in operation, including domestic, commercial and transport refrigeration systems, air conditioning systems, heat pumps as well as cryogenic systems (Dupont et al., 2019). Fig. 1 shows the share of individual sectors in this balance. According to the report published by IIR, over 40% of all refrigerating appliances in operation are domestic refrigerators (fridge-freezers). Air conditioning systems also have a large share in this balance, respectively 22% are home appliances, 10% commercial and 20% car air conditioning systems.

A significant number of cooling systems are located in cities, affecting the environment of urban spaces, directly or indirectly. The article attempts to present the impact of selected systems on this state. The total greenhouse gas emissions related to the use of selected refrigeration devices were used as a measure. For this purpose, working agents and cooling systems were characterized. In the literature on the subject, you can find a whole range of articles dealing with the impact of refrigeration systems on the natural environment. Nevertheless, none of them focus directly on the urban environment.

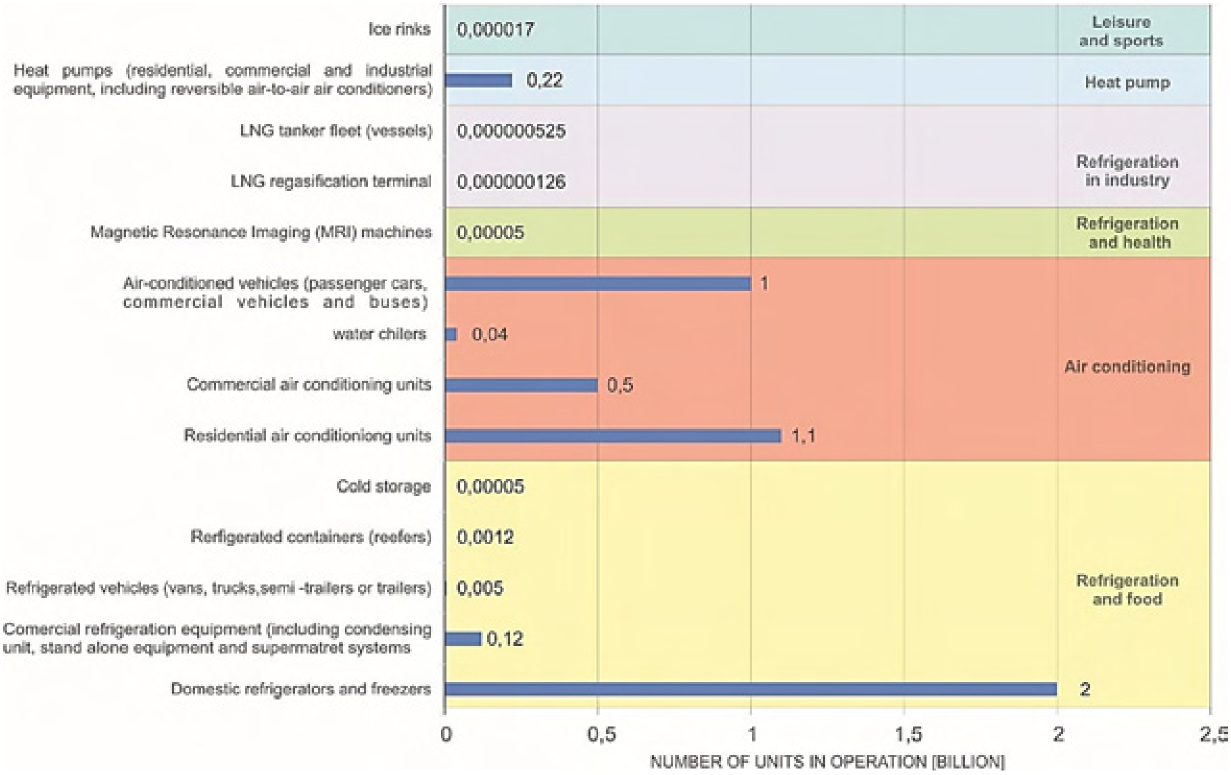

Figure 1. Number of refrigeration system in operation per application (Dupont et al., 2019)

2. Characteristics of selected cooling systems and agents

When analyzing refrigeration systems, the working factors cannot be ignored. When selecting a refrigerant for a given system, both its thermodynamic properties and safety considerations as well as the aforementioned ecological indicators are taken into account. In general, the refrigerants should have: a favorable course of the saturation curve, high volumetric cooling capacity, maintain chemical stability in the entire range of operating parameters, be chemically inert to the materials from which the system is made, and be a non-flammable, non-explosive and non-toxic substance. Table 1 shows the basic parameters of selected refrigerants commonly used in domestic and commercial systems. The table also includes examples of new refrigerants with a low GWP index, ie R1234yf, R1234ze, R32 or R450A, which are substitutes for the currently used substances.

Table 1.
Characteristics of selected refrigerants

	GWP*	ODP	Normal boiling point [ºC]	Molar mass [kg/kmol]	Critical temperature [ºC]	Critical pressure [bar]	Class	Application
R22	1810	0.05	-40.8	86.5	96.1	49.9	A1	Air-conditioning and cooling systems
R32	675	0	-51.6	52.02	78	57.8	A2L	
R134a	1430	0	-26	102.02	101.03	40.6	A1	Car air-con, air-conditioning and cooling systems
R290	3	0	-42.1	44.9	96.74	42.5	A3	medium and low temperature refrigeration
R404A	3922	0	-46.3	97.6	72.12	37.3	A1	Refrigeration, freezing
R410A	2018	0	-51.3	72.6	71.3	49	A1	Air-conditioning and cooling systems
R407C	1770	0	-47	86.2	86.1	46.3	A1	Air-conditioning, heat pumps
R600a	3,3	0	-12	58.1	134.6	36.2	A3	Cooling
R1234yf	4	0	-29.5	114.0	94.7	33.8	A2L	Air-conditioning
R1234ze	7	0	-18.9	114.0	109.4	36.3	A2L	Air-conditioning
R450A	547	0	-23.2	108.6	104.5	38.2	A1	Air-conditioning and cooling
R717	0	0	-33.3	17.0	132.4	113.6	B2L	Cooling
R744	1	0	-	44.01	31	73.8	A1	Cooling, heat pumps

* Counted on a 100-year scale,
A1 – low toxicity, incombustibility, A3 – low toxicity, higher combustibility, B2- higher toxicity, lower combustibility, A2L- low toxicity, lower combustibility,

Source: PN-EN, 2021, Lemmin et al., 2018.

As already mentioned, the analysis of the impact of refrigeration systems on the urban environment was based on selected systems. Taking into account the number of devices in operation, domestic refrigerators and individual air conditioners have been selected.

Fig. 2 shows a schematic diagram of a home fridge-freezer. A typical system consists of a hermetic compressor, a condenser, a regulating element feeding the evaporator (here a capillary tube) and an evaporator. The liquid pipeline supplying the capillary tube is routed in such a way as to heat the contact point of the refrigerator door. This has the dual benefits of preventing the door from freezing and subcooling the refrigerant fluid, increasing the cooling capacity of the unit.

The cooling capacity of modern refrigerators ranges from 60 to 300 W. The average annual energy consumption is approximately 1.8 kWh/year for each liter of refrigerated space, which is the average annual energy consumption for a 362 liter refrigerator 680 kWh. The refrigerants used in the systems are R600a, R290 and, less frequently, R134a. Filling the installation with refrigerant depends on its type and cooling capacity and ranges from 60 to 160 g. Analyzing the solutions of modern refrigerators, the defrosting process cannot be omitted. Many devices are equipped with an automatic system based on electric heaters. Their power varies from 150 to 385, depending on the size of the device. On average, the defrost cycle lasts from 6 to 12 minutes and is carried out once every two days (LG, 2019).

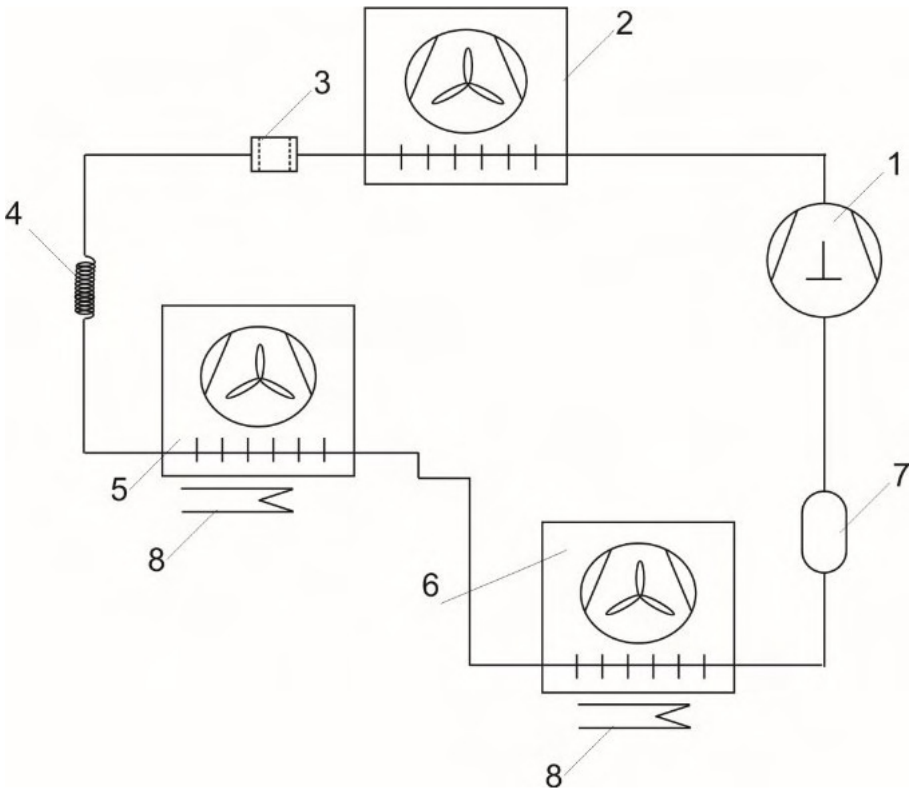

Figure 2. A schematic diagram of a "side by side" home refrigerator system: 1 – compressor, 2 – condenser, 3 – dehumidifier, 4 – capillary tube, 5 – refrigerator evaporator, 6 – freezer evaporator, 7 – liquid separator, 8 – electric defrost heater (own elaboration).

Air-conditioning and heat pump systems can be used in various configurations, in a wide range of capacities. This article focuses on individual split air conditioners (also multisplit), the efficiency of which does not exceed 15 kW. Figure 3 shows an exemplary schematic layout diagram. The use of a four-way valve (2) allows the system to work in the function of both cooling and heating. It is the most common solution that allows to shape the microclimate of rooms all year round. These systems work with the refrigerants R410A, R407C and R134a. Although there has been a trend for several years to introduce alternative substances such as R290 (Weier et al., 2017) or R744 or R1234yf (Juan et al., 2017).

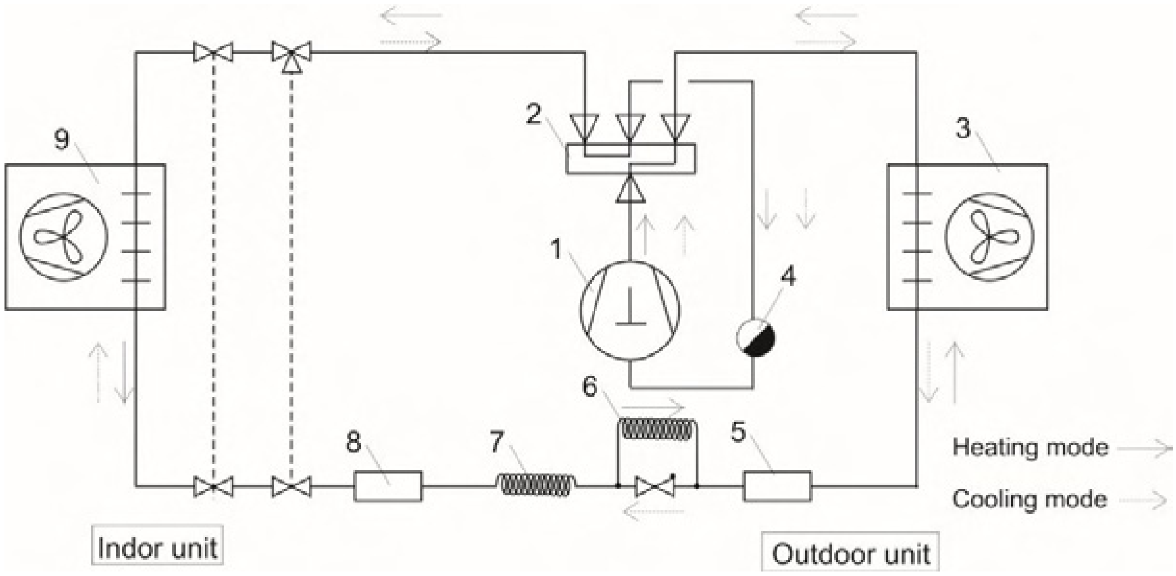

Figure 3. Concept diagram of the air conditioner/heat pump: 1 – compressor, 2 – four-way valve, 3 – condenser/evaporator, 4 – liquid separator, 5 – filter, 6 – caillary tube for heating, 7 – capillary tube for heating and cooling , 8 – filter, 9 – evaporator/condenser (own elaboration).

3. Evaluation of the impact of selected cooling units on the environment

To assess the impact of refrigeration equipment on the urban environment, the TEWI index (total equivalent of the greenhouse effect) was used (PN-EN, 2921). It is calculated in relation to the refrigerant itself and in relation to a specific refrigerating equipment. Its value changes depending on the type of device and depends on the values of parameters adopted in the assumptions, such as: operating time, service life or circulation efficiency. This indicator is described by the following relationship (United Nations, 1987):

$$TEWI = \left[(GWP \cdot L_{annual} \cdot n) + \left(GWP \cdot m \cdot \left(1 - \alpha_{recovery}\right)\right)\right] + (n \cdot E_{annual} \cdot \beta) \quad (1)$$

where:

L_{annual} – medium leak of refrigerant [kg/year],

n – system life time [years],

m – filling [kg],

$\alpha_{recovery}$ – level of refrigerant recovery,

E_{annual} – mean annual Energy use [kWh/year],

β – CO_2 emission indicator at power production [kg CO_2 /kWh].

The first part of equation (1) determines the direct influence of a refrigeration appliance on the greenhouse effect that results from the emission of refrigerants into the atmosphere L annual. To determine this effect, you need to know the refrigerant charged in the installation, the GWP value and the filling amount of the installation. The second part of the equation (1) concerns the indirect influence of refrigeration devices on the creation of the greenhouse effect. It takes into account the CO2 emission generated in the production of electric energy necessary to power the cooling device (β index), with the assumed level of average energy consumption E annual. All quantities in equation (1) must be related to the same time interval. Table 2 contains the data necessary to determine the TEWI index of domestic refrigerators. The data was compiled on the basis of publicly available information contained in manufacturer's documentation.

Table 2.
Assumptions for TEWI calculation of domestic refrigerators

Cooling efficiency [W]	300
Condensation temperature [ºC]	30
Cooling efficiency coefficient	~2.0
Evaporating temperature [ºC]	-20
Subcooling of the liquid refrigerant [K]	2
Overheating of refrigerant vapors [K]	5
Isentropic efficiency of compression	0.85
Average work time [h/day]	12
Refrigerant leakage (per year)	5%
Filling amount [g]	88 g for R600a and R290 /160g for R134a
Automatic defrost cycle	Once a day
Defrost heater power [W]	200
Average time of a single defrost cycle [min]	6
Device operation period [years]	20
β index	0.719 kgCO_2/kWh (11)

Source: own elaboration and Krajowa, 2019.

Fig. 4 presents achieved calculation results of TEWI index.

CO2 emission for each of the analyzed forfeits is practically the same. This is due to the fact that the major part of this emission is related to the process of generating electricity necessary to be fed. The direct CO2 emission related to the refrigerant for R134a is 514 kg CO2 eq, while for R290 it is 0.594 and for R600a it is 0.653 kg CO2 eq. These results relate to the time period of 20 years. Interestingly, the defrost cycle produces nearly 13.067 t CO2 eq, representing 0.55% of the total emissions. The impact of a single refrigeration system on the environment is not significant, but when the total number of devices in operation is taken into account, these numbers become more important and their share in the overall balance increases significantly.

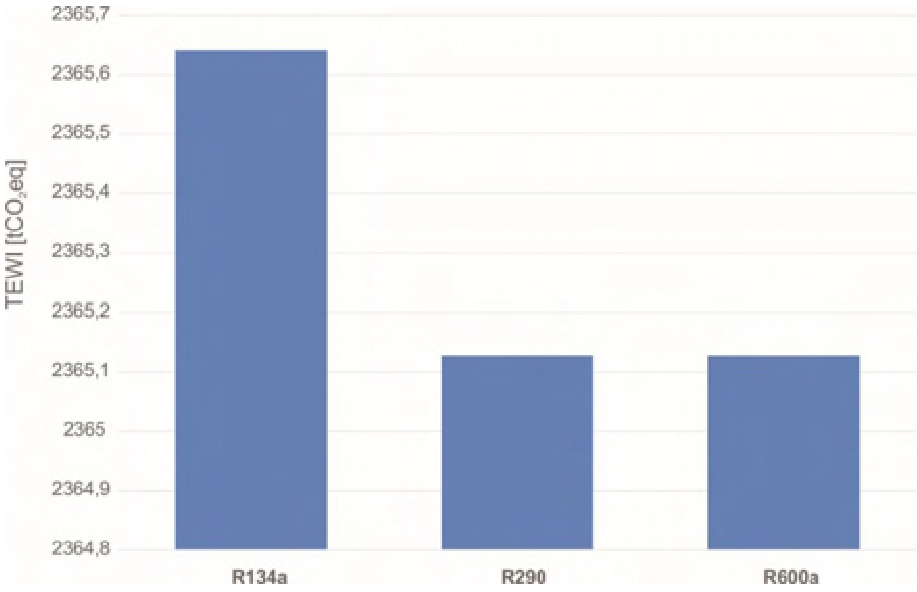

Figure 4. Comparison of the total CO2 emissions of domestic refrigerators for selected working media in the perspective of 20 years of operation.

Table 3.
Assumptions for TEWI calculation of air conditioning /heat pump unit

Nominal cooling efficiency [W]	1849	2500
Nominal heating efficiency [W]	1799	3015
Cooling efficiency coefficient Cooling / heating	~3.5 /4.0	3.68/4.4
Refrigerant leakage (per year)	5%	
Filling amount [kg]	R410A/1.450	R32/0.58
Device operation period [years]	20	20
Year of production	2001	2020
β index	0,719 $kgCO_2/kWh$	
Mean work time	250 days/8 h/day	

Source: own elaboration and Krajowa, 2019.

The calculations of the TEWI index for selected exemplary air-conditioning units have been shown in Fig. 5. The obtained values of the index were related to the efficiency of each of the analyzed devices.

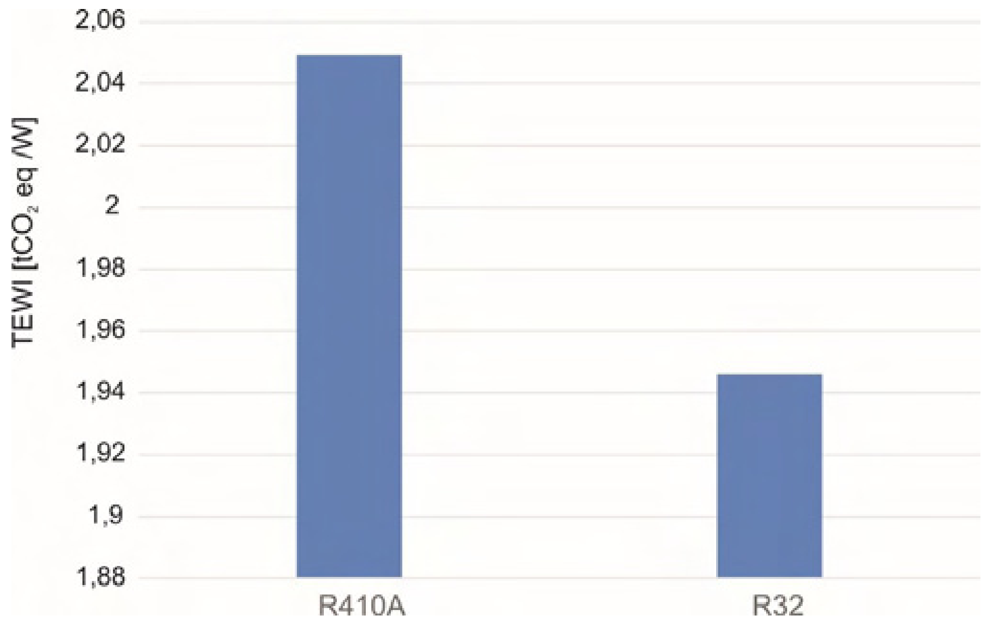

Figure 5. Comparison of CO2 emissions of air conditioners in relation to cooling capacity.

4. Conclusions

Currently, according to EU law, it is forbidden to fill new devices with the frequently used refrigerants for low and medium temperatures, i.e. R404a and R507. Since this year (2022), it is forbidden to use, inter alia, R134a, R407F and R410a. This means looking for substitutes based on pure natural agents as well as agents resulting from their mixtures. Another problem is the high prices of new, ecological substitutes, which result from the monopolization of the production of some of them.

In the coming years and in the long run, small refrigeration systems with a small load of the HFC refrigerant (in the order of a few or a dozen kilograms) will be popular for quite a long time due to relatively low investment costs. All other installations will be implemented with the use of natural factors such as: NH3 (ammonia), CO2 (carbon dioxide) and R290 (propane). These factors have virtually no impact on the greenhouse effect and will therefore be a solution for many years to come, although not all of them are suitable for use in every cooling concept.

Acknowledgements

This paper was financed from the resources of the Silesian University of Technology, project no. 13/010/BK_22/0065.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

STUDY OF THE IMPACT OF THE PANDEMIC ON THE FUNCTIONING OF MICRO-ENTERPRISES IN THE SILESIAN VOIVODESHIP

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Purpose: The objective of the paper is to study the impact of the global coronavirus pandemic on the standing of micro-enterprises in the Silesian Voivodeship.
Design/methodology/approach: A study sample of 120 micro-enterprises from the Silesian Voivodeship has been selected. The study methods such as an interview and a survey have been used. A questionnaire has been used as a tool. The properly completed surveys have been obtained from 43 enterprises.
Findings: It has been established that depending on the specific nature of a given enterprise and the area in which it operates, enterprises are, to varying degrees, susceptible to the impact of adverse factors related to the emergence of the global coronavirus pandemic, which, in turn, results in the differences in the standing of these enterprises.
Research limitations/implications: In view of the small study sample, the studies carried out do not create a complete picture of the impact of the pandemic on micro-enterprises in the Silesian Voivodeship. They are rather a contribution to further studies. These should be conducted on the basis of a larger study sample.
Originality/value: The global coronavirus pandemic which affected the world in the years 2019-2022 has left a strong mark on many aspects of human functioning, including pursuing business activity. It is important to gain knowledge on the impact of pandemic-related restrictions on the functioning of micro-enterprises in order to develop mechanisms to mitigate the adverse effects on entrepreneurship based on micro-enterprises.

Keywords: small and medium-sized enterprises (SMEs), micro-enterprise, global pandemic.

Category of the paper: Research paper.

1. Introduction

The global coronavirus pandemic, which started in the first quarter of 2019, has left its mark on many areas of human functioning, both individually and in a broader sense. Among other things, the economic model developed and established over the years has been destabilised. The adverse effects of the pandemic have been strongly felt among entrepreneurs associated with small and medium-sized entrepreneurship.

This article is an attempt to answer the question of how the standing of small and medium-sized enterprises has changed during the pandemic.

2. Specific nature of small and medium-sized enterprises

One of the manifestations of entrepreneurship is the pursuit of business activity through small and medium-sized enterprises (SMEs). Belonging to the SME sector is determined by the size of an entity. Commission Regulation (EC) No 800/2008 defines the criteria for determining whether an enterprise belongs to the SME sector. These determinants include (SME Sector..., 2022):

- number of employees employed,
- amount of annual financial results.

SMEs employ up to 250 employees and their annual turnover is below EUR 50 million.

The above determinants, the meeting of which determines belonging to the sector of small and medium-sized enterprises, are also the criterion for the internal division of SMEs into the following groups:

- micro-enterprises – entities employing fewer than 10 employees and achieving annual net revenue of up to EUR 2 million,
- small enterprises – employing no more than 50 employees, with annual net revenue of up to EUR 10 million,
- medium-sized enterprises – employing fewer than 250 employees, while their annual revenue may not exceed EUR 43 million.

The largest group are micro-enterprises. They account for more than 99% of all enterprises. In the Silesian Voivodeship, there are slightly more than 473, 203 registered micro-enterprises of various branches in the industrial, service and agricultural sectors (Poland in figures, 2022). The percentage distribution of micro-enterprises by economic sector is presented in Figure 1.

Micro-enterprises are a specific group of enterprises. The nature of their activities has both strengths and weaknesses (Daszkiewicz, 2004; Dylkiewicz, 2008). The former include the significant flexibility of entrepreneurs running micro-enterprises. This flexibility makes it possible to modify the operating profile or even completely change the industry, if necessary. On the other hand, the low inertia in responding to changes taking place in the environment in which they operate results in the fact that adaptation to new conditions may take place quickly (Klimek, 2015; Nehring, 2012).

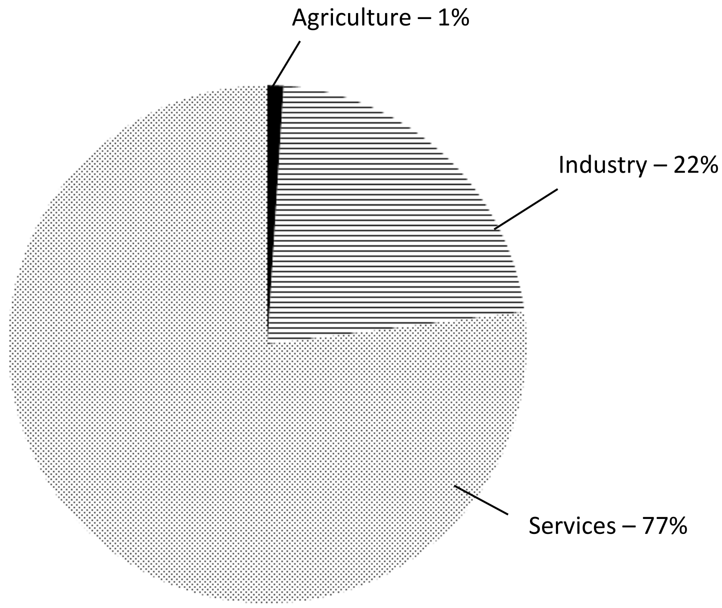


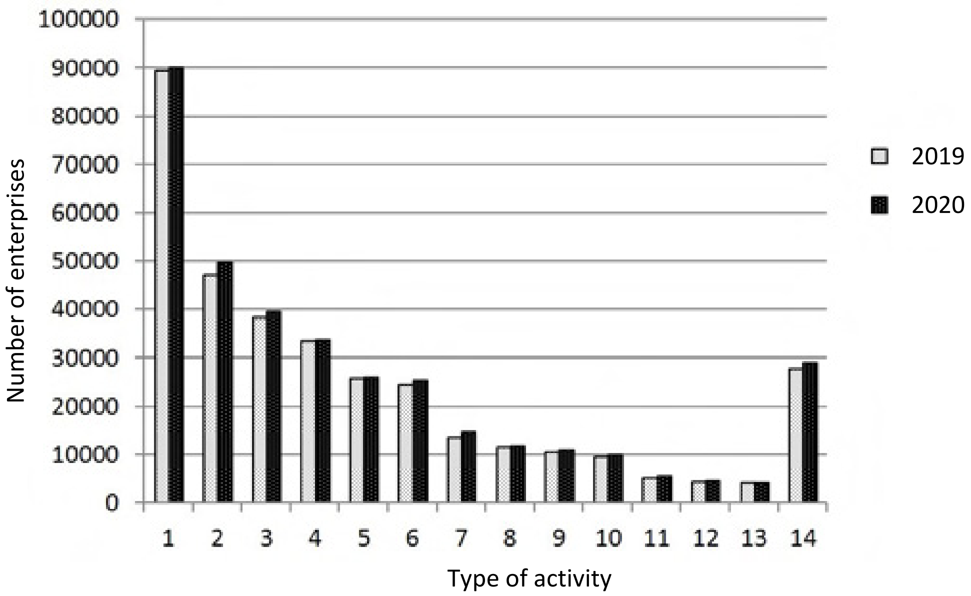
Figure 1. The percentage distribution of micro-enterprises by economic sector in the Silesian Voivodeship. As of the beginning of 2021. (Own elaboration based on Poland in figures, 2022).

Micro-enterprises are often one-person or family undertakings, the motivation to work is high and the costs of workplace(s) are relatively low (Smolarek, 2015; Safin, 2002).

The weakness of the functioning of micro-enterprises is the fact of financing them from own funds of owners, which, in turn, makes it difficult to develop a competitive position among other entities operating in a similar sphere (Smolarek and Dzieńdziora, 2011; Siuta-Tokarska, 2008). A certain trap for persons who are not strategically prepared for pursuing business in the form of a micro-enterprise is the great ease of setting up such an entity. The lack of a prepared plan covering a broader time perspective is most often the reason for the failure of a project (Oniszczuk-Jarząbek, and Gutowski, 2008). For this reason, the fate of a micro-enterprise is determined over the first year. In view of the improper preparation, only 60% of companies are able to get through this time.

Small and medium-sized enterprises serve basically every area of economic activity, and the popular form of entrepreneurship, i.e. running SMEs and, in particular, micro-enterprises, is a reason for which the number of registered entities in the Silesian Voivodeship is constantly growing.

Figure 2 presents the quantitative occupancy of selected types of activities by micro-enterprises in the Silesian Voivodeship over the years 2019-2020. It should be stressed here that each of the given categories of economy is extensive and includes a number of minor fields.



Key: 1 – commercial activities and repair workshops, 2 – construction, 3 – scientific and technical activities, 4 – industrial processing, 5 – transport and warehouse activities, 6 – medical assistance, 7 – information and communication, 8 – financial and insurance activities, 9 – accommodation and gastronomy, 10 – educational activities, 11 – real estate activities, 12 – cultural and entertainment activities, 13 – agricultural, horticultural, fishing activities 14 – other categories.

Figure 2. Comparison of changes in the number of micro-enterprises operating in specific areas in the period of 2019-2020. Own elaboration based on: "Poland in figures", 2022.

3. Selected study sample, method and tool applied

120 companies in the Silesian Voivodeship have been selected for the analysis aimed at determining the impact of the coronavirus pandemic situation on the functioning of micro-enterprises. The selected enterprises represented three sectors of the economy: service, industrial and agricultural.

The study methods such as an interview and a survey have been used. A questionnaire has been used as a tool. It contains 16 questions regarding the following issues:

1. Age of the company owner (below 20 years, 21-30, 31-40, more than 40).
2. Whether the enterprise is the only source of income for the entrepreneur.
3. Number of employees employed.
4. The length of the enterprise's operation in the market (below 1 year, from 1 to 5 years.
5. In which sector of the economy the micro-enterprise operates: service, production/ industrial or agricultural.
6. In what field the activity is pursued.

7. Whether the company has been operating in the indicated field since the beginning of its activity, or in the past, before the pandemic, there was a change of industry; if so, in which sector of the economy it operated and what was the profile of the company.
8. What is the method of financing a micro-enterprise from the pre-pandemic period: whether the entrepreneur uses own capital or relies on external sources of financing (EU funds or funds from the state budget, or other funds).
9. Whether the enterprise uses non-financial external support (training, professional consulting, business incubators) (Martin, and Staniec, 2018).
10. Whether the company recorded a decrease in revenue in any months of the year preceding the pandemic; if so, in what period(s) it happened and what the level of the decrease was: below 25% or exceeding 25% of revenue in the same period of the previous year.
11. Whether the company has recorded a decrease in revenue during the global pandemic; if so, in what period(s) and what the level of the decrease was: below 25% or exceeding 25% of revenue in the same period of the previous year.
12. Whether the company applied for financial support for companies affected during the coronavirus pandemic, and whether the company used facilities in the payment of taxes (European Funds Portal, 2021).
13. What were the main burdens during the pandemic: lack of available raw materials/semi-finished products/parts, impossibility to directly distribute products/services, impossibility to perform work in the place indicated by the client, rise in prices of materials/raw materials/products or others – for individual categories, it was necessary to indicate the degree of burdensomeness, using the four-point scale.
14. Whether the enterprise changed its business profile during the pandemic, if so, to what kind of.
15. Whether the entrepreneur, during the pandemic, was forced to close the enterprise; whether burdens resulting from pandemic restrictions were the main reason for ceasing business activity.
16. What was the general, subjective feeling about the impact of the pandemic on the functioning of the enterprise and how this impact translated into the quality of life of the employee(s) in specific areas of life:
    - impact on the feeling of insecurity of own well-being,
    - impact on the sense of insecurity of the existence of the close relatives,
    - impact on well-being resulting from concern about the employees,
    - impact on the feeling of lack of external support,
    - impact on the feeling of the lack of freedom,
    - impact on relationships with close relatives.

The answer had to be given by selecting one option from the five-point scale for each area (very adverse impact, adverse impact, no impact, positive impact, very positive impact).

Most of the questions in the survey were closed, the answer was selected from a list. One question, concerning the determination of factors perceived as burdensome for running a micro-enterprise during the pandemic period, included an additional option, allowing to enter own proposal for an answer. Where it was necessary for the respondent to determine the degree of severity of a specific factor, he/she used the proposed grade scale when answering.

Answers to the questions included in the survey were possible to obtain from 43 entities. The names of the enterprises have not been provided, the basic identification is the area in which they operate.

In several cases, the choice of answers to specific questions proposed by the author of the survey turned out to be insufficient and entrepreneurs, answering the questions, added their own option of the answer. This was due to the specificity and originality of certain solutions applied by them when pursuing business activity.

4. Results, discussion of study results

The subject of the study was to determine the impact of restrictions related to the coronavirus pandemic on the standing of micro-enterprises in the Silesian Voivodeship. The enterprises from which answers were obtained on the basis of the survey are dominated by those which, in addition to the owner, had 2 to 5 employees. These companies accounted for 61% of the respondents. 21% are those being one-person initiatives, while 18% are entities employing from 6 to 9 employees.

The distribution by economic sectors is as follows: micro-enterprises representing the services sector are dominant – 84%, the remaining 16% are those in the production sector. Among the surveyed, there are no enterprises from the agricultural sector.

Table 1 shows a comparison of the surveyed enterprises (business profile), the number of persons employed and the period in which these enterprises operate, provided in years.

Table 1.
Comparison of the surveyed enterprises in terms of business profile, number of employees and period of activity

No.	Sector	Type of activity	Number of employees (owner + employees)	Period of operation in years
1	SERVICES	photographic studio	1+3	more than 20
2		photographic service	1	10-20
3		garden services	1+7	10-20
4		computer graphics	1	1-5
5		computer graphics	1	5-10
6		graphic design	1	5-10
7		beauty salon, tattoo studio	1+2	10-20
8		sale of flowers	1+1	more than 20
9		sale of flowers	1+3	more than 20
10		food and industrial trade	1+4	more than 20
11		food trade	1+3	more than 20
12		transport services – emptying cellars	1+3	5-10
13		transport of goods and furniture (removals)	1+4	1-5
14		repair of electronic devices	1+1	10-20
15		computer services	1+1	more than 20
16		interior finishing services	1+2	more than 20
17		repair workshop	1+5	more than 20
18		tyre services	1+1	more than 20
19		wellness and spa	1+2	10-20
20		hairdresser	1	10-20
21		hairdresser	1+2	5-10
22		construction services	1+5	10-20
23		roofing services	1+2	more than 20
24		heating services	1+2	10-20
25		repair of instruments	1	more than 20
26		upholstery services	1+1	more than 20
27		cleaning of carpets	1+1	10-20
28		tailoring and knitting services	1	more than 20
29		installation of lightning protection systems	1+2	10-20
30		installation of garage doors	1+3	10-20
31		work at heights	1+5	
32		installation of alarm systems	1+1	5-10
33		translation of text into a foreign language	1	1-5
34	INDUSTRY AND PROCESSING	production and installation of window mosquito nets	1+6	1-5
35		production and installation of metal garages	1+8	10-20
36		production and installation of fences	1+7	5-10
37		bakeries	1+4	more than 20
38		construction works	1+4	10-20
39		construction and finishing works	1+5	more than 20
40		spring winding	1+3	more than 20
41		bakeries and confectionery	1+5	more than 20
42		artistic blacksmithing	1+1	more than 20
43		ironwork/turnery	1	more than 20

Own elaboration.

For 91% of entrepreneurs, their company is their only source of income, 9% have alternative sources.

Nine entrepreneurs used external financial support in the pre-pandemic period (this accounts for 20% of the total number of respondents), the remaining companies are financed from own capital (Figure. 3).

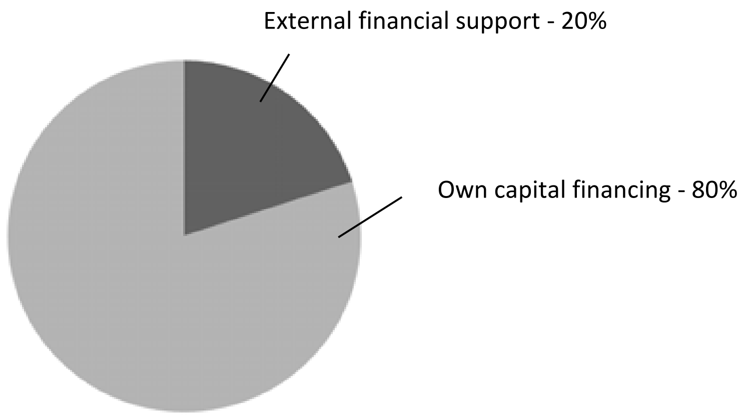


Figure 3. Method of financing of the surveyed micro-enterprises in the pre-pandemic period. Own elaboration.

The enterprises that used external financial assistance included: one service company operating for 1-5 years, three existing in the range of 5-10 years and pursuing service activities, four operating for 10-20 years in the services sector, and one enterprise from the production sector operating in the market for 10-20 years.

The chart presented in Figure 4 shows the interest of the surveyed entrepreneurs in using non-financial support before the pandemic. In drawing up the chart, the entities which used this support at least once have been taken into account.

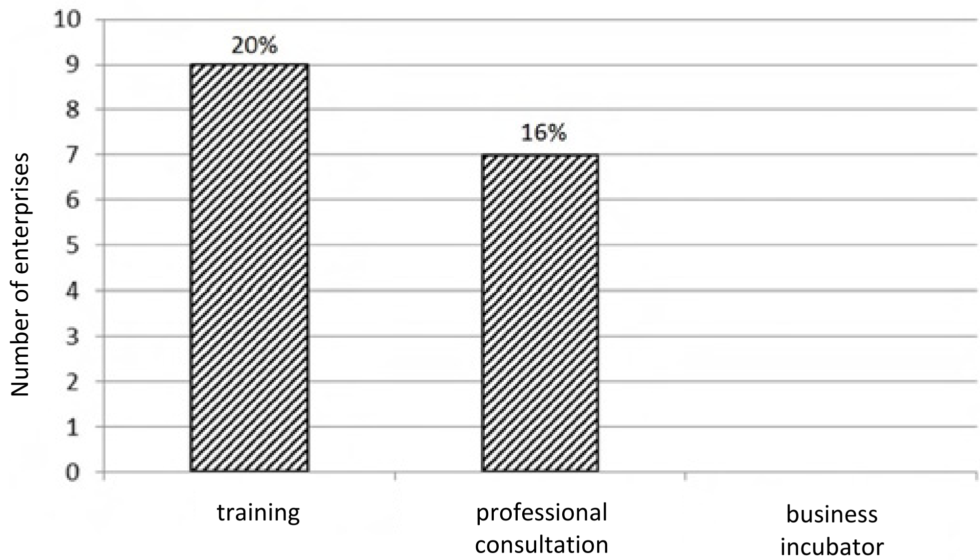


Figure 4. Use of non-financial external assistance by the surveyed enterprises before the pandemic period. Own elaboration.

20% of enterprises used nonfinancial support such as training. These were enterprises from the service industry – one existing in the market for 1-5 years, three for 5-10 years, and five operating for 10-20 years. None of the surveyed companies from the production sector used training. 16% of service micro-enterprises used professional consultation: one operating for 1-5 years, two for 5-10 years, two for 10-20 years and two from the production sector: one existing 1-5 years in the market and the other operating for 10-20 years.

Based on the results of the survey, a comparison of the change in the number of enterprises which experienced a decrease in revenue in 2019, preceding the pandemic (a decrease in relation to the same period of the previous year) to the number of enterprises that recorded a decrease in revenue in the year of the beginning of the pandemic (2020) has been made. This comparison is illustrated in Figure 5.

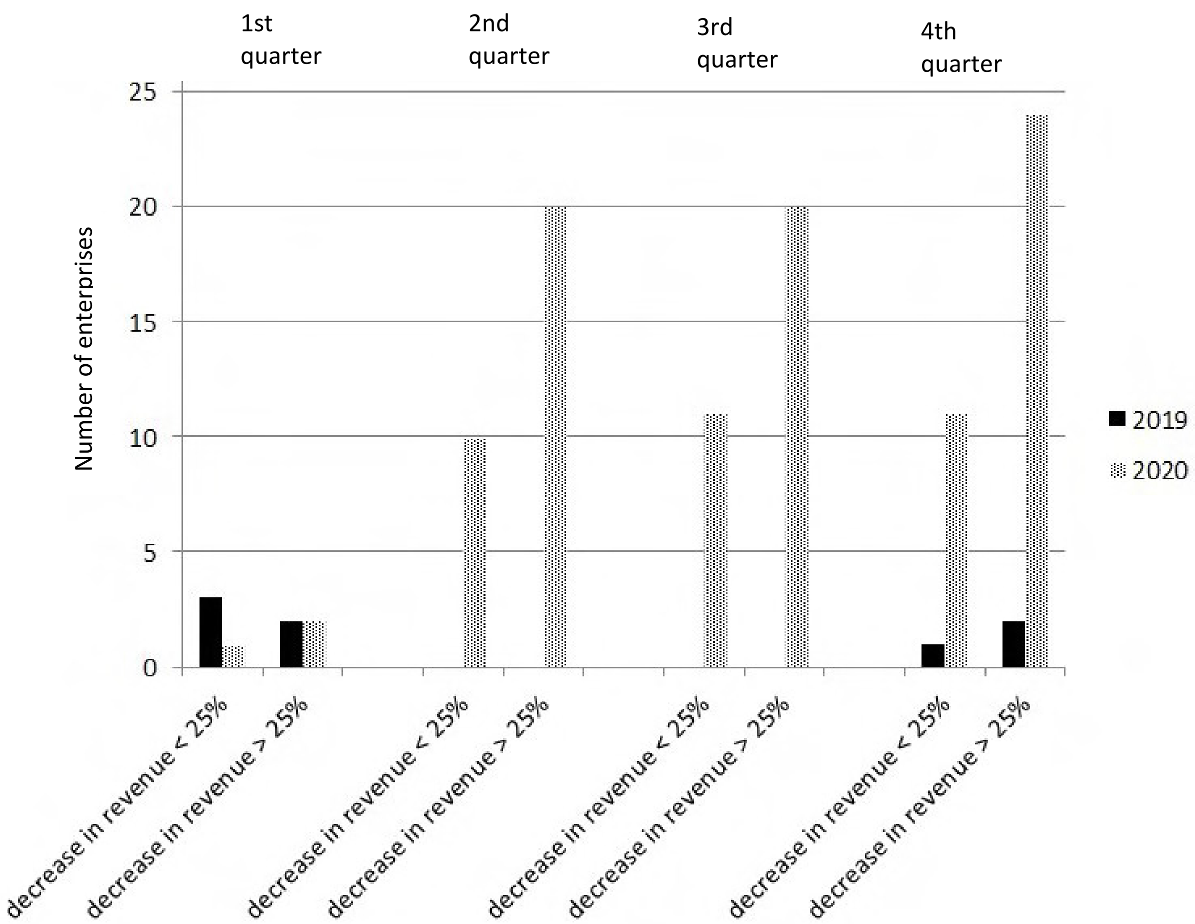


Figure 5. Comparison of the number of enterprises which recorded decreases in revenue in the year preceding the global pandemic and those which recorded decreases during the pandemic.
Own elaboration.

The 2nd, 3rd and 4th quarters of 2020 are marked by an increase in the number of enterprises recording a decrease in revenue. In 2019 - preceding the pandemic, in the 1st and 4th quarters there were also enterprises which experienced a decrease in revenue when compared to the same periods of the previous year. In the 1st quarter of 2019, a decrease of less than 25% affected three enterprises, a decrease of more than 25% affected two entrepreneurs.

In the 4th quarter, one micro-enterprise experienced a decrease below 25%, above this value – 2.

A garden service enterprise is in a specific situation. The basic activity of this enterprise, in the months from December to February, due to its specificity, is suspended. This situation recurs periodically every year (there are deviations, determined by various factors, but these are isolated cases) and the effects that are associated with it (decrease in revenue) are included in the enterprise's strategy of activity. In addition, its owner uses an alternative source of income. Although the winter months entail a decrease in the revenue of this micro-enterprise, the entrepreneur did not indicate this option in the survey due to the fact that every year this decrease remains at a comparable level.

The year 2020 made the number of enterprises recording a decrease in revenue increase significantly. While in the 2nd and 3rd quarter of 2019 the number of entities recording a decrease in revenue was zero, the year 2020 made the number of such enterprises increase to: ten with a decrease below 25% and twenty above this value in the 2nd quarter, and eleven with a decrease in revenue below 25% and twenty above 25%. In the last quarter of 2020, there were eleven companies with a decrease in revenue below 25%, and twenty-four companies with a decrease of more than 25%.

Some respondents did not indicate any burdens related to the restrictions and lockdown. These included entrepreneurs performing commissioned computer work and communicating with clients by phone or electronic media (e-mail, instant messaging).

Many surveyed companies used external assistance due to a decrease in revenue during the pandemic period. Figure 6 shows the percentage of enterprises among the surveyed entities which applied for any form of anti-crisis assistance.

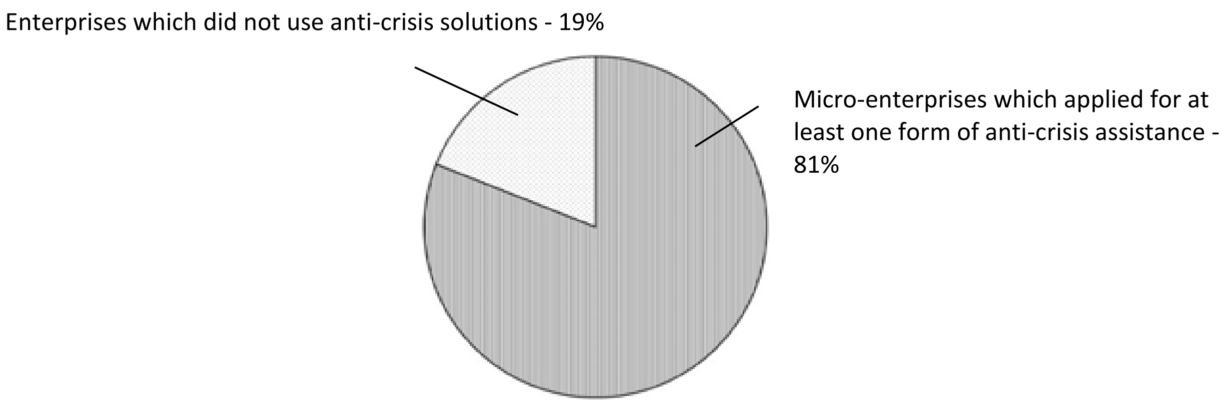


Figure 6. Percentage share of enterprises which used any form of financial assistance. Own elaboration.

The question about the main burdens of pursuing business activity during the pandemic allowed to determine the degree of this difficulty using a four-point scale (from 0 to 3) (0 – no difficulty, 3 – high degree of difficulty). The additional "not applicable" option allowed to disclose entities whose nature of activity meant that they did not participate in a given problem. The structure of the answers is as follows (Figure 7).

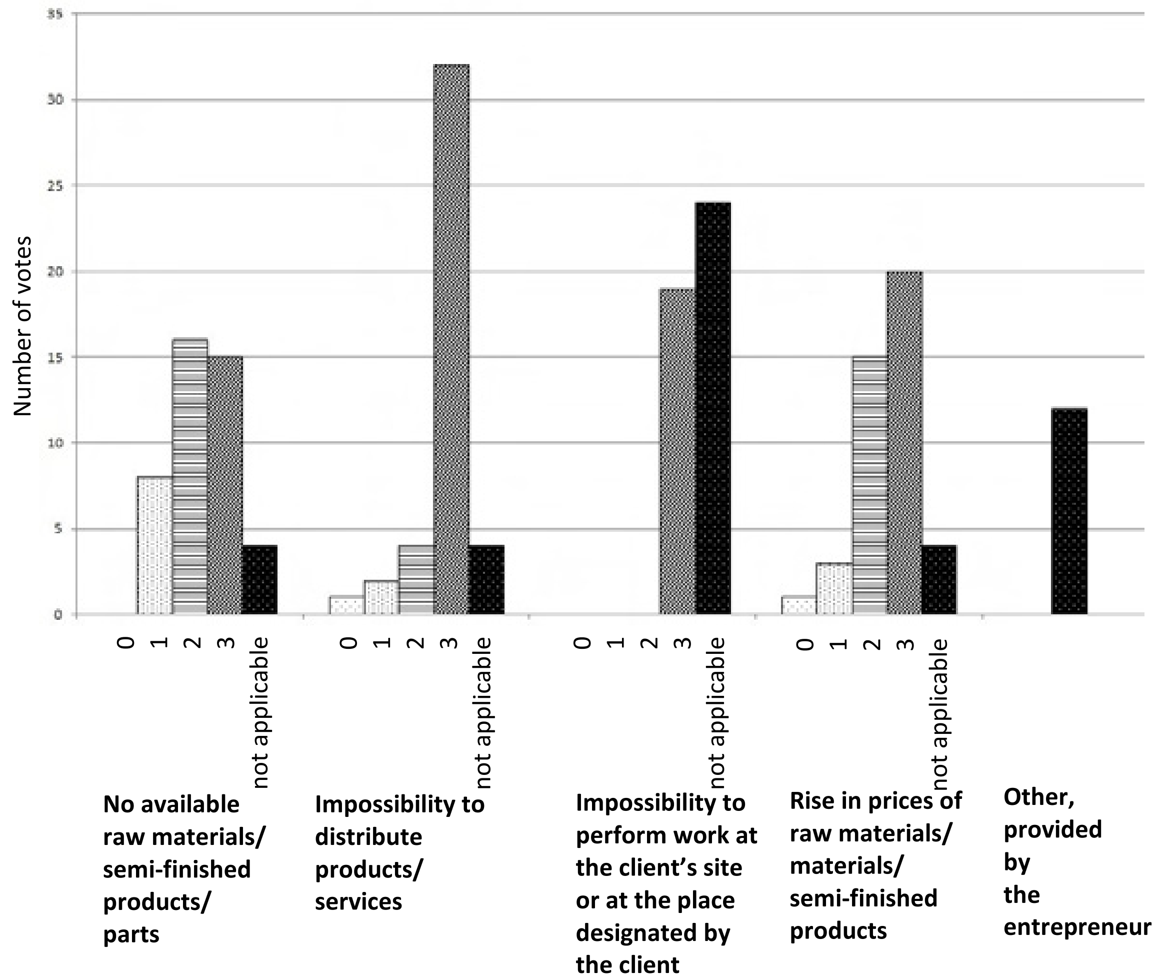


Figure 7. Comparison of factors making it difficult for entrepreneurs to run a micro-enterprise during the pandemic along with the number of votes cast for individual factors. Own elaboration.

The first factor – the lack of access to raw materials/semi-finished products/parts – was not considered by any entrepreneur to be non-burdensome (zero degree of burdensomeness), while four companies did not have this problem at all, as indicated in the survey. One degree of burdensomeness was given to this factor by eight entrepreneurs, for sixteen it was burdensome to the second degree of the scale, while fifteen entities considered it very burdensome (third degree of burdensomeness).

The votes in determining the impact of burdensomeness of the second parameter, i.e. the impossibility to directly distribute products or provide services, were distributed as follows: zero degree – one enterprise, the first degree – two enterprises, for thirty-two entities it was a very burdensome factor (the third degree). Four companies were not affected by the problem.

Nineteen micro-enterprises considered another factor – the impossibility to work at the client's site to be very burdensome (the third degree of burdensomeness), twenty-four did not have this problem.

The rise in prices of raw materials and materials was very burdensome (the third degree) for twenty enterprises, burdensome to the second degree for fifteen companies, for three – burdensome to a small extent (the first degree), one entrepreneur considered that for their enterprise the price rise was not important, while four companies were not affected by this burden.

Entrepreneurs provided their own proposals, including the burden associated with difficult direct communication with other entities and institutions. This issue appeared in 30% of the surveyed micro-enterprises.

None of the surveyed companies changed the profile of their activities during the pandemic period.

One enterprise, with more than 20 years of experience, ceased its activity during the coronavirus pandemic. According to the information that the owner included in the survey form, in 2021 the entity started recording a steady decrease in revenue exceeding 25% when compared to the previous year. However, for reasons not disclosed by the owner, the enterprise did not use external forms of financial assistance.

The last issue that entrepreneurs were asked about was the personal feelings related to the impact of the situation in which their companies found themselves on the perception of quality of life.

The answers regarding this issue turned out to be directly related to the dependence of the existence of the respondent (and their close relatives) on the profitable enterprise, being the only source of income. In many cases, the concern for the well-being of the employees was also important.

Some differences were found in the relationship between the fear for the survival of the company and the age of the owner and the company's metric. There were few (two) people below the age of 20 in the surveyed companies, they were basically at the initial stage of running their micro-enterprises, and in the event of failure they would receive financial support from the family. The comfort of these entrepreneurs in the pandemic situation was relatively high, they did not bear the burden of responsibility for failure. They account for 4.65% of the respondents.

Further age groups (21-30, 31-40 and more than 40) felt the pandemic situation in a similar way between these groups. These entrepreneurs were affected by similar concerns, regardless of their experience and years of work in their enterprise. The exception to this coherence were micro-entrepreneurs acting on their own, whose specific nature of work makes them independent of many crisis situations. They are designers, computer graphic designers, etc. – people whose main domain is to perform computer work, and contact with the client can be easily limited to remote contact. They account for 6.97% of the surveyed group.

The percentage distribution of answers provided by the entrepreneurs in the question concerning the impact of the pandemic situation on the fate of the enterprise, and thus – the fate of the entrepreneur and possibly their family, is as follows (Table 2):

Table 2.
Percentage distribution of the answers to the question regarding the impact of the company's standing on the selected aspects of the entrepreneur's quality of life during the pandemic period

Quality of life aspect	**Degree and nature of the impact of the pandemic situation on the selected aspects of the quality of life in the light of the company's standing**				
	very negative	**negative**	**no impact**	**positive**	**very positive**
Feeling of insecurity of own well-being	89%	7%	4%	0%	0%
Feeling of insecurity of the well-being of the close relatives	89%	7%	4%	0%	0%
Concern about the fate of the employees	68%	11%	21%	0%	0%
Feeling regarding external support	0%	65%	17%	18%	0%
Feeling of the lack of freedom	45%	46%	9%	0%	0%
Relations with the family	2%	67%	8%	23%	0%

Own elaboration.

The surveyed entrepreneurs pointed to the complexity of the issues contained in this question, which resulted in some difficulties in choosing a given option unequivocally. An example may be the subsection on relations with the close relatives: two percent of the respondents indicated a very negative impact of the whole situation on these relations, although as the respondents added, in principle, the relations themselves did not deteriorate, there was even some emotional consolidation in a difficult situation, but they considered that their growing, negative mental state, caused by fear for the close relatives, was felt by them as a very negative factor.

Another obstacle to providing an unambiguous answer was the progressive change in the situation in which entrepreneurs found themselves, even because of the aid programmes implemented, which protected 81% from a disaster. When answering, they had to decide whether to refer to the time when they perceived the future of their enterprise very negatively, or to the moment when, for example, they already used external support. So, they often averaged their rating, which does not fully reflect the actual situation.

5. Summary

The conducted studies, due to the size of the study sample, do not fully reflect the state of Silesian micro-enterprises in the era of the global pandemic. Nevertheless, in a cross-cutting manner, they show the diversity of attitudes and actions taken by entrepreneurs in order to keep their companies in the market.

Acknowledgements

This paper was financed from the resources of the Silesian University of Technology, project no. BK/ROZ-1/2022 (13/010/BK_22/0065).

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

STUDY ON KEY COMPETENCES FOR THE IMPLEMENTATION OF INDUSTRY 4.0 SOLUTIONS

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Purpose: The latest studies in the literature on the subject discuss the topic of future competences in the industry sector. The purpose of this article is to indicate the key competences for the implementation of Industry 4.0 solutions. The presented results are part of wider research (Michna, Kmieciak, Kruszewska, 2021).

Design/methodology/approach: The research methods consist of a comprehensive literature review of the subject under study and the results of empirical research conducted in 2021 based on an anonymous online survey completed by employees from different levels of organization, operating in diverse industries and located in multiple locations.

Findings: Study presents competences with the highest importance for survey participants – problem solving, process understanding, efficiency in working with data; and with the lowest importance – leadership skills and coding skills.

Research limitations/implications: Competences were grouped according to literature study results, chosen group was not always natural for specific competence, which could lead to difficulties in research. The study group was anonymous, it consisted of random employees from multiple organizations, not selected in advance.

Practical implications: The study's results provide knowledge about general perception of competences in Industry 4.0 with a division of specific groups: technical, social, economic, political and environmental.

Originality/value: The study can help HR practitioners and Industry 4.0 specialists in analyzing human resources competences and planning the development of possible competence gaps.

Keywords: Competences, Industry 4.0.

Category of the paper: Empirical research results.

1. Introduction

Globalization, technological progress and knowledge- based economic development caused increase of nonmaterial values such as employee competences. It is essential from organization point view but also important for the functioning of employees in the changing labor market. In actuality, competences more often than not are subject to devaluation and require improvements (Sitko-Lutek, and Jakubiak, 2020). Additionally, in the modern economy, the competitiveness of enterprises is the ability to constantly improve, generate new ideas, introduce new or improved processes, products and services or organizational solutions. These activities require creative employees and transforming their ideas and knowledge into innovative solutions (Michna, 2017). Especially in the realities of Industry 4.0, where technological development requires changes in organizational and personal areas, the subject of competence is actually noticed by researchers and studied in multiple dimensions. In most of the reviewed literature employee competences are shown as barriers as well driving forces for Industry 4.0 Implementation (Michna, and Kruszewska, 2021). Barriers understood as inhibitors or named as challenges are mentioned by (Kiel et al., 2017; Vuksanović Herceg et al., 2020; Stentoft et al., 2019). Competences as a drivers or potentials, which I4.0 could deliver are noted among others as: (Müller et al., 2018; Vuksanović Herceg et al., 2020).

Differentiations of employee competences lead to creation of multiple competences models. One of them proposed by (Szwajca, 2021) relies on a base of 5 levels of needed competences – personal competences, competences related to data, social competences in enterprises, technical competences and competences for functional area of industrial sector. On top of those levels author mentioned management skills and job- specific requirements.

Erol et al. (2016) grouped future competences into the following categories: personal competences, which can be understood as the ability of a person to act in a reflective and autonomous way; social/interpersonal competences such as ability to communicate, cooperate, as well as establish social connections and structures with other individuals and groups; action-related competences, meaning the ability of a person to take individual or socially-constructed ideas and act on them; and domain-related competences, which refer to the ability to access and use domain knowledge for a job or a specific task.

A different point of view is presented in the works of Hecklau et al. (2016). On the basis of the identified challenges, grouped according to the PESTEL analysis: economic (i.e. ongoing globalization), social (i.e. increasing virtual work), technical (i.e. growth on technology and data use), environmental (i.e. resources scarcity) and political (i.e. standardization or data security), authors divided the competences into: technological, methodological, social and personal competences.

The model of future employee competences, proposed by Vrchota et al. (2020), relies on two axes. The first one contains groups of technical and personal competences, while the other axis consists in the classification into needs – “must have”, “should have” and “can have”.

Irrespective of the researcher or model, results in recent studies on the subject of personnel competences in Industry 4.0 are focused around technical and social skills. As mentioned by Vereycken et al. (2021) increased employee involvement would be significant in Industry 4.0. In results presented by authors, prepared on the basis of periodic surveys performed in European companies we could see confirmation of strong positive impact of employee involvement on the newest digital technologies. Researchers also confirm that Industry 4.0 will be related to changing skill requirements and job training practices. In the work of Grzybowska and Łupicka (2017) with results of survey conducted among selected experts in automotive and pharmaceutical industries within transnational companies we could see that entrepreneurial thinking, decision making, efficiency orientation and problem and conflict solving belongs to key competences for managerial staff in Industry 4.0. Deeper analysis of required managerial competences specifically in the quality area was performed by Sumitha et al. (2021). This particular researcher pointed out gaps in the technical, methodological, social and personal competences in Malaysian electronics manufacturer as an example. She investigated competences such as awareness of data security, ability to solve complex problems, increased virtual communication, effective knowledge orientation concerning engineering and management level of employees regardless of geographic location. Another research was performed by Rakowska and Juana-Espinosa (2021) in 2016 and 2019 afresh in Spain, Thailand and Poland, on the subject of major employability skills, competences and main demand trends for it. Study has been performed by researcher on the basis of panel experts from academic and business background. As a result, key employability skills have been identified in all those three countries. What is visible in that research, is that Polish and Thai experts were focused more on IT skills while Spanish experts on social skills development. “Novel and adaptive thinking” was a competence which was constantly perceived as highly relevant in all countries. At the same time, it is worth mentioning that “formal education” and “work experience” significantly lost their value as employability skills in all those countries during the study period.

Another South African research of Industry 4.0 skills from manufacturing perspective has been introduced by Maisir and van Dyk (2021). Performed analysis confirms the importance of soft skills such as problem-solving, critical thinking, collaboration, communication, cross-cultural ability, teamwork, emotional intelligence, lifelong learning, and multiskilling in Industry 4.0.

Discussion related to competences could not be conducted without aspects such as: education, self-learning, knowledge management, skills development and trainings systems. All of the above are definitely connected with presented subject. Competence development could be accomplished by using different methods and techniques. In the research of Sitko-

Lutek and Jakubiak (2020) performed on 2,000 employees in 50 Polish enterprises, 80% of respondents declared learning during working – meaning on-job learning, 70% self-learning by using the internet. An interesting subject in the mentioned research was a fact that the higher the position in organizational hierarchy, the more frequent it is to seek information from professionals outside the workplace. Research also confirms that women more often than men seek competence development through participation in formal courses, training, studies and postgraduate studies. A different research made by Soniewicki and Paliszkiewicz 2(019) in Poland on the basis of the above 1,200 questionnaires confirms that intensity of knowledge management process is higher for bigger companies, especially in relation to competitiveness of companies with 250 employees or more. “Enterprises that do not have an implemented knowledge management system are unable to properly respond to market knowledge”. Statement by Michna et al. (2020) also confirms results from above research studies as acquiring new knowledge and using it, is an element of building a competitive advantage. In small and medium sized enterprises, the key factor for knowledge management evaluated by Brzostek and Michna (2016) is to make use of employee latent information and skills.

2. Methods

The elements used in this study were part of a pilot study in the research of barriers and drivers for Industry 4.0 implementations and additionally in the research of usage level of this concept in the organizations from various localizations and within employees from different level of organization (Michna et al., 2021). The survey method was chosen to carry out the mentioned study. Study tools have been designed according to previously planned research (Michna, and Kruszewska, 2020). The survey has been conducted using internet tool available at www.survio.com. A link with the survey has been directly distributed to potential participants via online communicators available on business and employment-oriented online services. Data collection using an anonymous questionnaire was conducted between 13 and 21 of October 2021. During that time 125 surveys have been finalized. In total, the web page registered 327 visits which gives a 38% response rate. The survey has been prepared in two languages: English and Polish. The respondents had the opportunity to use the questionnaire in their selected language.

Items of the questionnaire were measured using five-point Likert scale, where 1 means definitely not, 2 – rather not, 3 – I have no opinion, 4 – rather yes, 5 – definitely yes. Both surveys contained the same set of questions: metrics and a fundamental group of questions developed on the basis of literature research.

General metrics include items directly related to survey participants: questions related to their country of origin (Poland, Germany, India etc.), role in the company (owner, manager, engineer, employee etc.), working area (that is department like finance, manufacturing, logistic, quality, IT etc.). The other part of general metrics contained questions related to enterprise; country of operation (Poland, Germany etc.), years of enterprise's existence (0-2 years, 2-5 years, 5-10 years, 10-20 years and more), size of the enterprise: micro with 1-9 employees, small with 10-49 employees, medium with 50-249 employees, and large ones with more than 250 employees, sector of the activity (the following proposed general groups were available: manufacturing, service provider, information, and agriculture), and role of the enterprise in the Industry 4.0 with possible answers as a: provider (of I4.0 services, solutions, products), user (of I4.0 services, solutions, products), user and provider, none of the above.

Main part of the survey contained questions from literature sources such as: Michna and Kmieciak (2020), Müller and Voigt (2018), Vuksanović Herceg et al. (2020) which were arranged in order to support the stated objectives of the generic study: determining the usage of the concept of Industry 4.0 by employees at various levels; determining main barriers and drivers that enterprises might encounter in implementing Industry 4.0 technologies from an employee's point of view. For this detailed study authors decided to present results from section related to competences where the aim was to determine key competences for engineers and specialists in the Industry 4.0.

Statements related to competences have been used to create base for the above-mentioned competences model proposed by Hecklau et al. (2016). PESTEL method and available literature in the study subject have been used to group the studied answers. Survey participants were asked to choose competences for engineers and specialists in the era of Industry 4.0. Table 1 below presents questions with possible choices and their codes.

Table 1.
Questions related to competences

Question	Item	Choices
TECHNOLOGICAL competences of engineers and specialists in Industry 4.0	T1	Technical skills
	T2	Analytical skills
	T3	Efficiency in working with data
	T4	Coding skills
	T5	Understanding IT security
	T6	Virtual communication skills
	T7	Process understanding
	T8	Problem solving
SOCIAL competences of engineers and specialists in Industry 4.0	S1	Ability to transfer knowledge
	S2	Accepting work-task rotation and work related change (ambiguity tolerance)
	S3	Time and place flexibility
	S4	Leadership skills
	S5	Motivation to learn
	S6	Decision making
	S7	Communication skills
	S8	Ability to work in a team
	S9	Ability to be compromising and cooperative
	S10	Conflict solving

Cont. table 1.

ECONOMICAL competences of engineers and specialists in Industry 4.0	E1	Intercultural skills
	E2	Language skills
	E3	Time flexibility
	E4	Networking skills
	E5	Entrepreneurial thinking
	E6	Creativity
	E7	Work under pressure
	E8	State-of-the-art knowledge
	E9	Research skills
LAW/POLITICAL competences of engineers and specialists in Industry 4.0	LP1	Understanding of IT security (Data and personal)
	LP2	Understanding of compliance
	LP3	Standardization
ENVIRONMENTAL competences of engineers and specialists in Industry 4.0	EN1	Sustainable mindset
	EN2	Motivation to protect the environment
	EN3	Creativity to develop new sustainable solutions

3. Results

In the group of technological competences authors listed competences such as: technical and analytical skills, efficiency in working with data, coding skills, understanding IT security, virtual communication skills, process understanding and problem solving. Table 2 presents basic statistics for technological field of competences. In detail Table contains: mean value, StDev – standard deviation means average deviation from the mean value, median as an obtained middle value, mode – dominant, the most common value in the sample and lastly N for mode means number of responses for the dominant.

Table 2.
Basic statistic for technological competences

Variable	Item	Mean	StDev	Median	Mode	N for Mode
TECHNOLOGICAL competences	T1	4,26	0,75	4	4	58
	T2	4,37	0,71	4	5	61
	T3	4,43	0,69	5	5	66
	T4	3,72	1,02	4	4	50
	T5	4,20	0,84	4	5	54
	T6	4,17	0,83	4	4	52
	T7	4,44	0,70	5	5	67
	T8	4,47	0,70	5	5	72

Note. StDev – Standard deviation.

Highest mean value 4,47 was achieved for T8 – problem solving. That competence was also the most common answer – 5. It was given 72 times. On the other hand – the lowest mean value was 3,72 for T4 – coding skills.

Table 3 presents similar results for social competences. That group contains such competences as: ability to transfer knowledge, ambiguity tolerance, time and place flexibility, leadership skills, motivation to learn, decision making, communication skills, ability to work in a team, ability to be compromising and cooperative and conflict solving.

Table 3.
Basic statistic for social competences

Variable	Item	Mean	StDev	Median	Mode	N for Mode
SOCIAL competences	S1	4,13	0,80	4	4	61
	S2	4,02	0,71	4	4	72
	S3	4,06	0,79	4	4	65
	S4	3,43	1,11	4	4	43
	S5	4,30	0,74	4	4	60
	S6	4,00	0,97	4	4	60
	S7	4,22	0,86	4	5	54
	S8	4,11	0,91	4	4	53
	S9	4,06	0,83	4	4	64
	S10	3,99	0,92	4	4	53

Note. StDev – Standard deviation.

In the social area of competences S5, which means motivation to learn, achieved the highest mean value – 4,3. The lowest mean was recorded for S4 – leadership. The most common answers "4" was observed for accepting work-task rotation and work related change (ambiguity tolerance). 72 participants gave such an answer.

Table 4 presents basic statistics for economical competences. That group contained such competences as: intercultural and language skills, time flexibility, networking skills, entrepreneurial thinking, creativity, work under pressure, state-of-the-art knowledge and research skills.

Table 4.
Basic statistic for economical competences

Variable	Item	Mean	StDev	Median	Mode	N for Mode
ECONOMICAL competences	E1	3,90	0,94	4	4	58
	E2	4,30	0,84	4	5	60
	E3	3,89	0,94	4	4	57
	E4	4,18	0,75	4	4	63
	E5	4,00	0,84	4	4	55
	E6	4,29	0,86	4	5	61
	E7	3,95	0,98	4	4	49
	E8	4,38	0,66	4	5	59
	E9	3,91	0,93	4	4	55

Note. StDev – Standard deviation.

The highest obtained mean value – 4,38 for competence E8 – state-of-the-art knowledge, simultaneously with the highest possible modal value – 5 and the lowest value of standard deviation – 0,66 shows that the participants treat the latest knowledge in a given field as an important competence. On the other hand, the lowest mean value 3,89 has been attributed to E3 – time flexibility.

Table 5 presents data for law and political competences. In this area three such competences have been available: understanding of IT security (data and personal), understanding of compliance and standardization. Definite highest mean value of 4,3 was achieved by understanding IT security. Lowest – 4,14 by understanding of compliance.

Table 5.
Basic statistic for political and legal competences

Variable	Item	Mean	StDev	Median	Mode	N for Mode
LAW/POLITICAL competences	LP1	4,30	0,75	4	5	56
	LP2	4,14	0,80	4	4	55
	LP3	4,27	0,72	4	4	57

Note. StDev – Standard deviation.

The last table, Table 6, presents data and statistics for environmental competences: sustainable mindset, motivation to protect the environment and creativity to develop new sustainable solutions. Developing new sustainable solution got the highest score for mean value – 4,19 while the motivation to protect the environment the lowest – 3,94.

Table 6.
Basic statistic for environmental competences

Variable	Item	Mean	StDev	Median	Mode	N for Mode
ENVIRONMENTAL competences	EN1	3,99	0,86	4	4	60
	EN2	3,94	1,01	4	4; 5	44
	EN3	4,19	0,83	4	5	53

Note. StDev – Standard deviation.

Figure 1 below presents run chart with mean values for each of studied competences. Independently of the competences area, the lowest medium value has been observed for S4 – leadership while the highest value for T8 - problem solving. Similarly figure 2 presents data for N for mode value – that is the most common answers given by survey participants. Problem solving competence is also one of the most common answer. The same grade was obtained for competence – accepting work-task rotation and work related change – N for mode – 72, meaning 58% of participants consider them as essential. The lowest N for mode value received leadership competence – see Figure 2.

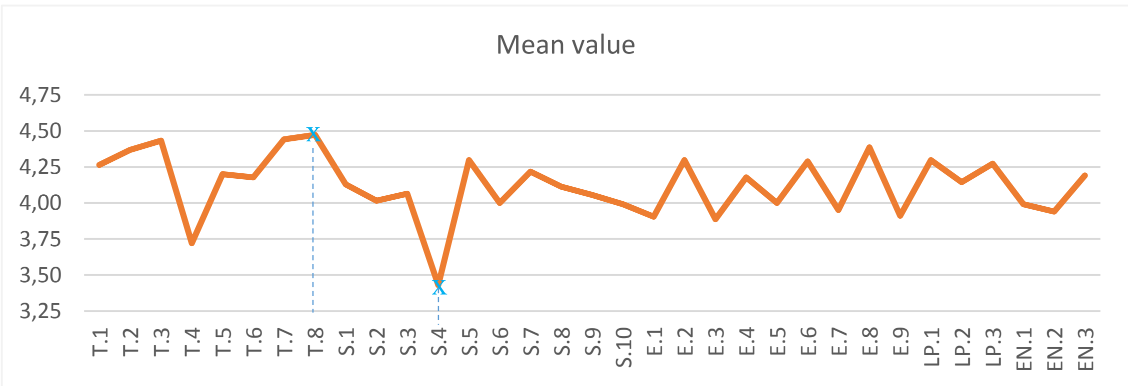

Figure 1. Run chart – mean value.

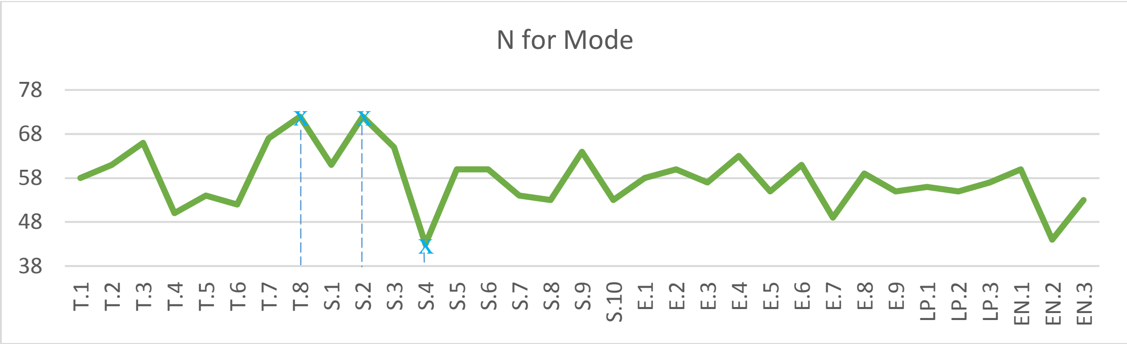

Figure 2. Run chart – N for Mode.

Another way to identify competences with the highest importance for the participants was the sum of positive confirmations of the tested statement. In fact, the answers; 4 – rather yes and 5 – definitely yes, were summed up. During the next step, the % of all results was calculated. Table 7 shows the results in this respect.

Table 7.
% of positive (4 and 5) answers for statements. Data stacked from highest to lowest value

Item	%	Item	%	Item	%	Item	%
T3	92	LP3	87,2	S9	81,6	S10	75,2
T7	92	LP1	87,2	T5	80,8	E5	74,4
E8	92	E6	86,4	S2	80,8	E1	73,6
T8	91,2	E4	85,6	S8	80,8	E7	72,8
S5	90,4	S7	84,8	LP2	80,8	E3	72,8
T2	89,6	S1	83,2	S6	80	E9	72,8
T1	88	T6	81,6	EN3	80	EN2	70,4
E2	88	S3	81,6	EN1	76,8	T4	64
						S4	52,8

The largest group of people confirmed great importance of T3 – Efficiency in working with data, T7 – Process understanding and E8 – State-of-the-art knowledge. On the opposite side we have EN2 – Motivation to protect environment, T4 – Coding skills, S4 – Leadership skills.

Depending on the methods the most important and the least important competences have been presented in Table 8. Independently of statistics, leadership competence has been chosen as a competence with the lowest importance. Understanding processes and ability to solve the issues together with the latest state-of-the art knowledge reveal themselves as the most important competences for all survey participants.

Table 8.
Summary of importance by basic statistics metrics

Competences	Acc. to mean value	Acc to mode value	Acc to % of positive answers
The most important	T8 Problem Solving		T3 Efficiency in working with data T7 Process understanding E8 State-of-the-art knowledge
The least important	S4 Leadership skills		

Analysis by control variables

For deeper analysis control variables have been used: size of enterprise and its sector. In research with 125 participants, 83 of them were working in large companies, 32 in medium and small ones while 10 were working in micro organizations. 93 organizations represented industry sector while 32 service. Due to this uneven distribution of data, results by control variables were used primarily for illustrative purposes and preliminary analysis. First part of data below represents results by size of enterprise, second one – company sectors.

Table 9 presents basic statistics for competences with highest mean value by company size.

Table 9.
Basic statistics for competences with highest medium value by organization size

Organization size	Competence	N	Mean	StDev	Median	Mode	N for Mode
Micro enterprises	S8	10	4,70	0,68	5	5	8
	S7	10	4,60	0,70	5	5	7
	S9	10	4,60	0,70	5	5	7
Small and medium enterprises	T3	32	4,47	0,51	4	4	17
	T7	32	4,41	0,56	4	4	17
	T8	32	4,41	0,71	4,5	5	16
Large enterprises	T7	83	4,52	0,61	5	5	48
	T8	83	4,52	0,67	5	5	50
	T3	83	4,49	0,63	5	5	47

Note. StDev – Standard deviation.

For micro organizations the highest mean values were S7 – Communication skills, S8 – Ability to work in a team and S9 – Ability to be compromising and cooperative, while highest scores in small and medium sized enterprises (SME) as well as in large companies were T3 – Efficiency in working with data, T7 – Process understanding and T8 – Problem solving received the highest mean values.

Table 10 presents competences by organization size with the lowest medium value calculation based on participants' grades.

Table 10.
Basic statistics for competences with lowest medium value by organization size

Organization size	Competence	N	Mean	StDev	Median	Mode	N for Mode
Micro enterprises	T3	10	3,80	1,23	4	5	4
	E7	10	3,80	1,23	4	4	4
	T4	10	3,70	1,06	3,5	3	4
Small and medium enterprises	EN2	32	3,53	1,05	4	4	14
	E9	32	3,50	0,92	4	4	13
	S4	32	3,22	1,13	3	4	11
Large enterprises	E1	83	3,88	0,94	4	4	38
	T4	83	3,66	1,05	4	4	35
	S4	83	3,40	1,06	4	4	31

Note. StDev – Standard deviation.

For micro organizations competences with lowest scores are: T4 – coding skills, E7 – work under pressure and T3 – efficiency in working with data, for SME organizations – S4 – leadership and E9 – research skills, as well as EN2 – motivation to protect the environment received the lowest values. Participants working in large companies pointed out leadership as a less important issue too, but additionally considered T4 – coding and E1 – intercultural skills as less important.

Table 11 shows competences with the highest N-mode value. The presented competences are those which were predominant among the answers. Data from table 12, on the other hand, presents answers with the lowest N-mode values.

Table 11.
Basic statistics for competences with the largest number of the most common answers by organization size

Organization size	Competence	N	Mean	StDev	Median	Mode	N for Mode
Micro enterprises	S8	10	4,70	0,68	5	5	8
Small and medium enterprises	S9	32	3,91	0,73	4	4	21
Large enterprises	T8	83	4,52	0,67	5	5	50

Note. StDev – Standard deviation.

Table 12.
Basic statistics for competences with the lowest number of the most common answers by organization size

Organization size	Competence	N	Mean	StDev	Median	Mode	N for Mode
Micro enterprises	T4	10	3,70	1,06	3,5	3	4
Small and medium enterprises	S4	32	3,22	1,13	3	4	11
Large enterprises	S4	83	3,40	1,06	4	4	31

Note. StDev – Standard deviation.

Large enterprises pointed out problem solving, SME – ability to be compromising and cooperative while micro organizations ability to work in a team most often as the important competences. Large and SME marked leadership skills as less important while for micro organizations considered coding skills the least important.

Next verification was based on summary percentage results of answers 4 and 5. The highest values presented in table 13 confirm significance of studied abilities and the lowest summary percentage presented in table 14 could lead to the conclusion that the studied competences are less important for surveyed companies.

Table 13.
Highest % of positive (4 and 5) answers for statements by company size.

Organization size	Competence	1	2	3	4	5	4and5
Micro enterprises	S1	0,00%	0,00%	10,00%	50,00%	40,00%	90,00%
	S10	0,00%	0,00%	10,00%	50,00%	40,00%	90,00%
	S8	0,00%	0,00%	10,00%	10,00%	80,00%	90,00%
Small and medium enterprises	T3	0,00%	0,00%	0,00%	53,13%	46,88%	100,00%
	T7	0,00%	0,00%	3,13%	53,13%	43,75%	96,88%
	T8	0,00%	3,13%	3,13%	43,75%	50,00%	93,75%
Large enterprises	T7	0,00%	0,00%	6,02%	36,14%	57,83%	93,98%
	E8	0,00%	1,20%	4,82%	44,58%	49,40%	93,98%
	T2	0,00%	1,20%	6,02%	43,37%	49,40%	92,77%

Table 14.
Lowest % of positive (4 and 5) answers for statements by company size

Organization size	Competence	1	2	3	4	5	4and5
Micro enterprises	T4	0,00%	10,00%	40,00%	20,00%	30,00%	50,00%
	T7	10,00%	0,00%	30,00%	10,00%	50,00%	60,00%
	T2	0,00%	0,00%	40,00%	0,00%	60,00%	60,00%
Small and medium enterprises	S4	3,13%	31,25%	18,75%	34,38%	12,5%	46,88%
	E9	0,00%	15,63%	31,25%	40,63%	12,50%	53,13%
	EN2	3,13%	15,63%	21,88%	43,75%	15,63%	59,38%
Large enterprises	S4	2,41%	21,69%	24,10%	37,35%	14,46%	51,81%
	T4	2,41%	14,46%	19,28%	42,17%	21,69%	63,86%

The highest % of positive confirmations for micro organizations can be seen for competences such as: ability to transfer knowledge, conflict solving and ability to work in team. For SME the highest score was achieved in: efficiency in working with data, process understanding and problem solving. Large companies also confirm the importance of process understanding but additionally pointed out state-of-the-art knowledge and analytical skills. For competences with the lowest values of % with answers 4 and 5 we have: coding skills, process understanding and analytical skills for micro organizations, leadership, research skills and motivation to protect the environment for SME and coding and leadership skills for large companies.

Table 15.
Summary of importance by organization size

<table>
<tr><th>Competences</th><th>Organization size</th><th>Acc. to mean value</th><th>Acc to mode value</th><th>Acc to % of positive answers</th></tr>
<tr><td rowspan="3">The most important</td><td>Micro enterprises</td><td>S7 Communication skills</td><td colspan="2">S8 Ability to work in a team</td></tr>
<tr><td>Small and medium enterprises</td><td>T3 Efficiency in working with data</td><td>S9 Ability to be compromising and cooperative</td><td>T3Efficiency in working with data</td></tr>
<tr><td>Large enterprises</td><td>T7 Process understanding</td><td>T8 Problem solving</td><td>T7 Process understanding</td></tr>
<tr><td rowspan="3">The least important</td><td>Micro enterprises</td><td colspan="3">T4 Coding skills</td></tr>
<tr><td>Small and medium enterprises</td><td colspan="3" rowspan="2">S4 Leadership skills</td></tr>
<tr><td>Large enterprises</td></tr>
</table>

Independently of statistic types, the less important competences were coding skills and leadership. Technical competences such as: process understanding, problem solving but also communication skills, being compromising and cooperative, ability to work in a team and with data were definitely important for the surveyed companies.

Analysis of mean values by company sector have been presented in table 16 – containing the highest values, and in the table 17, containing the lowest value.

Table 16.
Basic statistics for competences with highest medium value by sector

Organization sector	Competence	N	Mean	StDev	Median	Mode	N for Mode
Industry	T8	93	4,54	0,64	5	5	56
Service	E2	32	4,53	0,72	5	5	20

Note. StDev – Standard deviation.

Table 17.
Basic statistics for competences with lowest medium value by sector

Organization sector	Competence	N	Mean	StDev	Median	Mode	N for Mode
Industry	T4	93	3,30	1,09	4	4	35
Service	T4	32	3,81	1,09	4	5	11

Note. StDev – Standard deviation.

Results verified by the control variable – sector, present similar results as previous analysis. Problem solving competence is important for the industry sector. For service companies language skills obtained the highest mean. Leadership skills received the lowest results, independently of organization type. Exactly the same competences got the same results in case of analysis by N for mode statistics. Problem solving and language skills received the highest values, leadership the lowest.

Language skills importance has been confirm also by analysis of % positive answers. Data presents table 18. Additionally, process understanding received 94.62% of positive answers. Analysis also confirms the lowest importance for leadership skills with 59,38% in service companies and 50,54% in Industry sector – table 19.

Table 18.
Highest % of positive (4 and 5) answers for statements by company sector

Organization sector	Competence	N	Mean	StDev	Median	Mode	N for Mode
Industry	T7	0,00%	0,00%	5,38%	37,63%	56,99%	94,62%
Service	E2	0,00%	3,13%	3,13%	31,25%	62,50%	93,75%

Note. StDev – Standard deviation.

Table 19.
Lowest % of positive (4 and 5) answers for statements by company sector

Organization sector	Competence	N	Mean	StDev	Median	Mode	N for Mode
Industry	S4	3,13%	6,25%	31,25%	25,00%	34,38%	59,38%
Service	S4	2,15%	29,03%	18,28%	37,63%	12,90%	50,54%

Note. StDev – Standard deviation.

Table 20 presents summary data for all types of analysis: by mean value, by N for mode, and % of positive answers. Based on those data, it can be concluded that for industry sector process understanding and problem solving are the key competences, while service companies rely on language skills. Leadership skills for both types of companies are definitely less important in the Industry 4.0 reality then other competences.

Table 20.
Summary of importance by company sector

<table>
<tr><th>Competences</th><th>Organization sector</th><th>Acc. to mean value</th><th>Acc to mode value</th><th>Acc to % of positive answers</th></tr>
<tr><td rowspan="2">The most important</td><td>Industry</td><td colspan="2">T8 Problem solving</td><td>T7 Process understanding</td></tr>
<tr><td>Service</td><td colspan="3">E2 Language skills</td></tr>
<tr><td rowspan="2">The least important</td><td>Industry</td><td colspan="3" rowspan="2">S4 Leadership skills</td></tr>
<tr><td>Service</td></tr>
</table>

4. Discussion and conclusion

The aim of this article was to present the latest research results related to Industry 4.0 and the competences that the research group indicates as important for the era of new technologies. The conducted analysis of the anonymous questionnaires provided general information on the perception of the subjected aspects. Basic statistics were used to analyze the data. The authors, based on the average value, the number of the most common answers, i.e. the "N for mode" value and the percentage of positive responses, obtained the results on the perception of competences in the era of industry 4.0.

Problem solving competence has been pointed by multiple participants. On the basis of statistics, this competence is important mostly for large companies and the industry sector. Together with competences such as efficiency to work with data, process understanding and the state-of-the-art knowledge it is clear that in large enterprises, especially from industry area, those competences are needed on a daily basis. In small and medium sized enterprises, the ability to be compromising and cooperative was also important. As companies were multiple task must be performed using limited resources, being able to compromise and the ability to cooperate are easily understandable needs. Similarities have been found in micro companies as well. Ability to work in a team and communication skills have been found to be important for those types of organizations. In relation to service companies, it was not surprising to see that language skills and ability to communicate, which are the main “tool” for business continuity, were considered the most significant. On the other hand, leadership competence turned out to be the least important for the survey participants. Despite the statistics used and control variables leadership received the lowest results.

This research was not free from limitations. Competences were grouped according to literature study results. This meant that a chosen group was not always natural for specific competence, which could lead to difficulties in research. The study group was anonymous. The survey was taken by random employees from multiple organizations, who were not selected in advance and who sometimes did not even have any general knowledge about Industry 4.0 basics. Uneven data distribution by sector and size companies meant that presented results could be used mostly for illustrative purposes and preliminary analysis. Moreover, it is recommended to investigate presented subject in specific company sector and for a chosen employee level to obtained even data and more representative conclusions.

5. Summary

The study investigated the subject of competences in Industry 4.0. On the basis of anonymous survey via online tool, participants representing manufacturing industries and service companies identified key competences in the new era of technology development. Study results reveal that aside from technical skills, the crucial role in Industry 4.0 is played by soft skills such as ability to work in team, problem solving, communications skills and ability to work with data. It is worth adding, that based on the results, leadership skills became less important for survey participants then other studied competences.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

FUNCTIONALITY ANALYSIS OF THE SOFTWARE SUPPORTING THE PRODUCTION OF SPARE PARTS USED IN THE COMPLAINT REPAIR: A CASE STUDY

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Purpose: The main purpose of this paper was to present the possibility of using IT systems in a production company for managing complaints and the manufacture of spare parts.
Design/methodology/approach: The paper presents the legal regulations in force in Poland in the field of complaints under warranty and guarantee. It discusses the rules of the complaint procedure in consumer sales and characterizes product complaints. It also presents the definition of a spare part and its classification and discusses the activities related to the management of pare part availability.
Findings: This paper discusses an example of the implementation of an IT system supporting the company's production activities. The author assesses the usefulness of this tool in the implementation of activities related to the production of dedicated spare parts and comprehensive handling of complaints. The functionality of the software is analysed and the conditions and requirements related to the complaint procedure in consumer sales are presented. In addition, the limitations of data exchange and additional expectations of the users of the IT system, which may be the direction of its development, are described.
Research limitations/implications: The author has pointed out that an extremely important issue in the complaint procedure is keeping the deadlines both in terms of the feedback that should be given to the consumer and the completion of the contracted production work. Verification of the compatibility of the used spare part with the repaired device is also required. It is vital as the components used are often subject to technological improvement.
Practical implications: The paper shows that the method of managing spare part availability affects the handling of complaints. It is also a platform for interference in the course of production processes of new products.
Originality/value: Undoubtedly, the original contribution of the paper to the literature on the subject is the assessment of the suitability of the selected software supporting production activities used in the improvement of the complaint management system.

Keywords: Industry 4.0, spare parts, after-sales services, knowledge management.

Category of the paper: Research paper, Case study.

1. Introduction

Even the most thoughtful purchases are not able to ensure satisfaction and trouble-free use of the purchased product. The initiation of complaint procedures is often necessary. A complaint notification is a dissatisfaction expressed by a consumer, most often resulting from a quality non-compliance of the purchased goods or services. It is carried out to repair a defective product, replace it or receive compensation in the form of a reduced price or a refund. The consumer sends it to the seller or the manufacturer, making a claim under the warranty or guarantee.

From the manufacturer's point of view, it is important to identify the source of the defect and take corrective actions to remove the reported non-compliance. The repair of the sold goods based on quality reservations is a particularly difficult issue for non-standard goods, made to order or in accordance with the specification provided by the customer. It results from the necessity of the seller to respond to the notification in a statutory manner within fourteen days from the date of its receipt. Warranty claims may be subject to other rules because they are handled under contractual conditions imposed by the guarantor. Usually, the provisions of the guarantee agreement extend the period of the guarantor's response to the defect reported by the consumer and prolong the deadline for the remedy which will restore the required parameters of the product. The need to replace or repair non-standard components that were used in the construction of the product complained about is often associated with the need to launch dedicated production. This is highly challenging, which is why guarantee claims are a more preferred form of customer service for the manufacturer than a warranty.

In the area under consideration, IT tools supporting production and complaint management systems are extremely useful. The former enable efficient coordination of production activities, including, apart from serial production of new products, also unit production of spare parts. It is not always possible to use the available stocks of semi-finished products. Unfortunately, the necessity to meet the deadlines in the complaint handling process forces service and guarantee repairs to be processed urgently, which significantly affects the previously planned course of production activities. The tools that support the implementation of the described production activities are most often the production modules of ERP (Enterprise Resource Planning) systems, but also the following systems: MES (Manufacturing Execution System), SCADA (Supervisory Control and Data Acquisition), HMI (Human Machine Interface), EDI (Electronic Data Interchange), WMS (Warehouse Management System), or SCM (Supply Chain Management) and TMS (Transportation Management System).

The second group is complaint management systems. The most frequently configured tools. These include CSS (Customer Service) or CRM (Customer Relationship Management) systems. Their functionality makes it possible to record and process claims, manage the circulation of documents and carry out statistical analysis of the data collected in them.

There are many different systems of the listed classes on the market. They are dedicated to selected industries or enterprises of specific industries. Universal tools that are subject to broadly understood parameterization are less often. In the sector of large production companies, however, solutions based on one IT system are most often preferred. This is due to the need to maintain the efficiency of not only separate IT tools, but also to design and supervise the work of mechanisms that integrate these systems. The construction of these mechanisms requires the specification of the frequency of communication between the systems, the direction and scope of data synchronization, and the definition of rules ensuring the security and confidentiality of the information sent. However, it is an indispensable element, because it affects the continuity of the business processes of the enterprise, and thus keeping the timely implementation of previously planned tasks (Milewska, 2020). The way of construction and the effectiveness of operation of various integration mechanisms is described in the literature. The connection between the CRM and ERP systems describes, among others Ruivo (Ruivo et al., 2014), while the integration of the CRM and WMS systems is presented by Khan (Khan et al., 2012).

In this article, however, the task of evaluating the operation of an IT system was undertaken, the functionality of which supports two areas of the company's business activity. The first one covers manufacturing activities. It represents both the production of new products, as well as undertaking tasks related to the production of spare parts and the repair of advertised products. The second area covered by the research is the handling of complaints. As part of the research, the possibility of keeping the deadliness in the consumer service process and the manufacturer's response to the need to produce non-standard spare parts, the use of which is necessary in repair or service activities, will be verified.

2. Legal Basis For Complaints

From 25 December 2014, the handling of complaints under the warranty is carried out in Poland based on the provisions of the Consumer Rights Act of 30 May 2014 (Journal of Laws 2014, item 827). It implements the provisions of Directive 2011/83/EU of the European Parliament and of the Council of 25 October 2011 on consumer rights (Directive 2011/83/EU), which requires the harmonization of consumer issues in the European Union. This Directive amended (Journal of Laws 2002.141.1176) and repealed (Journal of Laws 2004.54.535) the statutory provisions previously in force in Poland.

Pursuant to the aforementioned Act (Journal of Laws 2014 item 827), the buyer should contact the seller regarding the identified physical defect of consumer goods consisting in non-compliance of the product with the contract (Articles 560-561). In their declaration, the customer may submit a request for a price reduction or withdrawal from the sales contract, unless the seller immediately and without undue inconvenience to the customer replaces the defective product with a non-defective one or removes the defect. The customer may also request replacement of the product or removal of the defect found. These rights are of an equivalent nature, which means that the customer can immediately use either the first or the second option.

The declaration of non-compliance of the goods with the contract should be understood as the obligation to provide information about the undesirable quality of the goods (Article 556 and section 3 of Article 557) (Journal of Laws 2014 item 827). The buyer does not have to explain the reasons for this quality. The description of goods can be graphic. In order to respond to the consumer's complaint and remove the defect, the customer may be asked to deliver the product to the address indicated by the seller. If, due to the type of non-compliance or the method of installation, the delivery of the goods is difficult or impossible, the customer is obliged to make the product available at the place of its use. The seller's failure to respond within fourteen days from the date of receipt of the request shall be deemed as the acceptance of the complaint. The refund to the consumer should take place immediately, as requested by the customer.

The regulations (Journal of Laws 2014 item 827) do not impose any special requirements regarding the complaint procedure. However, according to the Act on counteracting unfair market practices of 23 August 2007 (Article 6(4)(4)) (Journal of Laws 2007.171.1206), consumers should be able to familiarize themselves with the seller's procedure for handling complaints before concluding the sales contract. This applies in particular to situations where the complaint handling procedure deviates from the standards that can reasonably be expected from the trader in their relations with consumers, in accordance with fair market practices or the general principle of good faith in the scope of their business (Article 7(4)(d) related to Article 2(h)) (Directive 2005/29/EC). The complaint handling procedure may in no case contain provisions that are inconsistent with the Consumer Rights Act (Journal of Laws 2014 item 827). It may, however, contain provisions more favourable than the act provides or issues not specified by law. Most often, it determines the place and form of submitting complaints, regulates the method of describing the non-compliance, determines the method of product delivery as well as the form and scope of communication with the buyer.

Complaints under the warranty are not uniform in nature and their diversity affects the manner in which claims are handled. Taking into account the method of recording goods rotation in the company and the rules of complaint procedure in consumer sales, complaints are classified into value and material ones. Value complaints result from accounting errors in the sales documents. They mainly concern: prices, the method of calculating the discount or the margin. Submitting a value complaint usually results in reducing the amount to be paid by the disputable amount. The settlement is adjusted with a correcting invoice. Material complaints concern qualitative reservations about or quantitative non-compliance of the delivered goods. Identified apparent defects of the goods may be removed by repairing the sold goods or by providing compensation in the form of replacing the product with a defect-free one or making a refund.

Handling guarantee claims is a separate issue. Guarantee is a voluntary obligation of the manufacturer of the equipment or the provider of a given service (Kirkizoğlu and Karaer, 2022; Sundina et al., 2010; Zhu et al., 2022). It does not exclude, limit or suspend the consumer's rights under the warranty. The guarantor undertakes to provide solutions that meet certain parameters for a clearly defined period of time. In this way, they declare their readiness to undertake the obligations connected with the restoration of the required operating parameters of the sold product. In the guarantee agreement they also specify the guarantee claim procedure, i.e. the method of removing the defect, e.g. by repairing or replacing a component, as well as the processing time and the deadline for claim satisfaction. It should be noted that relatively often the guarantee also imposes obligations on the customer. In order to meet the terms of a guarantee agreement, the consumer should perform the inspections or maintenance procedures recommended by the manufacturer, often periodically. They can be quite challenging not only financially, but also in terms of organisation, because they require timely performance of certain actions.

3. Management Of Spare Part Availability

According to the standard DIN 24 420, spare parts are defined as elements (also called parts), groups of elements (also called assemblies and subassemblies) or complete products that are used to replace damaged, worn or defective parts, assemblies or products (DIN 24420-1, 1976). They must be unambiguously assigned to one or more machines or devices and should not be used on their own. American Production and Inventory Control Society has defined the concept of a spare part as a module, component and element that is used without any additional modification to replace original parts (APICS, 2004).

Taking into account the intended use of spare parts, the following classification is applied (Biedermann, 2008):

- replacement of damaged or missing parts,
- replacement of worn parts which, due to their design or the materials used, cannot be repaired.

Spare parts are characterized by high variability of demand (Rahimi-Ghahroodi et al., 2019), therefore they are divided into two groups:

- parts that require constant replenishment of stock,
- and parts for which keeping stocks is economically unviable.

Although inventories freeze capital, they are essential in many cases. The determinant of maintaining an inventory of selected spare parts is to conduct factor analysis (Kennedy et al., 2002; Van Kooten and Tan, 2009). The basic criterion for these activities is the classification of parts as elements subject to wear and tear. The selection of the method of replenishing the stock of spare parts requires the determination of the statistical distribution of material flow. The level of inventory should be determined, among others, on the basis of (Kolińska and Doliński, 2013):

- the degree of component wear,
- the frequency of its releases,
- the number of machines/devices in which it was installed,
- the frequency of component failure,
- the significance of the device used for ensuring continuity of customer processes.

Unfortunately, the classic inventory control models are not always effective (Christopher, 1996; Niemczyk, 2010; Sarjusz-Wolski, 2000; Sleptchenko et al., 2018). Manufacturers keep expanding the range of their offer and commonly use the practice of replacing the original components with other that have a lower risk of damage. These activities may change the management method of spare part availability (Durao et al., 2017; Shi, 2019).

It should be noted, however, that the factor having a significant impact on maintaining spare parts stocks is not only the need for efficient implementation of service activities, but also the manufacturer's continuous processing of complaints (Sabaei et al., 2015). According to the guidelines of the Act (Journal of Laws 2014.827), the completion of remedy proceedings should take place within the set deadline. Otherwise, a refund to the consumer may be required. This means that handling complaints under the warranty, but also under the guarantee, requires, apart from organizing repair and logistics activities, also the production of spare parts that will replace previously damaged or worn components. It is obvious that time is a critical factor in these proceedings. The production of spare parts that are not in stock should be extremely efficient. Their production technology is of great importance. Long normative duration of the operation, commissioning work to external contractors or the need to change the resources of the machine park are just some of the reasons that may hinder or even prevent timely implementation of the planned tasks. It should be emphasised that from the perspective of the Act, but also the guarantee agreement, timeliness is of key importance for the course of the entire process. It requires the integration of manufacturing activities with logistics services. In both cases, the delivery of spare parts to the place of repair or replacement may take place both at the authorized service point and directly at the customer's premises, if due to the method of installation or the type of non-compliance, the delivery of the equipment is difficult or even impossible (Journal of Laws 2014.827). As it has been shown above, the manufacturer's reaction to the confirmed quality non-compliance of the sold product will not always result in the immediate launch of unit production for the missing components. Economic viability may force them to take alternative solutions and persuade them to maintain a stock of spare parts, which are necessary for immediate remedial actions in guarantee and after-sales service (Rao, 2011).

4. Example Of Use Of IT System

Currently, the foundation of production process management and material flow control in the company and the basic condition for the integration of business activities is the implementation of IT systems supporting the acquisition, processing and transmission of information. Obtaining an efficient control system is associated with the creation of an implementation that reflects the significant factors determining the production capacity of the enterprise as well as limitations and disruptions occurring in the course of manufacturing processes. Most often, the model is obtained through parametrization of the process, but also technology, and the integration of data that is obtained from various sources. This means that individual functional areas of IT tools used are adapted to the size and structure of the business entity and the way it is organized. It should be noted that this adjustment is not a one-off activity, but a cyclical action of various scope, which not only takes into account the dynamics of internal changes in the organization, but also the impact of environmental factors. System flexibility understood in this way is recognized, among others, by the declaration of the alternative use of production resources in the course of the company's production activities.

An example of an IT system that comprehensively supports the company in terms of both production management and complaint notification management is a tool called IPOsystem™. It is designed by UiBS Teamwork Sp. z o.o., which supports discrete unit production, but also small batch production. It was implemented at the Polish manufacturer of highly specialized machines, where this research was conducted. The implementation is based on Microsoft SQL Server. The data it collects describes the workflow and material flow. Task allocation is performed autonomously. Instructions to perform a technological operation are issued with a terminal located in the hall and connected by network to the server. Through the RFID identifier, the terminal recognizes the person performing the task and enables them to confirm the completion of work or to receive another instruction. Alternately issuing instructions and receiving completion reports is a solution that systematically provides up-to-date information on the current status of work. In addition to continuous recording of the start and end time of each technological operation, IPOsystem™ enables registering on the terminal the number of semi-finished products leaving the workstation and the number of shortages, for which the previously adopted classification of the causes of non-compliance is used.

The basic document of IPOsystem™ that enables the registration of the course of production activities and auxiliary processes is the work order. It enables the collection, processing and sharing of data that describe the technology used in production or the manner of taking other activities supporting basic processes. The order class determines the way the process is handled in the system. It forces the introduction of some data, determines the urgency of its implementation and specifies the stages of undertaken actions. Order class is selected at the stage of defining the order (when a new document is created). One of the many classes available in IPOsystem™ is a complaint order. It is used to register and process complaints, which signal the consumer's dissatisfaction with the product used. They can represent the circulation of documents necessary to decide whether the complaint is justified, be used in planning and recording corrective actions or correspond to the production of non-standard spare parts that are used in after-sales customer service. In the described implementation, they are used in each of the abovementioned areas. They are a record of work carried out both at the customer's premises, i.e. outside the company, and internally.

Whenever a complaint notification is accepted by the examined company, a work order is created in IPOsystem™. The complaint processing procedure is implemented in accordance with a predefined scenario. It has been saved in IPOsystem™ as a template and constitutes a pattern of operation, which may be changed. Converting a template into a work order is most often performed by users through a context menu (Figure 1).

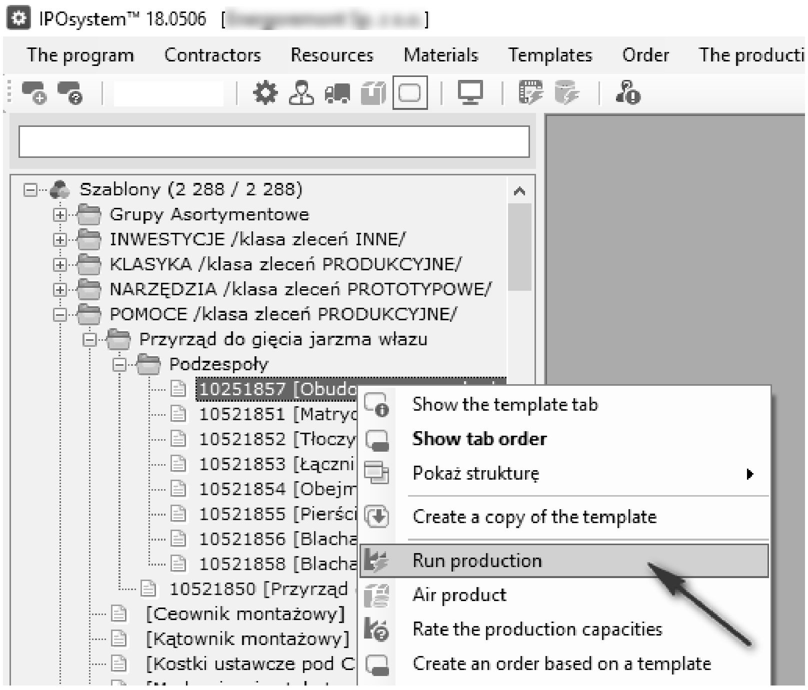


Figure 1. Creating a work order on the basis of a predefined template. Source: Own elaboration.

The complaint procedure includes accepting the product suspected of being dysfunctional, performing diagnostic tests showing the current operating parameters of the device and issuing an opinion or expert opinion on the legitimacy of consumer dissatisfaction with the reported non-compliance of the quality with the manufacturer's declaration. An alternative place for the performance of the abovementioned activities are external authorized service centres. If this stage ends with a positive opinion, i.e. with the acceptance of the customer's claims, repair activities are carried out as part of the continuation of the complaint procedure, or production activities are undertaken, resulting in the production of spare parts used in the faulty product. The implementation of these tasks is reflected in IPOsystem™. As part of the technological preparation of production, the technology of the complaint order is created and entered in the

IT system. The declaration of the method of execution is built through the selection, parameterization and prioritization of technological operations as well as the allocation of the material structure. The technology representing repair activities most often does not have precisely defined normative execution times. They are supplemented after the completion of the task and constitute the basis for estimating the costs incurred to remedy the product.

In the production of spare parts, data describing already completed production orders is extremely useful (Figure 2). It provides a summary of planned production activities with their completion reports. This means that the functionality of IPOsystem™ enables not only determining the effectiveness of the actions taken, but also the human and machine resources involved in these activities, and defining precisely the time of execution of each technological operation and the use of direct-production materials.

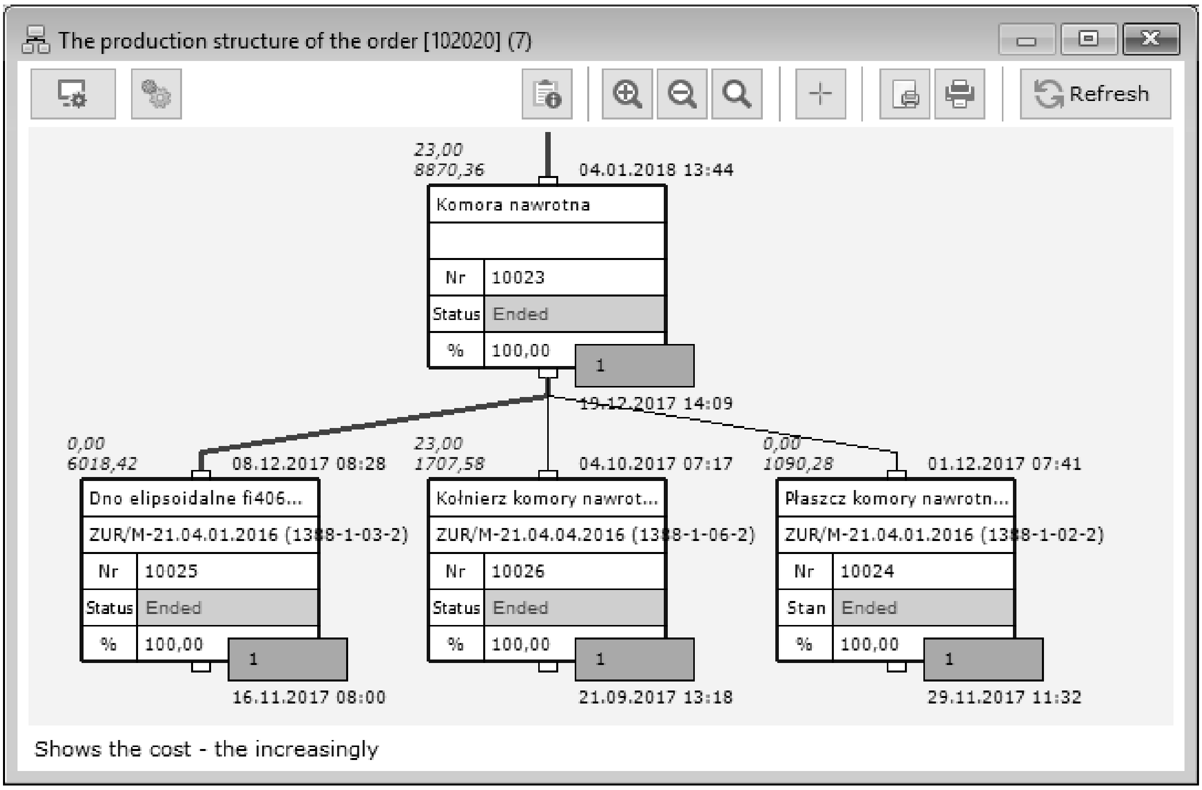
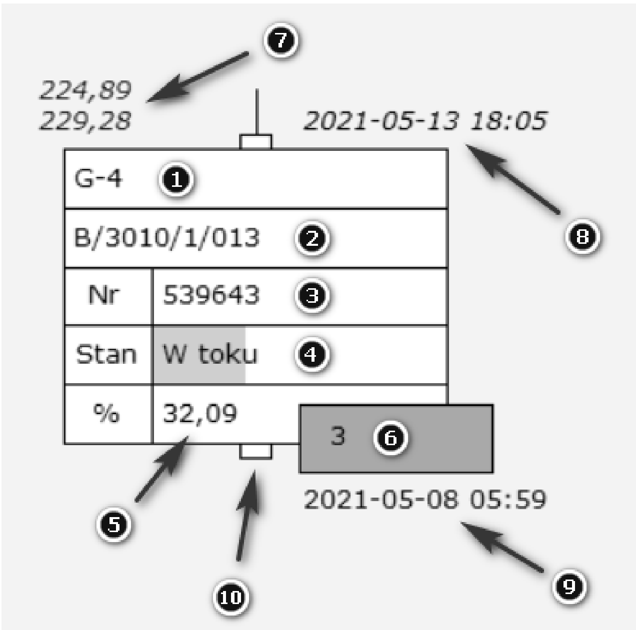


Figure 2. Diagram of a multi-level technological structure of a completed production order. Source: Own elaboration.

Using the product genealogy stored in IPOsystem™, it is possible to keep track of the production process, supervise the workload of individual resources, react to undesirable disturbances in the course of production activities and create multidimensional statistical analyses showing the efficiency and effectiveness of selected areas of the company's business activity. For this purpose, data summaries in tabular form and graphical forms of presentation, such as diagrams (Figure 3) or charts, are used.

It should be noted that most of the windows opened in IPOsystem™ are interactive. It means that the system simultaneously receives information provided by the user and immediately responds to it in terms of widely understood functionality. Mutual interaction of the user and the system takes place on various levels. Although the response of the system to each of them is a continuously generated plan of production activities, each time it adopts a different form of communication. The operational level includes the ongoing recording of events, initiated by direct-production employees. It is performed through terminals located in the production hall, and the plan is communicated in the form of operator's instructions.

On the tactical level, information is exchanged through supervision. It is the user's reaction to disruptions occurring in the course of production, but also an adaptive activity, within which the investments made are reflected in the operation of the system. It is made by correcting the list of production resources, changing their quantity or the distribution of hourly working time and many other values that define the production capacity of the enterprise. It is implemented by the executive team at standard workstations, who receive feedback, among others, on the degree of use of resources or the scale and type of commissioned or implemented cooperation services.



Key:
1 Order name.
2 Execution drawing number.
3 Order number.
4 Order status name (the bar shows % of execution).
5 Percentage of execution.
6 Material quantity and requirements.
7 Unit manufacturing cost*: planned/real.
8 Work completion date*.
9 Work commencement date.
10 Control point marker.
* Values representing the planned nature of the activities are written in italics.

Figure 3. Graphic visualization of a fragment of a production order. Source: Own elaboration

On the other hand, the strategic level is created by communication in the area of demand, which is expressed by the quantity, quality and type of the manufactured products. Activities in this area include defining and launching orders, for which production technology and material structure are specified. The interactivity of the system is particularly important here from the point of view of processing complaints. Employees are constantly struggling with the pressure of time, because they are obliged to keep the deadlines for initiated proceedings. The functionality of IPOsystem™ helps them by suggesting possible actions, quick transfer of user activity between related workspaces and graphical presentation of data, whose colours additionally interpret the displayed record. Of course, the invaluable information provided by IPOsystem™ is the planned completion date, determined on the basis of the order technology and concurrent production. An example of the area of occurrence of this functionality is a window showing the production structure in the form of an interactive diagram. There, it is possible to use the 'Drag & Drop' mechanism and the context menu for which the location of the mouse cursor dynamically changes the availability of individual commands. Selecting any part of the technology enables its quick copying or transfer to another order. The implementation of this task is illustrated in Figure 4.

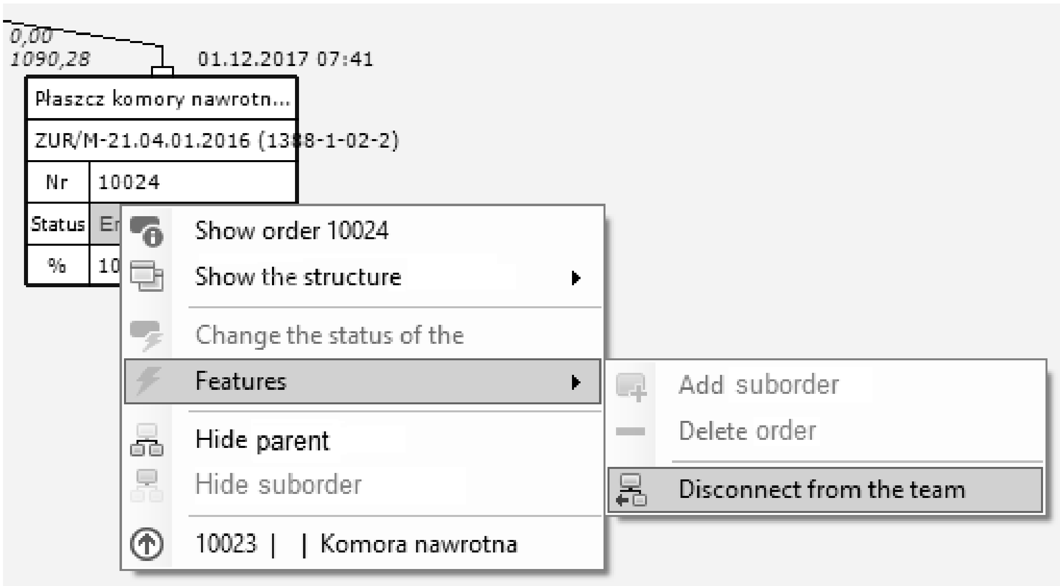


Figure 4. Disconnecting an assembly for further use. Source: Own elaboration.

In complaint notifications, however, it is important to search for the production technology of the damaged component in advance in order to be able to recreate it in the order under which the spare part will be manufactured. However, in time the components used are subject to technological improvement. Of course, it is a producer's reaction to previously made design or execution errors, or a response to the changing expectations of users. Then, the condition of adjustment is not only meeting the required assembly tolerances and compliance in terms of aesthetics, but also the range of functions performed by the element. The new engineering version of the spare part should effectively and reliably fulfil all functional tasks assigned to it, therefore, final verification of its compatibility with the repaired device is required. It should be remembered that the use of non-standardized components in the solutions sold is associated with a high risk of starting the production of a single spare part, dedicated to the complaint procedure, and often entails higher production costs.

5. Summary

The complaint management system plays an important role in the process of improving the products and services provided. It is a valuable source of information on the ways of using products as well as the needs and expectations of consumers. Understanding them is the key to gaining a competitive advantage in the market. However, since effective business activity is also impacted by the efficient flow of information, the functionality of the IT tools used in the company is of great importance. Due to the undertaken remedial actions and the production of spare parts, the functionality of IT systems of production companies should cover both the area of processing complaints and support production activities. Having regard to the above, the author of this paper has attempted to assess the efficiency of a system named IPOsystem™, whose functionality covers both these areas. The possibility of starting document circulation procedures and producer response to demand for non-standard spare parts, the use of which is necessary in repair or service activities, has been analysed. The conducted research has shown the usefulness of IPOsystem™ in the implementation of tasks related to the comprehensive processing of complaints and the discreet production of dedicated spare parts. The usefulness of production technology templates as well as document flow scenarios has been confirmed. The mechanisms of searching for historical data have been verified, which enable determining the genealogy of the faulty products. Moreover, the possibility of starting and tracking the production of spare parts undertaken in connection with the planned repair of the faulty products was investigated. It should be noted that the interface of the IPOsystem™ system is highly intuitive and flexible. The configuration options enable the application to be adjusted to the user's requirements, and the multi-threaded system operation enables simultaneous editing of many documents.

At the same time, the research carried out showed the limits of IPOsystem™ with regard to analysing with the use of the data collected in it. Although most system windows have built-in reports, they offer little possibility of modification. Only in a few places where they built in the form of multi-level aggregation of data or enable comparative analysis. Importantly, it should be noted that IPOsystem™ does not offer tools that would allow the user to create reports on their own. However, since the data from IPOsystem™ is exported into standard recording formats, the search for correlation between selected data areas can be performed in an external environment. In the analysed company, summaries prepared in this way are used to indicate the most favourable conditions for conducting business activity.

Acknowledgements

This article was created as part of statutory work 13/010/BK_22/0065 conducted at the Institute of Economics and Informatics at the Faculty of Organisation and Management of the Silesian University of Technology.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

DEVELOPMENT OF SOLAR ENERGY IN POLAND IN THE CONTEXT OF EUROPEAN COUNTRIES

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Purpose: The aim of the article is to analyse the development of solar energy in Poland against the background of other European countries.
Design/methodology/approach: The research was conducted on data for 22 countries between 2012 and 2020 using dynamic analysis and multivariate analysis in the form of cluster analysis.
Findings: Between 2012 and 2020, intensive development of solar energy sources was observed in the 22 countries studied. Although Poland invests very intensively – compared to other countries – in solar technologies (especially in photovoltaics), it does not yet belong to the cluster of high-performing countries in this respect.
Originality/value: The article's value is to view the development of solar thermal systems in Poland and Europe from the perspective of a multidimensional analysis, which we conducted in two separate time units. This allowed us to draw conclusions about the development of solar systems in Poland also with regard to time.

Keywords: solar energy, collectors, photovoltaic, renewable energy, Poland in the context of Europe.

Category of the paper: research paper.

Introduction

Energy is a vital issue for the development of the modern economy. The current method of obtaining it from fossil fuels generates huge environmental problems such as air pollution and carbon dioxide emissions. Renewable energy sources (RES) include solar, wind, geothermal, flowing water, wave, tidal, and biomass energy. Renewable energy sources are considered inexhaustible in the very long term, and their resources are not depleted as they are used. Hence, in recent years, there has been a shift towards renewable energy sources to overcome existing environmental problems. In addition, in 2021, the European Commission published the "Fit for 55" package (Fit for 55, 2021), which contains many changes to the existing regulations and which is to serve the new target of reducing carbon emissions by 55% in 2030. The package includes, among others, a proposal to increase the share of renewable energy in gross final energy consumption to 40% in 2030. Adoption of an increased RES target will accelerate investments in new, non-emission sources in the generation sector. This article is dedicated to solar energy. The development of solar energy technology is currently being intensively explored in research. Technological opportunities and innovations in this area are being explored (Ge et al., 2018). Factors delaying the implementation of solar technologies are analysed (Budin et al., 2021; Zarębski et al., 2021; Szultka et. al., 2021; Jasiński et al., 2021). Factors influencing public acceptance of solar technologies are also investigated (Parzonko et al., 2021; Graziano and Gillingham, 2015; Müller and Trutnevyte, 2020; Zdonek et al., 2022).

In view of the long-standing interest in solar energy, the development of solar energy in Poland is interesting compared to European countries. It has already been explored research-wise, but usually, the analyses were dedicated to a specific technology, e.g. photovoltaics (Olczak et al., 2020, 2021; Wolniak and Skotnicka-Zasadzień, 2022) or the analyses lacked multidimensionality and international context (Mularczyk and Hysa 2015; Mularczyk, 2016). Therefore, the main objective of this article is to analyse the development of solar energy in Poland in comparison with other European countries. Consequently, we posed the following research questions:

Research question 1: How have the variables describing the development of the solar systems evolved in particular European countries over the period 2012-2020, and how does Poland compare?

Research question 2: Which group of countries did Poland belong to in terms of developing solar systems in 2012 and 2020?

To address the research questions posed, dynamics analysis and cluster analysis were carried out on data from 2012-2020 for 22 European countries downloaded from Eurostat. Accordingly, the article is organised as follows: section one presents the literature background of the study, section two discusses the methodological aspects of the study, section three presents the results, and the final fourth section presents a discussion of the results obtained.

1. Literature review – characteristics of solar systems

Solar systems can be divided into two main groups: with photothermal conversion (solar collectors) and with photovoltaic conversion (photovoltaic panels). Solar collectors enable the direct conversion of solar energy into heat. At the same time, photovoltaic technology directly converts solar energy into electricity (Górzyński, 2020; Ge et al., 2018). Solar water heating is one of the most widely used water heating systems in the world, as collectors efficiently convert solar energy into heat with relatively low life cycle costs (Ge et al., 2018). Therefore, the collectors are used for heating domestic and process water, supporting the central heating system, heating water in swimming pools and cooling buildings. According to (Tokarczyk et al., 2020), collectors are a technology that, together with heat pumps and, temporarily, biomass boilers, will allow Poland's heating sector to decarbonise. However, it should be added that insolation conditions in Poland do not allow collectors to become the only source of heating in single-family houses, although they are an important auxiliary source (Fordrowksa, 2021). Even though the collector market in Poland has been developing at its best since 2010, mainly due to subsidised loans provided by the National Fund for Environmental Protection and Water Management, it has started to shrink with the development of PV panels. The collector and PV market is currently stimulated by anti-smog programmes and the Clean Air Programme.

Photovoltaic (PV) systems, which directly convert solar energy into electricity, have recently become increasingly popular. Both photovoltaic farms and prosumer micro-installations are developing intensively in Poland. Numerous studies on PV microgrids show that many factors influence public acceptance of these systems. These primarily include economic factors (Parzonko et al., 2021; Briguglio and Formosa, 2017; Müller and Trutnevyte, 2020), where the income of those investing in PV systems and the costs of these systems, as well as subsidies provided by the state to cover part of the installation costs, play a decisive role. Therefore, the development of PV systems is dependent on GDP per capita, as shown in a study (Wolniak and Skotnicka-Zasadzień, 2022). Besides, the emphasis on PV systems are supported by environmental factors, i.e. environmental awareness (Zhang et al., 2011), the share of hybrid or electric cars in total cars purchased (Davidson et al., 2014) and the level of pollution in a region (Balta-Ozkan et al., 2015). Furthermore, investment in PV systems depends on the characteristics of households and their environment, i.e. household size, the background of its members, population density, building type and the influence of friends and family (Balta-Ozkan et al., 2021; Graziano and Gillingham, 2015). In Poland, according to a study (Zdonek et al., 2022), investments in PV microgrids were most influenced by economic factors. This is why introducing the discount system, and the Mój Prąd (My Current) programme has contributed to the high interest of Poles in-home photovoltaics. Typically, electricity from domestic photovoltaics is used to power household appliances and lighting, but with the development and promotion of heat pumps, domestic photovoltaics will make an important contribution to the greening of district heating in Poland. Photovoltaic panels, like collectors, are regarded as environmentally friendly technology. Still, the issue of their disposal in a nature-friendly manner has not yet been resolved.

To summarise solar thermal systems, it should also be added that, in economic terms, both systems feature low running costs when using free renewable energy, yet high initial costs. The payback period for such systems is in the range of 3-15 years, which is strongly dependent on the type of components, geographical location and subsidies from different governments (Ge et al., 2018). In terms of technical investment conditions, the installation of solar systems is quick (about 2 days), and the equipment on the roof can serve for at least 20 years with proper maintenance. These installations are generally viewed as easy and maintenance-free, which further promotes their acceptance in the market (Zdonek et al., 2022).

2. Materials and methods

Collecting data

Data for the analysis were extracted from the online Eurostat database (Eurostat) and supplemented based on the results of the EuroObserver portal report (Solar Thermal and..., 2022). In this way, data was obtained from 22 European countries from 2012 and 2020 on the level of advancement of renewable energy sources (countries with missing data were not taken into the analysis). The following variables were extracted from the databases in question: 1) consumption of solar thermal, 2) solar thermal collectors' surface area, 3) gross electricity production from solar photovoltaic and 4) share of renewable energy in gross final energy consumption. These variables are summarised in table 1.

Table 1
Variables used for the study

Variable	Description	Unit
ConsOfRen_solTherm _perCapita	Consumption of Solar thermal	GJ/capita
SolarThermalColSurf _perCapita	Solar thermal collectors' surface	sqm/capita
GrossProdElecPV _perCapita	Gross electricity production from Solar photovoltaic	MWh/capita
Share_of_ren_en	Share of renewable energy in gross final energy consumption	Percentage

The first two variables are related to the topic of thermal energy. The consumption of energy from solar collectors is presented in GJ/capita. Solar collector area refers to all sectors with solar collectors in a country. Solar collector area data includes solar thermal (not photovoltaic). The unit, in this case, is sqm/capita. The third variable relates to issues of PV advancement in the country. It measures the gross electricity generation from solar PV in MWh/capita. And the last variable: the renewable energy share in gross final energy consumption is the share of renewable energy consumption in gross final energy consumption (according to the Renewable Energy Directive). It refers to all renewable energy in a country. This variable, therefore, corresponds in some way to a country's commitment to RES. The value of this share is expressed as a percentage. To allow the comparison analysis, the data collected, presented in the appropriate units (variables 1 to 3), have been divided by the country's population, bringing information about the size of the 'per capita' variable.

Data analysis

During the exploratory data analysis, the dynamics of the four study variables were first examined. To do this, the total change was calculated for each variable, which was obtained by dividing the 2020 value by the 2012 value (whereby, when interpreting this figure, it is necessary to convert it into percentages after subtracting the singularity: and this is how it is presented in the table and charts). Later, the average pace of change (the geometric mean of the chain indices calculated from the values of the phenomenon in successive periods; that is, in this case, the eighth-degree root of the total change before subtracting the singularity – on which a similar transformation as above must be performed for interpretation) was calculated, denoted as average growth. This stage of analysis was performed in a spreadsheet, and the results obtained were additionally visualised in bar charts made in Tableau. A hierarchical *cluster analysis* of the 22 countries was then carried out using these four variables. Ward's method was employed as the agglomeration method during the cluster analysis, and Euclidean distance was taken as the distance measure. This time the calculations were made in the R environment, and the results were visualised on dendrograms. Accompanying analyses were additionally performed, mainly characterisation of clusters using measures of descriptive statistics.

The flowchart of the data collection and analysis stages is shown in the figure below.

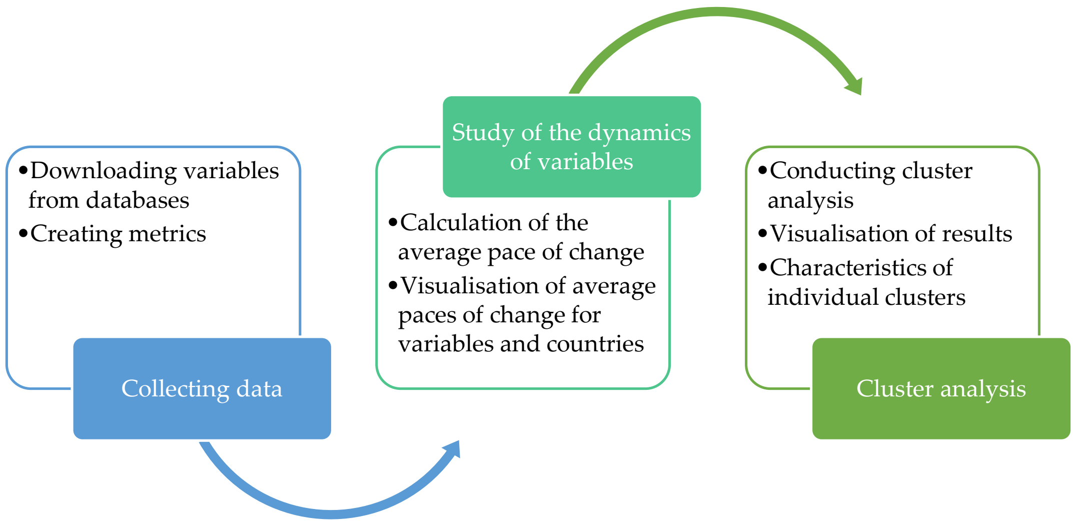

Figure 1. Flow chart for data collection and analysis. Source: own work.

3. Results

3.1. Evolution of variables describing the development of solar energy in European countries over the period 2012-2020

To address research question 1, i.e. to present the evolution of variables describing the development of solar thermal systems in Europe, table 2 was carried out. It shows the average values of all variables, the total change and the average pace of change over the period 2012-2020 over the whole area of the study countries combined (in this case, the indicators were calculated for the total area of the study countries). In addition, figure 2 and figure 3 were performed, which show how the average pace of change of the studied variables evolved between 2012 and 2020, separately in each country.

Table 2.
Average levels of variables combined in 2012 and 2020

	Solar thermal energy consumption [GJ/capita]	**Surface of solar collectors [sqm/capita]**	**Gross electricity production from solar photovoltaics [MWh/capita]**	**Share of renewable energy in gross final energy consumption [%]**
2012	0.3101	0.0906	0.1533	17.9643
2020	0.4171	0.1195	0.3149	24.1422
Total change	*35%*	*32%*	*105%*	*34%*
Average pace of change	***4%***	***4%***	***9%***	***4%***

Note: The results refer to the total surface area per capita of the surveyed countries.

Source: own work.

In the 22 countries' analysis area, the most significant change in the years under study was in the gross electricity generation from solar PV per capita. In 2020, it was as much as 105% higher than in 2012, representing an average year-on-year increase of 9%. Also, a significant increase in the solar thermal variables can be observed: 35% and 32%, with a constant year-on-year increase of around 4%. The values of the fourth variable, the share of renewable energy in gross final energy consumption, were at a similar level.

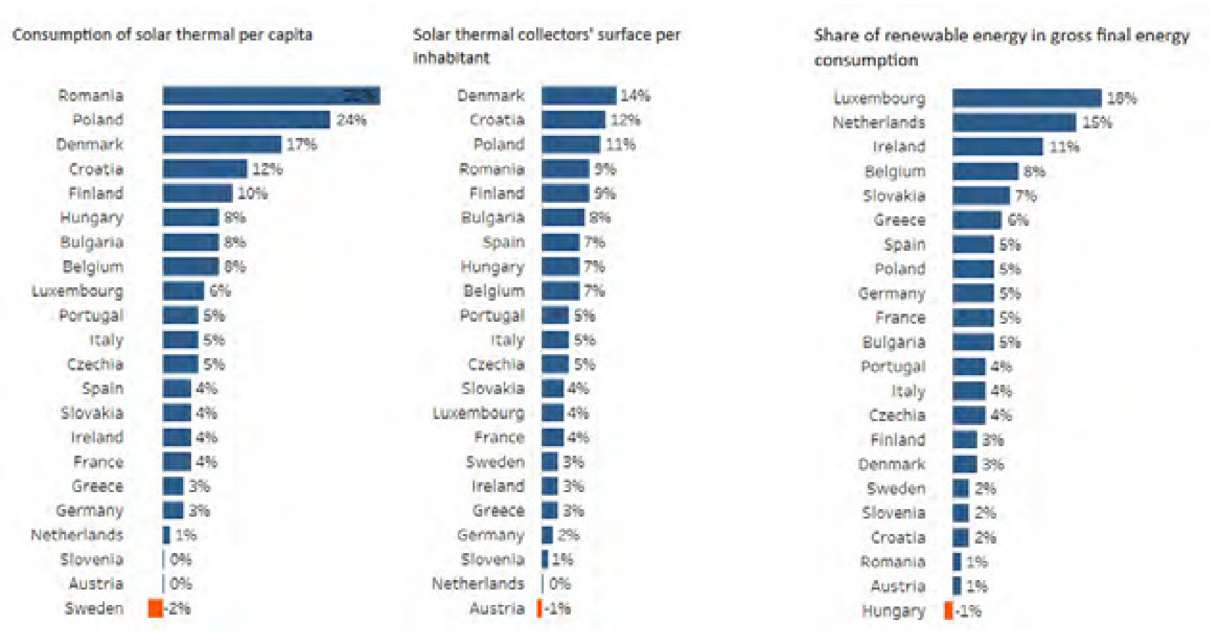

Figure 2. Average year-on-year growth of the study variables from 2012 to 2020, part 1. Source: own work.

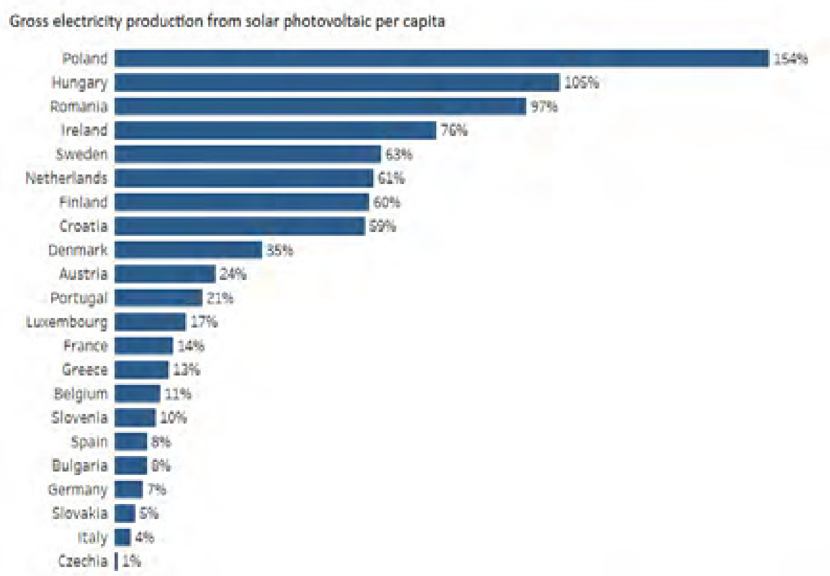

Figure 3. Average year-on-year growth of the study variables from 2012 to 2020, part 2. Source: own work.

In most of the countries analysed, different levels of an upward trend in the variables studied can be observed. Poland is a country where this development has been particularly evident during this period due to the only developing RES market. For variables describing the development of energy from solar collectors, Poland ranks second and third in terms of growth pace. The average year-on-year increase in solar collector area was 11% while moving up from 17th to 10th place compared to other countries (with the most significant increase for Denmark: 14%, which moved from 4th to 3rd place). The countries with the highest solar collector surface per capita were Austria, Greece, Germany (2012) and Denmark (2020). However, in the case of the variable describing the consumption of energy obtained from solar collectors, the increase amounted to 24% on average per year in Poland. It meant a change from 20th to 15th place (with the highest rise for Romania: 31%, which however remained in 22nd place).

In contrast, the countries with the highest energy consumption generated from solar panels were consistently: Spain, Greece and Austria. The rapid development of photovoltaics in recent years in Poland has probably contributed to its first place in terms of the pace of change in gross electricity generation from this source (on average, by as much as 154% per year). It means swapping place 22 for 19. The leading countries in this respect were Germany, Italy (2012), the Czech Republic (2012) and the Netherlands (2020) and Belgium (2020). Regarding changes in the share of renewable energy in gross final energy consumption, Poland ranks eighth, with an average year-on-year increase of 5%. However, this means swapping 17th place for 18th (with the most considerable increase for Luxembourg: 18%, which ranked 22nd in both periods). The countries with the highest share of renewable energy in gross energy consumption were Sweden, Finland and Austria. This points to other renewable energy sources used in the first two countries.

3.2. Development of solar energy systems in Poland compared to other European countries from the perspective of 2012 and 2020

To address research question 2, a cluster analysis of the countries studied was conducted in terms of the four variables analysed. Data from 2012 were explored first, followed by data from 2020.

Analysis for 2012

After performing the cluster analysis, the dendrogram shown in figure 4 was obtained. Its research established the division of the countries studied into four clusters. Poland is in cluster one along with Bulgaria, France, Hungary, Ireland, Luxembourg, the Netherlands and Slovakia. The individual mean values of the studied variables for each group are presented in table 3. This table is complemented by figure 5. It presents box plots for the study variables in isolated clusters, showing their differences.

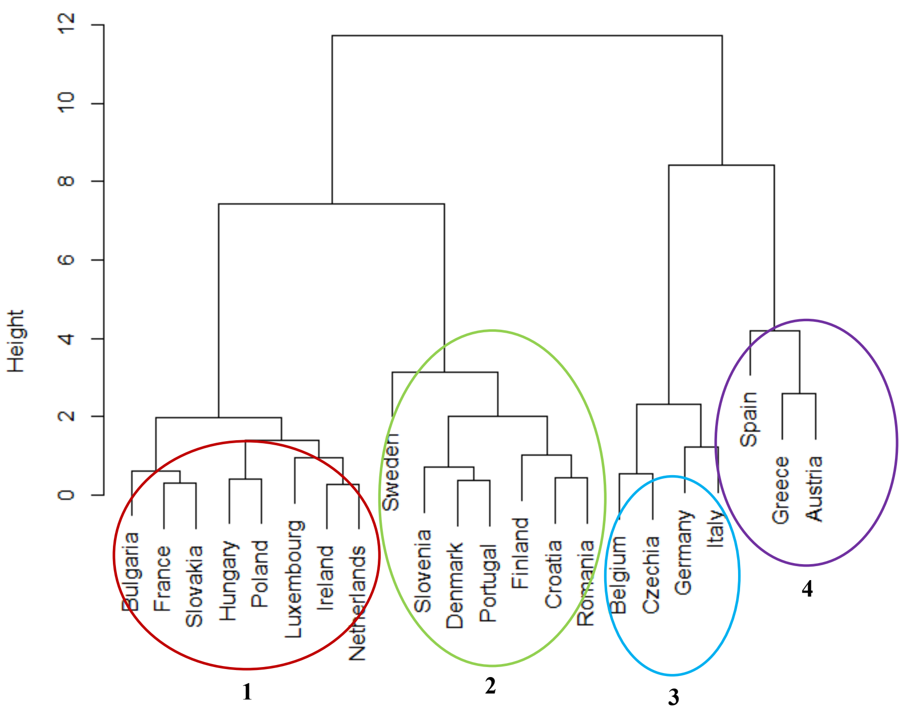

Figure 4. Dendrogram for 2012. Source: own work.

Table 3.
National average variables for countries in each cluster in 2012

Cluster	**Solar thermal energy consumption [GJ/capita].**	**Solar collector area [sqm/capita].**	**Gross electricity production from solar photovoltaics [MWh/capita]**	**Share of renewable energy in gross final energy consumption [%]**
1	0.0658	0.0415	0.0428	10.10
2	0.1075	0.0539	0.0199	**29.26**
3	0.1280	0.0825	**0.2611**	12.22
4	**1.1017**	**0.3378**	0.1226	20.24

Source: own work.

Countries that are in cluster one together with Poland are those whose average values rank fourth in three cases and third for the variable on energy production from photovoltaics. Countries in the second cluster have the highest shares of renewable energy in gross final energy consumption. Still, as other variables have lower values for them, this energy probably comes from sources other than solar. Countries belonging to cluster three are characterised by the highest electricity generation from photovoltaic panels. These include Germany, the Czech Republic, Belgium and Italy. Countries belonging to cluster four have the most developed solar collector infrastructure. These are Spain, Austria and Greece. The box plots illustrate the above analysis.

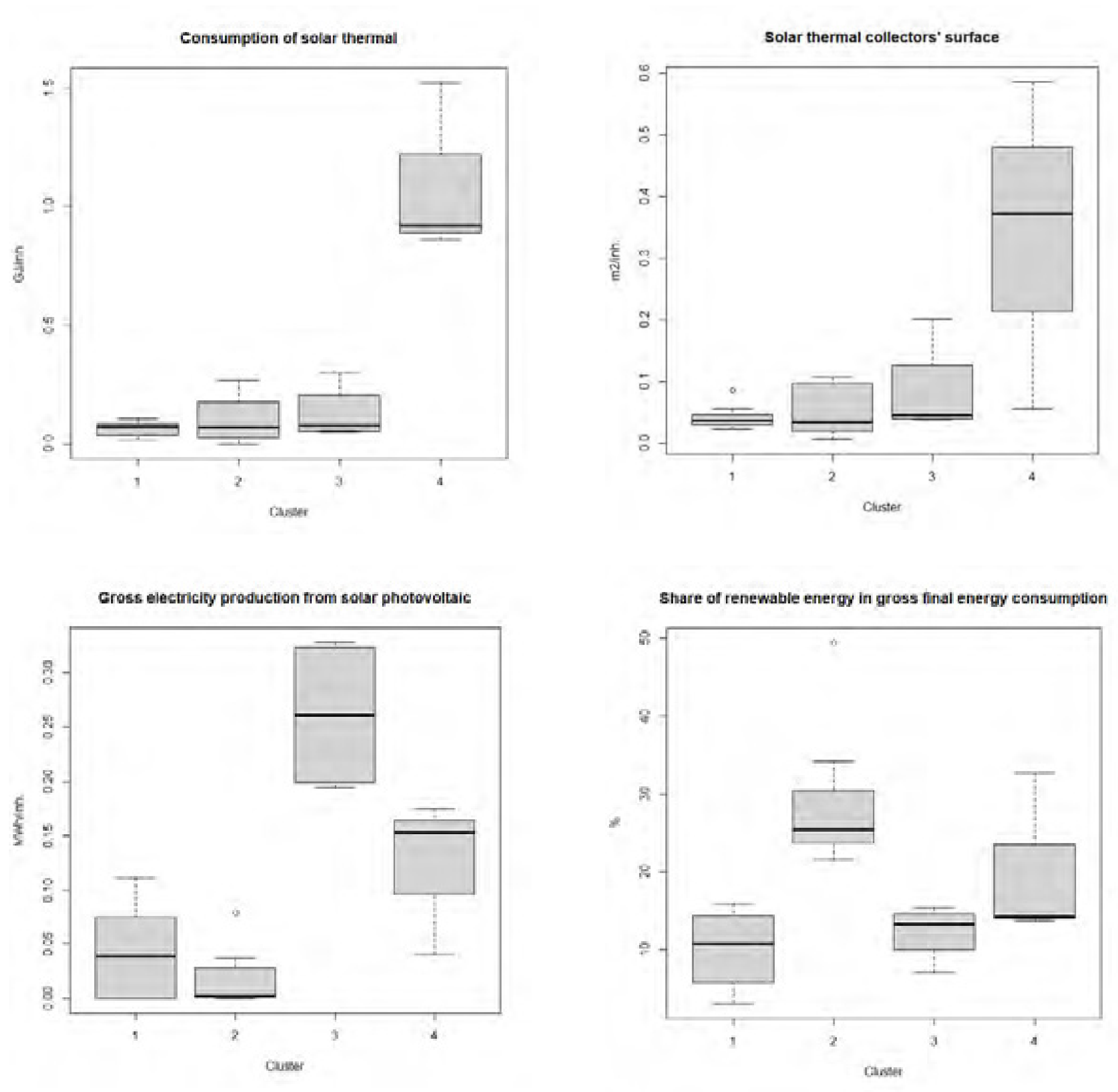

Figure 5. Study of differences in individual clusters in 2012. Source: own work.

Analysis for 2020

The analysis presented in this article includes changes over time, so similar calculations have been made for 2020. The results of the cluster analysis are shown in figure 6. As in 2012, 4 clusters can be distinguished. Poland is in the largest second cluster, together with Bulgaria, the Czech Republic, Ireland, France, Croatia, Luxembourg, Hungary, Portugal, Romania, Slovakia and Slovenia. In turn, the mean values of the variables for each cluster are shown in table 4. This table is complemented by figure 8. It presents box plots for the study variables in each group, showing the differences between clusters. To better visualise the clusters found in the context of the variables studied, a biplot (figure 7) was performed.

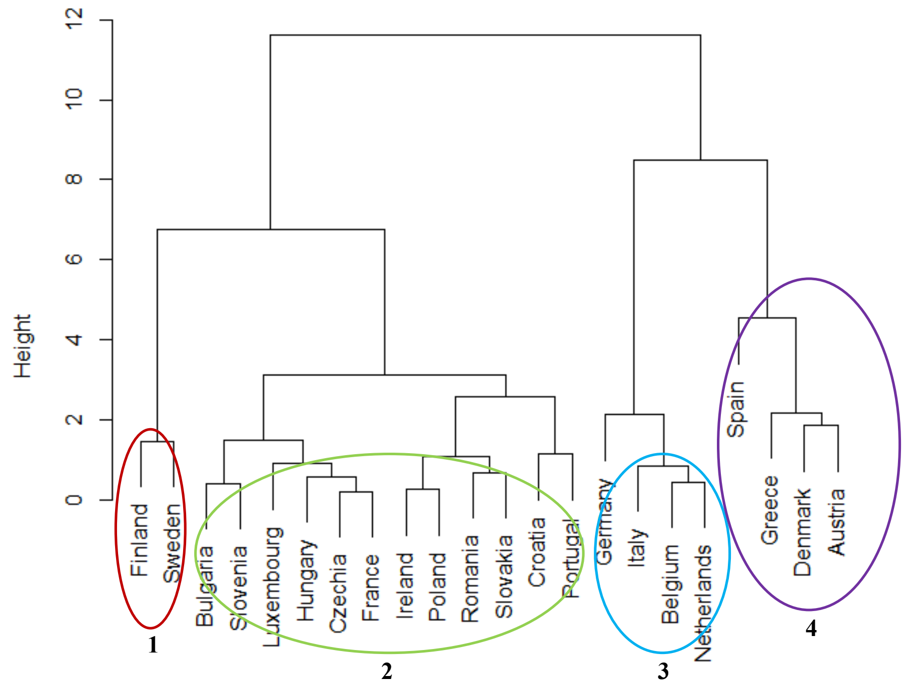

Figure 6. Dendrogram for 2020. Source: own work.

Table 4.
National average variables for countries in each cluster in 2020

Cluster	**Solar thermal energy consumption [GJ/capita]**	**Surface of solar collectors [sqm/capita]**	**Gross electricity production from solar photovoltaics [MWh/capita]**	**Share of renewable energy in gross final energy consumption [%]**
1	0.0302	0.0285	0.0740	**51.96**
2	0.1372	0.0696	0.1480	20.78
3	0.1771	0.1038	**0.4874**	16.67
4	**1.1469**	**0.3560**	0.2946	27.79

Source: own work.

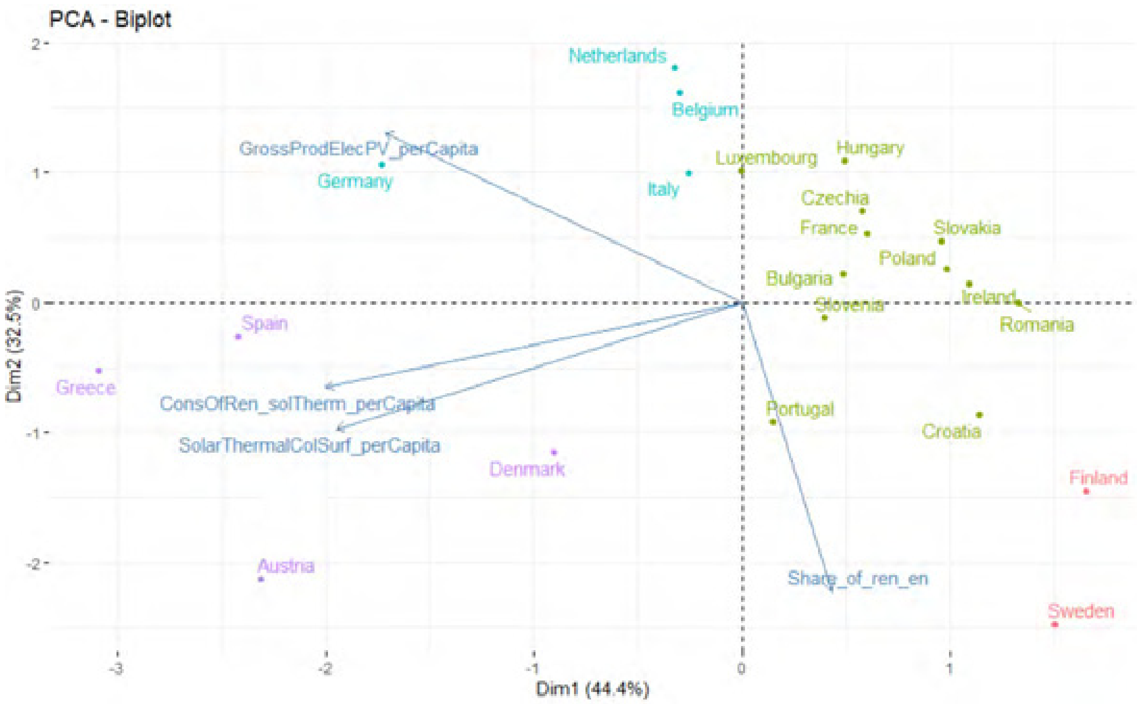

Figure 7. Biplot: country clusters in the context of the study variables in 2020. Source: own work.

The countries classified in the first cluster (Finland and Sweden) have the highest shares of renewable energy in gross final energy consumption. The biplot, therefore, shows the closest neighbourhood of these countries with the variable Share_of_ren_en. The other variables examined for cluster 1 take small values. This means that renewable energy in these countries comes from sources other than solar (typically hydroelectric, wind, biofuels). The low share of solar sources can be explained by the unfavourable insolation conditions due to the northern location of these countries.

Countries in cluster two together with Poland are the former Eastern Bloc countries and countries such as France, Portugal, Ireland, and Luxembourg. Their average values for the variables studied ranked third in each case. Therefore, this cluster is far from the vectors presenting the variables under study on the biplot. Exceptions are Portugal and Croatia, which are close to the variable Share_of_ren_en and Luxembourg, close to the variable GrossProdElecPV_perCapita. The analysis of Poland's situation showed an increase in the average values of the metrics (in relation to cluster one of 2012, in which Poland was located).

Countries belonging to cluster three are characterised by the highest electricity generation from photovoltaic panels. Therefore, on the biplot, they are located close to the variable GrossProdElecPV_perCapita, and on the box plots, cluster 3 reaches the highest mean value for this variable. These include countries such as Germany, Belgium, the Netherlands and Italy.

Countries in cluster four have the most developed solar collector infrastructure and consume the most solar thermal energy. On the biplot, these countries are located close to variables such as ConsOfRen_solTherm_perCapita and SolarThermal ColSurf perCapita. These are countries such as Greece, Spain and Austria and Denmark. Analysis of box plots for cluster 4, on the other hand, for variables representing solar thermal energy consumption and solar collector area shows a difference between the mean values of clusters 1, 2 and 3 and cluster 4 with significantly higher mean values.

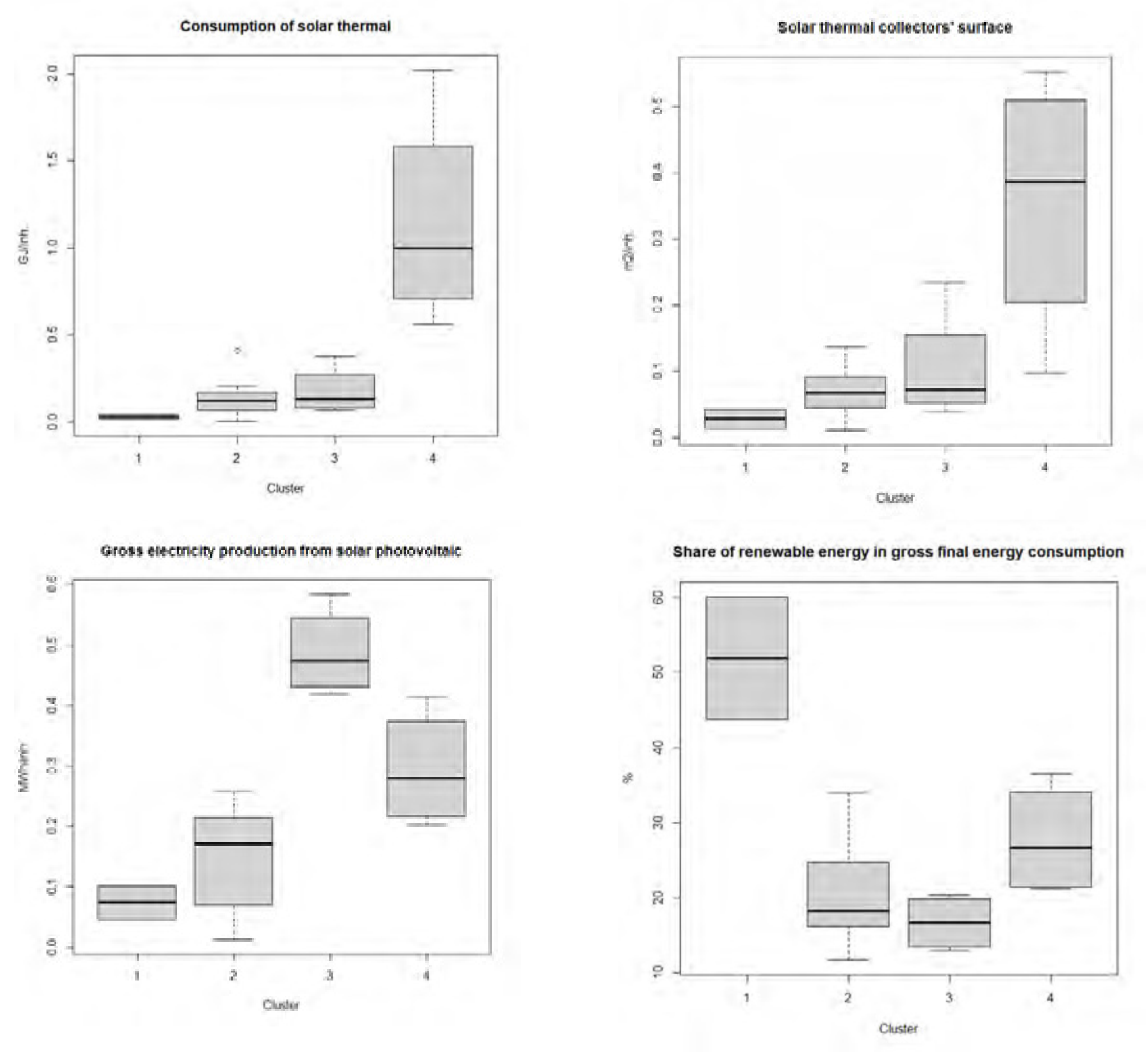

Figure 8. Study of differences in individual clusters in 2020. Source: own work.

4. Discussion and findings and conclusion

When analysing the development of solar systems, two aspects were taken into account: the change in the variables studied from 2012 to 2020 and the positioning of the values of these variables for each country in relation to each other. The first aspect was related to the first research question, related to the evolution of variables describing solar systems in individual European countries (including Poland) over the period 2012-2020. While the second aspect was related to the second research question concerning the search for a group of countries similar to Poland in terms of the development of solar systems in 2012 and 2020.

Summarising the first aspect, therefore, it is essential to recognise that, in total, the years under study have seen the most significant growth in photovoltaics. It was more than doubled by as much as 105%, giving an average annual increase of 9%. A considerable increase was also observed for collectors – by one-third and by an average of 4% per year. These results support the conclusions presented in the paper (Fordrowska, 2021). The share of renewable energy in final gross consumption increased by 34%, with an average annual increase of 4%. Among the 22 countries studied, Poland emerged as the country with the highest growth in gross electricity generation from solar PV (which averaged 154% per year) between 2012 and 2020. This is due to the subsidy system to support the development of prosumer photovoltaics proposed in Poland. It can therefore be concluded that the conclusions of the studies have been confirmed (Parzonko et al., 2021; Ge et al., 2018; Briguglio and Formosa, 2017; Müller and Trutnevyte, 2020). As far as energy from solar collectors is concerned, Poland ranked in the top three (solar thermal energy consumption and the area of solar collectors – per capita – increased on average year by year by 24% and 11% respectively, which gave Poland 2nd and 3rd place). In turn, the eighth place in terms of growth of the share of renewable energy in energy consumption (annual average increase of 5%; also in the top ten) testifies to the dominant share of solar energy in our country's renewable energy sources. All of these increases are higher than the average increases calculated for all countries surveyed combined. They, therefore, indicate a great deal of dynamism and change in attitudes towards renewable energy sources.

However, it is worth noting that the large values of the relative increases are mainly due to the small initial sizes of this variable (in 2012 - which is especially true for photovoltaics). It should be borne in mind during the analysis that countries with high initial values of the analysed variables, such as Germany, do not show such great dynamics due to probable market saturation (this development had already taken place there, which can be explained by the correlation with GDP presented in (Wolniak and Skotnicka-Zasadzień, 2022). This is supported by the fact that in 2020, Poland ranked in the second cluster, achieving results in the third place, in terms of the size of the examined variables. In contrast, in 2012, its cluster (No. 1) was in last place in terms of most variables. In the context of the intensive development that accompanied the years 2012 - 2020, this confirms the growing trend of solar energy use in Poland. With reference to the study (Zdonek et al. 2022), this can be explained by the influence of economic factors, particularly the subsidy system promoting solar technologies in Poland.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

HUMAN CAPITAL AND ITS EFFICIENCY ON THE EXAMPLE OF INDUSTRIAL AND NEW TECHNOLOGIES COMPANIES

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Purpose: Comparative analysis of human capital and its efficiency in enterprises with various business profiles, especially the so-called old and new economy.
Design/methodology/approach: The analysis was carried out on the example of companies listed on the Warsaw Stock Exchange operating in the industrial and high-technology sectors. For its purposes, indicators based on financial data and used, among others in the method of assessing the efficiency of intellectual capital – VAIC.
Findings: The obtained results allow to conclude that the situation in terms of human capital level and its efficiency, including labour efficiency, in the analysed enterprises is highly diversified. These differences not only exist between companies from different sectors, but also within individual sectors, industrial as well as high-tech. Companies from high-tech sectors are generally characterized by a higher human capital level, as well as its efficiency, which is particularly distinguished by the sector Video Games Developers.
Research limitations/implications: Due to the limited quantitative research sample, compared to the total number of companies listed on the Warsaw Stock Exchange and the industries and sectors they represent, the results obtained and the conclusions drawn on their basis can be treated as preliminary and contributing to further broader research.
Practical implications: As the results of the analysis show how individual industrial and high technology companies compare to the competition in terms of the level and efficiency of human capital, it may be an indication for their management boards of the need for actions aimed at improving the efficiency of human capital.
Social implications: As the subject of the analysis is human capital in an enterprise, its results may contribute to changes in the field of corporate social responsibility in the analysed enterprises in the area of employees.
Originality/value: The topic of the article is not new, but in the literature there are hardly any studies on the assessment of the efficiency of human capital in the intersectoral approach.

Keywords: human capital, efficiency, comparative analysis, listed companies.

Category of the paper: Research paper.

http://dx.doi.org/10.29119/1641-3466.2022.161.13 http://managementpapers.polsl.pl/

1. Introduction

The increasingly frequent and dynamic global transformations we have been witnessing in recent decades, have posed particular tasks for managers of enterprises and force them to change the perception of factors influencing success in the long-term strategy of their development. Thus, intangible resources increasingly often constitute a competitive advantage of contemporary enterprises, pushing traditional tangible resources, associated mainly with fixed assets, into the background (Barney, 1991, DeNisi et al., 2003, Szwajca, 2012). At this point, attention should be paid to the important role of a human being (employee), which is one of the possible intangible resources, which started to be perceived as a component of various aggregate values concerning the company – intellectual capital, innovation, competitiveness or finally value (Schultz, 1961; Becker, 1962; Dobija, 2005; Nawrocki, 2012). Only a few decades ago, the common opinion was that remuneration is only a payment for work done by employees and the value of the company is increased only by investments in fixed assets. Nowadays, which has been greatly influenced by the development of the resources-based view (RBV), whose precursor is considered to be E. Penrose (1959), it is obvious that the employee is not only a labour force, but one of the most valuable resources that the company has. It is necessary for its proper functioning, and having a certain value, verified on the market, it constitutes the economic potential of a given entity and allows building its competitive advantage (Szopik-Depczyńska, Korzeniewicz, 2011) and improving the efficiency of its operations (Berk et al., 2010; Wang et al., 2014; Asare et al., 2017; Nawaz, 2019). The significant importance of human resources stems directly from their characteristics – they are developmental, creative assets that have the capacity for continuous improvement (Gorczynska, 2009). Therefore, more than other resources, they contribute to the creation of additional value for the company (Wyrzykowska, 2008). To reflect these characteristics of human resources, it has become accepted in the literature to refer to them as human capital (Haq, 2016).

With the growing scientific interest in the importance of employees for the development of enterprises and the improvement of their performance, the term "human capital" has lived to see many interpretations and measurement concepts. As a result, currently we can meet with numerous approaches to this issue, which are very diverse in terms of detail and recommended assessment criteria. At the same time, a question arises here about the applicability of particular criteria of human capital measurement and the universality of their interpretation from the point of view of sector specificity and corporate information policy. Therefore, as the main objective of this article it was assumed to carry out a comparative analysis of human capital and its efficiency in enterprises of different business profiles, especially the so-called old and new economy.

2. The concept of human capital and how it can be assessed

Although the very idea of human capital dates back to the seventeenth century and is associated with economic and financial researchers (e.g. William Petty, Adam Smith, William Farr), the origins of human capital theory as an organised discipline of knowledge date back to the late 1950s and early 1960s (Kiker, 1996). It was then that some scholars concluded that a person's knowledge, education, skills and health status have productive potential (Mincer, 1958; Schultz, 1961; Becker, 1962).

Human capital can be classified as a concept that is difficult to define. There are many definitions of it in literature, depending on the perspective of consideration (Jabłoński, 2021). For the purpose of this article, it has been assumed that human capital is a resource of knowledge, skills, abilities, qualifications, attitudes, motivation and health of employees, which has significant meaning in economic activity and, therefore, is a source of future earnings (OECD, 1998, Fischer et al., 2006, Łukasiewicz, 2009).

The concept of human capital can be considered from a macroeconomic and microeconomic perspective. In the macroeconomic perspective, human capital is characterised as one of the basic resources remaining in the economy, which determines economic growth. In microeconomic terms, on the other hand, the concept of human capital refers to an individual employee (worker) and is treated as an element of intangible resources of an enterprise (Kucharcikova, 2011).

A company can seek competitive advantage based on properly prepared, highly motivated and loyal personnel (Noe et al., 2006; Bloisi, 2007; Gabcanova, 2011). Activities aimed at increasing the value of human capital consist of (Nellis and Parker, 2006; Ackroyd et al., 2005; Zieliński, 2006):

- acquiring human capital (by employing suitably prepared staff, replacing staff),
- retention of human capital remaining in the company (by means of an appropriate motivational system and creating development opportunities),
- development of human capital within the company (training).

Some authors divide human capital into general capital and specific capital. General (universal) capital, can be used in all types of economic activity, while specific capital (qualifications gained in practice), determines productivity in a given enterprise (McConnell, Brue, 1986).

From a corporate perspective, human capital is a component of intangible resources. According to Edvinsson and Malone (2001), it is a component of intellectual capital. Intellectual capital includes: knowledge, experience, technology, customer relationships and professional skills that are a source of competitive advantage for the organisation. Intellectual capital, apart from human capital, also includes structural capital, which is defined as everything that supports employee productivity, in particular organizational infrastructure, including organizational systems, management tools and philosophy as well as innovative capital.

Human capital, apart from the features an employee brings to the organisation (skills, knowledge, experience, health, attitudes, professed values, etc.), also includes the employees' ability to learn, motivation (e.g. to share information and knowledge), striving to achieve goals, or ability to work in a team. It should also be noted that apart from the individual human capital of each employee, the human capital of an enterprise also includes the creativity and innovativeness of employee teams (Czechowska-Świtaj, 2005; Król, 2006; Sokołowska, 2005). What is important, all the issues mentioned above are particularly important from the point of view of the Industry 4.0 concept popularised in the recent years, where one of the key conditions for its implementation is the acquisition of appropriate education and skills by employees (Flores et al., 2020; Singh et al., 2021).

Attempts to measure human capital are generally based on treating employees as assets of the firm and measuring changes in their value. Many authors raise doubts about the possibility of measuring human capital, which revolve around the questions: can human capital be treated as a business asset at all?, what human capital costs should be capitalised? how reliable are the methods of determining the value of human capital and their links to costs? At the same time, the most frequently used methods of human resources valuation are those based on costs related to personnel policy or income achieved, or earned, by the employee (Phillips et al., 2003).

In the case of estimating the value of human capital according to the "cost" approach, the concepts most frequently recommended in the literature are: the historical cost method and the replacement cost method. In the first one the value of human capital is illustrated by the expenditures incurred for the acquisition and further training of an employee. The latter assumes that human capital is worth as much as the company would have to spend to replace the currently employed worker. The main measures to estimate the value of human capital in the case of the historical cost method are: recruitment and selection costs and training costs. For the replacement cost method, the main measures are: the cost of recruiting, selecting and training a new employee and the cost of leaving an existing employee (Samul, 2011). The disadvantages of cost-based methods for determining the value of human capital include: the lack of an unambiguous link between the cost of producing a good and its economic value, the difficulty in distinguishing between investment and consumption expenditure, the lack of taking into account the biological and moral degradation of human capital over time (e.g. the obsolescence of knowledge), and the difficulty in isolating costs in relation to individual units. On the other hand, the advantages of cost methods include the possibility to use real data published in statistical yearbooks, published compilations and analyses (Łukasiewicz, 2009; Czajkowski, 2012). In general, however, given the differences in the openness of the information policy of companies (Nawrocki and Zieliński, 2013), the practical application of the mentioned cost concepts of estimating the value of human capital is quite difficult, mainly due to the problematic access to the required data. Therefore, often for the purposes of research a simplified approach is used, in which the value of human capital is taken as the data disclosed in the financial statements of companies about the amount of wages and benefits for employees – such an approach was used, for example, in the framework of the value-added coefficient of intellectual capital VAIC (Pulic, 2004).

Estimating the value of human capital using the income approach assumes that it is equal to the present value of future receipts per employee. Estimates using the income method are hampered by changing tangible (raw materials, technology) and intangible (organisation and management) assets, as these changes cannot be predicted over several decades (when attempting to estimate the expected income earned over an employee's entire working life), and they significantly affect employee productivity (King, 2006). Besides, calculations based on the income approach are based on assumptions or probabilities of changes in wages over the entire working life, the degree of work activity and the health of the employee. On the other hand, the advantage of income-based estimations is their market nature, i.e. taking into account employers' preferences regarding the level of education, professional experience, taking into account employers' reactions to changes in the economic situation and changes in the labour market situation, which translate into establishing the level of wages, constituting a valuation of human capital of individual employees (Łukasiewicz, 2009).

Difficulties in the valuation of human capital are also related to changes in the employment structure and staff rotation. A departing employee may take with him/her experience related to the mechanisms of operation, informal ties with customers, suppliers, other employees (Sokołowska, 2005), which entails disruptions in the functioning of the organisation (Probst et al., 2004). The higher the position of the departing employee in the organisation's hierarchy, the more knowledge he/she possesses and the more difficult it will be to replace him/her. Therefore, it is necessary to monitor the structure of redundancies in terms of the share of those leaving at their own request, the structure of those leaving by seniority, the share of the most productive employees among those leaving (King, 2006). It should be emphasised that human capital is in practice the property of employees, therefore staff fluctuations may in a short period of time very seriously change its valuation (Zieliński, 2008).

In order to gain an insight into the area of human capital in the company, and especially into the changes occurring in it, a number of measures can also be used. The number of employees participating in projects, the number of employees with a planned career path, work efficiency, expenditure on health care, the number of sick days, accidents at work, etc. (Łukasiewicz, 2009).

Although it is difficult to determine the objective value of human capital on the basis of the above-mentioned measures, they illustrate changes in the personnel policy of an enterprise and may be used to assess its development prospects.

3. Basic assumptions and research methodology

Due to the ease of access to data resulting from the disclosure obligations of securities issuers, a comparative analysis of human capital and its efficiency was carried out for selected companies listed on the Warsaw Stock Exchange. The selection of individual entities for the study was deliberate. First, the affiliation of the analysed companies to industrial (so-called traditional) and high-tech sectors of the economy was taken into account, and second, the availability of their annual reports for 2016-2020 as well as their size and market value. The research sample obtained in this way is presented in Table 1.

Table 1.
Research sample

Industry (Old Economy)		**High-tech (New Economy)**	
Fuel and Energy: ▪ PKN Orlen ▪ PGNiG ▪ Lotos ▪ PGE ▪ Tauron PE	Construction: ▪ Budimex ▪ Mirbud ▪ Unibep ▪ Polimex MS ▪ Erbud	Video Games Developers: ▪ CD Projekt ▪ Boombit ▪ Ten Square Games ▪ CI Games ▪ 11 bit	Information Technology: ▪ Wasko ▪ Asseco Poland ▪ Comarch ▪ Sygnity ▪ Atende
Chemical: ▪ Grupa Azoty ▪ Ciech ▪ PCC Rokita ▪ PCC Exol	Electromechanical: ▪ Apator ▪ ZPUE ▪ Aplisens ▪ Sonel ▪ Lena Lightning	Production of Drugs, Materials and Medical Equipment: ▪ Celon Pharma ▪ PZ Cormay ▪ Bioton ▪ Mercator Medical ▪ Voxel	Media: ▪ ATM Grupa ▪ Kino Polska ▪ Agora ▪ Wirtualna Polska ▪ Comperia
Polwax Mining and Steel Industry: ▪ JSW ▪ Bogdanka ▪ KGHM ▪ Stalprodukt ▪ Kęty		Biotechnology: ▪ Selvita ▪ Synektik ▪ PBKM ▪ Pure ▪ Onco Arendi Therapeutics	

Source: Own work based on www.gpw.pl, 29.03.2022.

Taking into consideration the possibility of access to the required data for the needs of human capital estimation and its efficiency in the companies accepted for the research, in reference to the first of the mentioned categories it was decided to apply a simplified cost criterion in the form of the value of remuneration and employee benefits. In order to neutralise a possible distortion connected with the size of the analysed entities, the value of salaries and employee benefits was related to the average size of employment in the financial year, which can be expressed by the formula:

$$HC_P = \frac{S\&B}{\bar{L}} \tag{1}$$

where:
HC_P – valuation of human capital per employee,
$S\&B$ – value of salaries and benefits for employees in the financial year,
$\bar{L}$ – average employment during the financial year.

It should be noted that the above approach to human capital valuation may be in a way distorted by the employment structure (e.g. if a small number of employees received significantly higher salaries and benefits than the rest). At the same time it is difficult to neutralise this shortcoming as only nearly 30% of companies listed on the Warsaw Stock Exchange provide more detailed information on the employment structure, and in most cases it concerns a division into white-collar and blue-collar workers (Nawrocki, Zieliński, 2013).

On the other hand, for the purposes of comparison, within the second of the distinguished categories, the human capital efficiency coefficient from the VAIC – intellectual capital value added model (Pulic, 2004) and a simplified labour productivity coefficient, based not on production, but on sales revenues, were adopted, which was expressed by the formulas:

$$HCE = \frac{VA}{S\&B} \tag{2}$$

where:
HCE – human capital efficiency,
VA – value added (difference between sales revenues and operating costs excluding salaries and benefits of employees),
$S\&B$ – value of salaries and benefits for employees in the financial year.

$$WE = \frac{S}{\bar{L}} \tag{3}$$

where:
WE – work efficiency,
S – sales revenue for the financial year,
$\bar{L}$ – average employment during the financial year.

A comparative analysis using the criteria highlighted above was carried out using data from the annual financial statements of the companies under study for the period from 2016 to 2020 year.

In addition, in order to determine the range of variation in the level and efficiency of human capital in the analysed entities, representing at the same time specific sectors of the economy, with reference to the assessment criteria distinguished above, an analysis was conducted based on basic statistical characteristics, i.e. the expected value and standard deviation, given by the formulas:

$$R = \frac{1}{n}\sum_{t=1}^{n} r_t \tag{4}$$

$$s = \sqrt{\frac{\sum_{t=1}^{n}(r_t - R)^2}{n-1}} \tag{5}$$

$$TIV \in (R - s, R + s) \tag{6}$$

where:
R – expected value of a variable on an arithmetic mean basis,
n – the number of periods (cases) from which the data originate,
r_t – value of the variable at t-th period (case),
s – standard deviation of the variable,
TIV – typical interval of variation.

The main goal of the research is a comparative analysis of human capital and its efficiency, as well as work efficiency, in traditional and high-tech industries exemplified by the Polish economy. Additionally, in the course of the conducted analyses, answers to the following research problems are sought:

R1: Are enterprises operating in high-tech industries associated with a higher human capital level?

R2: Are enterprises operating in high-tech industries associated with a higher human capital efficiency, including work efficiency?

4. Research results

The results of the conducted analysis were presented in two approaches. In the first one, based on the average values of the criteria for assessing human capital and its efficiency from 2016-2020, the analysed companies were compared within two sectoral groups of the economy and their selected subsectors (Table 2). In turn, the second focuses on the overall comparison of human capital and its efficiency in the main sectors and their selected subsectors, based on the average values of the assessment criteria of their representatives and taking into account the range of variability of these values (Figures 1-4).

Table 2.

Human Capital (HCp), Human Capital Efficiency (HCE) and Work Efficiency (WE) in analysed companies from Old and New Economy sectors (Average values from 2006-2020)

Old Economy Industrial sectors & companies		***HCp***	***HCE***	***WE***	**New Economy High-tech sectors & companies**		***HCp***	***HCE***	***WE***
Fuel and Energy	PKN ORLEN	128	4,08	4,45	Video Games Developers	CD PROJEKT	397	4,57	2,84
	PGNIG	118	3,40	1,54		BOOMBIT	213	3,05	1,21
	LOTOS	159	4,40	4,96		TEN SQUARE GAMES	200	5,52	2,71
	PGE	121	2,35	0,79		CI GAMES	38	8,10	0,59
	TAURON PE	107	1,73	0,72		11 BIT	61	6,57	0,49
Chemical	GRUPA AZOTY	104	1,77	0,68	Production of Drugs, Materials and Medical Equipment	CELON PHARMA	67	2,86	0,43
	CIECH	91	3,02	0,89		PZ CORMAY	86	1,00	0,31
	PCC ROKITA	98	2,64	0,80		BIOTON	105	1,56	0,39
	PCC EXOL	157	2,12	2,25		MERCATOR	45	4,23	0,60
	POLWAX	69	2,04	0,94		VOXEL	109	2,35	0,60
Mining and Steel Industry	JSW	134	1,49	0,29	Biotechnology	SELVITA	109	1,22	0,21
	BOGDANKA	120	2,09	0,35		SYNEKTIK	98	2,12	0,84
	KGHM	155	1,90	0,63		PBKM	118	1,73	0,40
	STALPROD	90	1,82	0,57		PURE	95	1,07	0,10
	KĘTY	84	2,23	0,59		ONCO ARENDI THERAPEUTICS	39	0,94	0,30
Construction	BUDIMEX	147	1,57	1,06	Information Technology	WASKO	97	1,23	0,28
	MIRBUD	96	1,85	1,40		ASSECO POLAND	190	1,29	0,39
	UNIBEP	108	1,43	1,13		COMARCH	129	1,26	0,23
	POLIMEX MS	86	1,15	0,44		SYGNITY	121	1,06	0,29
	ERBUD	125	1,20	0,93		ATENDE	130	1,56	0,72
Electro-mechanical	APATOR	80	1,60	0,34	Media	ATM GRUPA	721	2,34	4,60
	ZPUE	65	1,34	0,27		KINO POLSKA	149	4,25	1,22
	APLISENS	66	1,80	0,23		AGORA	116	1,35	0,40
	SONEL	90	1,59	0,32		WIRTUALNA POLSKA	158	2,08	0,54
	LENA LIGHTNING	95	1,99	0,84		COMPERIA	84	0,70	0,37

Source: Own work based on data from Notoria Serwis.

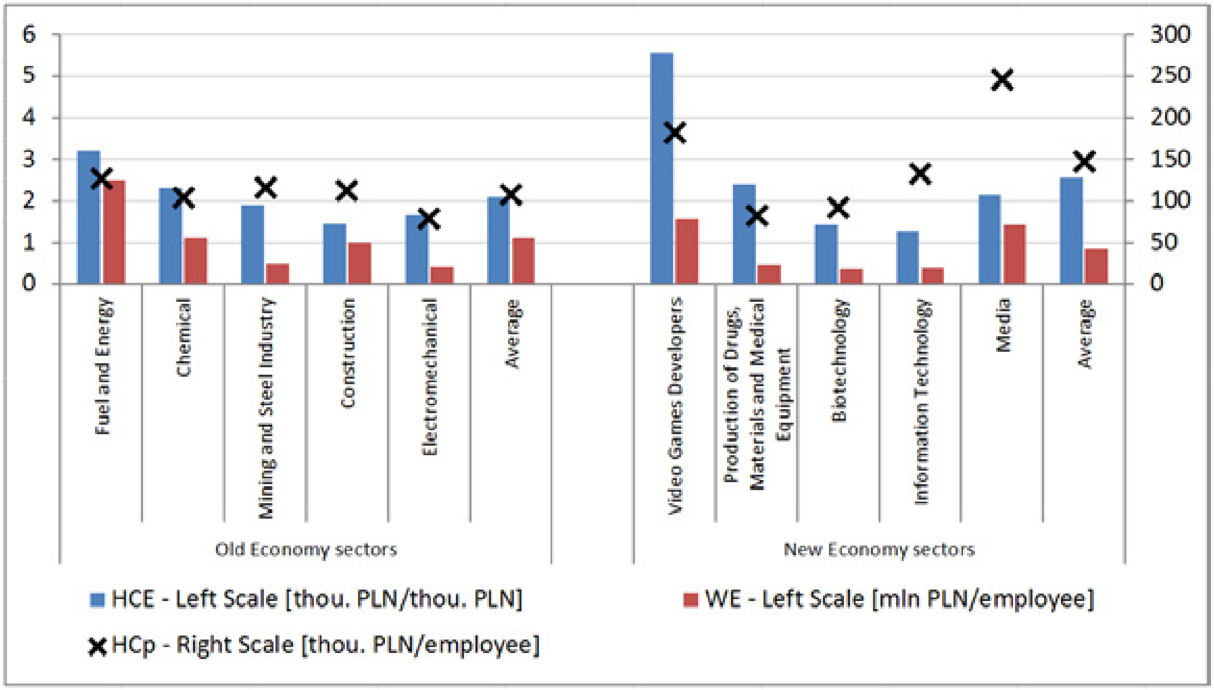

Figure 1. Human Capital (*HCp*), Human Capital Efficiency (*HCE*) and Work Efficiency (*WE*) in Old and New Economy sectors. Source: Own work based on data from Notoria Serwis.

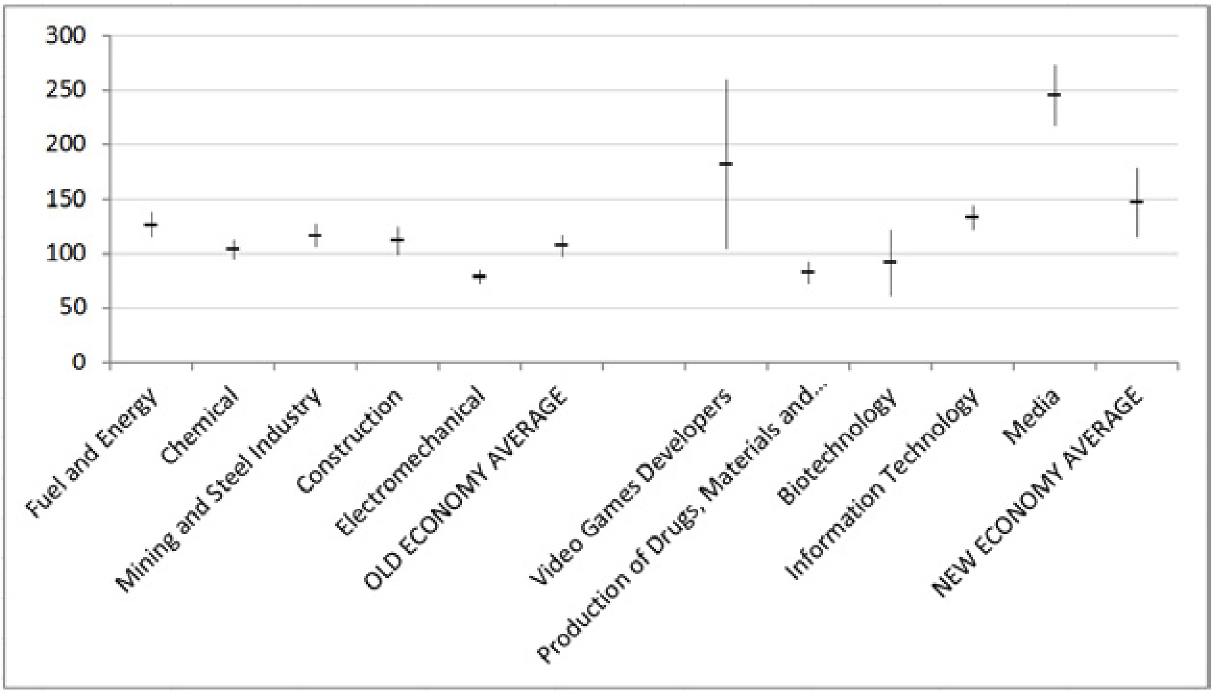

Figure 2. Typical Interval of Variation (*TIV*) and Expected Value (*R*) of Human Capital (*HCp*) in Old and New Economy sectors [thou. PLN/employee]. Source: Own work based on data from Notoria Serwis.

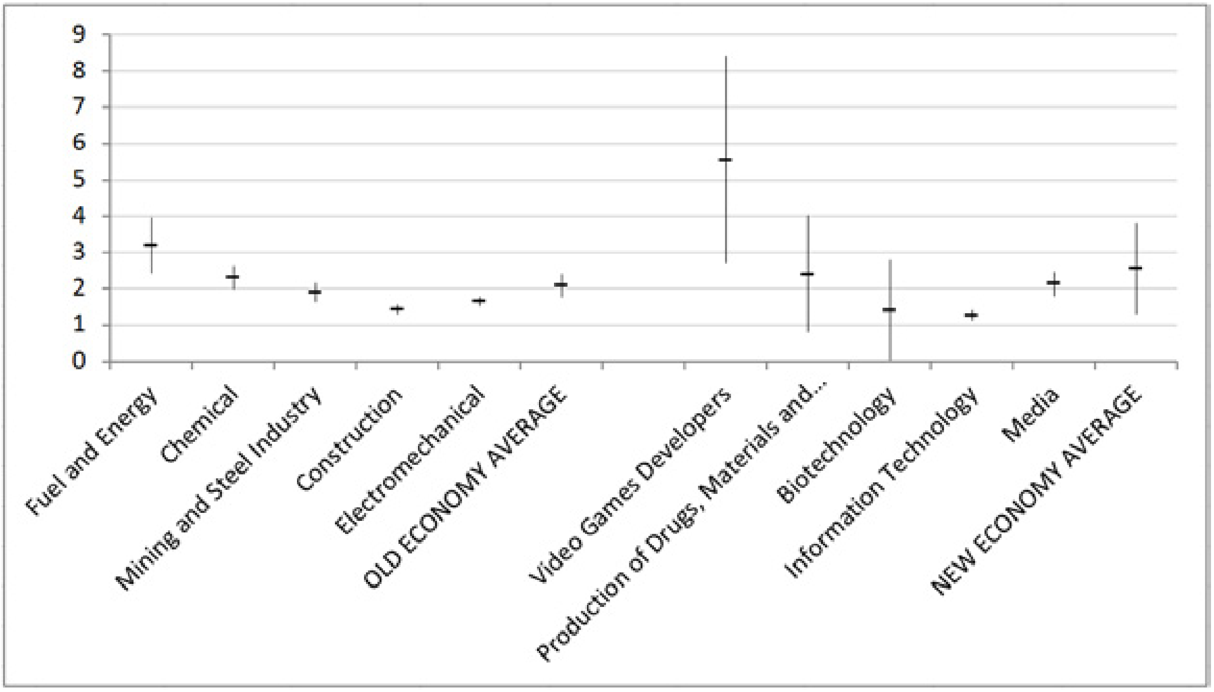

Figure 3. Typical Interval of Variation (*TIV*) and Expected Value (*R*) of Human Capital Efficiency (*HCE*) in Old and New Economy sectors [thou. PLN/thou. PLN]. Source: Own work based on data from Notoria Serwis.

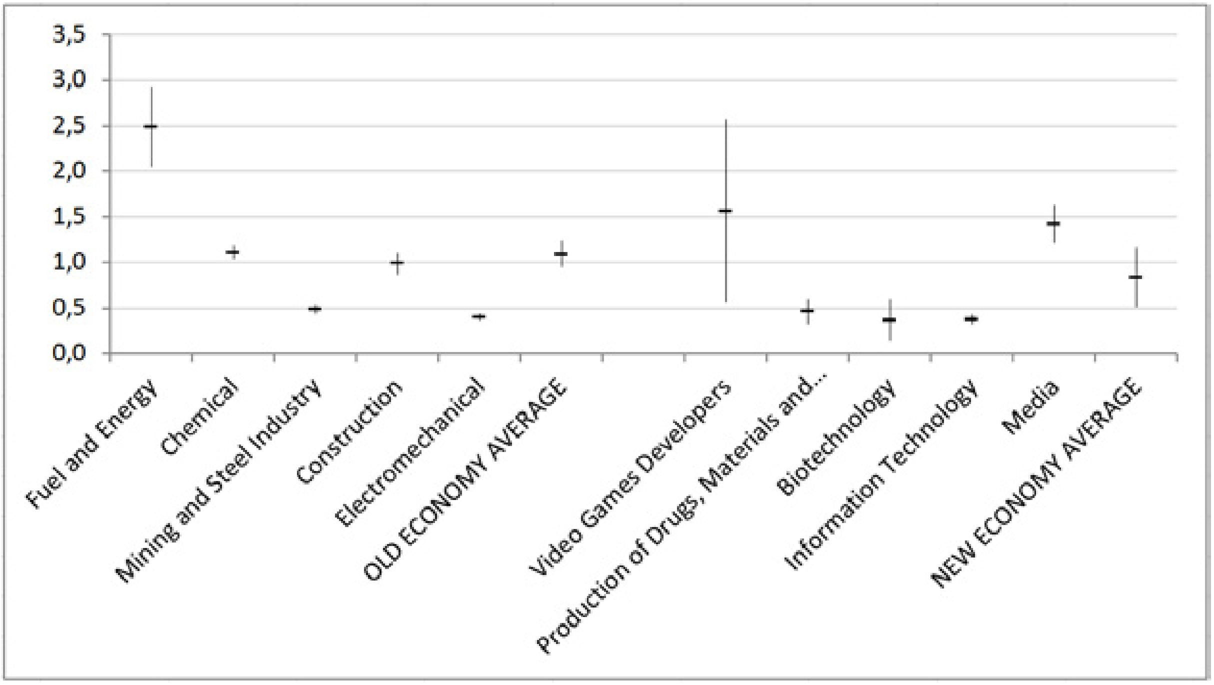

Figure 4. Typical Interval of Variation (*TIV*) and Expected Value (*R*) of Work Efficiency (*WE*) in Old and New Economy sectors [mln PLN/employee]. Source: Own work based on data from Notoria Serwis.

Taking into account the results of the analysis presented in Table 2 and Figures 1-4, the following conclusions can be drawn:

- For both high-tech and industrial companies, significant variation can be noted in the level of human capital (HCp), as well as in its efficiency (HCE) and work efficiency (WE), with generally greater variation for high-tech companies. The Video Games Developers sector in particular stands out in this regard.
- Companies from high-tech sectors are generally characterised by a higher level of human capital (HCp) as well as its efficiency (HCE); the Video Games Developers and Media sectors in particular stand out in this respect. On the other hand, industrial companies, as a group, look better in terms of work efficiency (WE), which is mainly due to fuel entities from the Fuel and Energy sector, i.e. PKN Orlen and Lotos. The above conclusions also answer research questions R1 and R2 formulated in the methodological part.
- In terms of the analysed variables, some of the high-tech sectors are at the level or even below the values characteristic for the industrial sectors; this applies in particular to the Production of Drugs, Materials and Medical Equipment as well as Biotechnology. Some explanation for this situation is the specific nature of the activities of entities in these sectors, which are often at the initial stage of development, characterised by low sales revenues and income as well as limited financial capabilities.

Irrespective of the conclusions formulated above, attention should also be drawn to certain issues related to the specificity of certain sectors, which may have slightly affected the analysis results. This concerns mainly entities from the Fuel and Energy sector (all) and Mining and Steel Industry (JSW, Bogdanka, KGHM), which, having a dominant shareholding of the State Treasury, are at the same time characterised by high labour union power. It translates into often non-market levels of salaries and employee benefits in these entities, which are the basic variables in the Human Capital Index (HCp) and somehow artificially increase its value.

Moreover, with respect to the fuel companies (PKN Orlen and Lotos), which recorded generally higher work efficiency levels for the Fuel and Energy sector and the average for the industrial sectors than the high-tech sectors, attention should be paid to the impact of the specific nature of fuel trading activities, which are mainly based on the volume of trading and to a lesser extent on its margins. For this reason, the work efficiency indicator, which is based on sales revenues, is relatively higher than in other industrial and high-tech entities, while the human capital efficiency indicator, which is based on added value (where material costs are deducted from revenue), is not, or at least not to the same extent.

5. Summary

The obtained results of the comparative analysis allow to state that the situation in terms of the level of human capital and its efficiency, including work efficiency, in the companies under study is strongly diversified. What is important, these differences occur not only between entities from different sectors, but also within individual sectors, industrial or high technology. This type of situation is a significant difficulty for more complex analyses, where human capital is only one of many assessment criteria, as it is difficult to adopt here some normative limits of the value range for individual criteria of its assessment – everything depends on the specificity of the entities included in the research sample. Nevertheless, the analysis shows that as a group the entities of the high technology sectors are more favourable in terms of the level and efficiency of human capital.

As the results of the analysis show how individual industrial and high-tech companies compare to their competitors in terms of the level and efficiency of their human capital, it may be an indication for their managements of the need for actions aimed at improving the efficiency of human capital, as well as a contribution to changes in corporate social responsibility in the analysed companies in the area of employees.

Admittedly, due to the limited quantitative research sample, compared to the total number of companies listed on the Warsaw Stock Exchange and the industries and sectors they represent, the results obtained and the conclusions drawn on their basis can be treated as preliminary and constituting the basis for further, wider research, including the relationship between the efficiency of human capital and work efficiency and the amount of salaries and employee benefits per 1 employee. On the other hand, however, it should be noted that the information policy of companies listed on the Warsaw Stock Exchange in the field of human capital is highly diversified, which will not necessarily cover all entities with extended research – e.g. about 10% of companies do not provide information about the amount of employment at all, and nearly 70% of them provide information on the employment structure in a very general or not at all (Nawrocki, Zieliński, 2013). So, in the end, a compromise is needed between the quantity of the research sample and the research methodology adopted, which determines the quality of the final results.

Acknowledgements

This research was funded by Silesian University of Technology, Poland, grant number 13/010/BK_22/0065.

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

THE STUDY OF THE INTERDEPENDENCIES OF AREAS AND ASPECTS OF SMART CITY IN POLISH CITIES

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Purpose: To determine the interdependencies between Smart City areas as well as the aspects and areas between resident-oriented IT areas of the city.
Design / methodology / approach: The data for the study was collected during a survey of 287 cities for Smart City. The study of interdependence was based on a correlation analysis using: Pearson's correlation coefficient, Cramér's V coefficient, and Kendall's tau. In addition, a PCA analysis was used to reduce variable dimensions.
Findings: The results of the research indicate that the scope of using services within e-office services is more strongly related to functionality than to IT equipment. In turn, the economic area plays a fundamental role in the perception of the city as a Smart City. There was also a clear difference in self-evaluation regarding Smart City areas and IT aspects of the city depending on the size of the city. However, this difference does not translate into declarations regarding the readiness for evaluation in Smart City categories.
Originality/value: presentation of the relationship between the areas defining the concept of Smart City dependence on the basis of an original study addressed to city representatives. The results of the study allow us to look at the Smart City concept from the perspective of the city. The results of the analysis, in addition to scientists dealing with Smart City, may be of interest to city managers in Poland. They show the way of understanding and dependencies between individual areas. They also show those dependencies that need to be strengthened in the context of sustainable development.

Keywords: Smart City, PCA, survey research, dependency analysis.

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

1. Introduction

The idea of a Smart City is multifaceted. On one hand, it refers to people and the quality of their lives, on the other hand, it refers to the development of science and technology, especially information technology (Albino et al., 2015).

The definition of Smart City has a hierarchical structure (Giffinger et al., 2007). The concept of Smart City is separated into areas and sub-areas, and sometimes into more specific categories In the European Smart Cities Ranking (Giffinger, Gudrun, 2010), the Smart City model includes: Smart Economy (which includes: an innovative spirit, entrepreneurship, city image, productivity, a labor market, international integration), Smart Governance (political awareness, public and social services, efficient and transparent administration),Smart Living (cultural and leisure facilities, health conditions, individual security, housing quality, education facilities, tourist attractions, social cohesion), Smart People (education, lifelong learning, ethic plurality, open-mindedness),Smart Environment (air pollution, ecological awareness, sustainable resource management) and Smart Mobility (local transport system, international and national accessibility, ICT-infrastructure, and sustainability of the transport system). The same main areas are considered in The Smart Cities Wheel concept with slightly differently defined subareas (Cohen, 2014). A similar look at Smart City is presented by the Bilbao Smart City Study (Azkuna, 2012). Slightly different areas are presented by the Triple-Helix Model for Smart City (Lombardi, 2011), in which five areas are considered: Governance, Economic Development, Human Capital, Culture and Leisure, Environment. Also, five areas of Smart City are considered in the CITYkeys project (Airaksinen et al., 2017; Bosch et al., 2017): people and quality of life, environment, economy (prosperity), management, and propagation. At the same time, these areas refer not only to cities, but also to projects related to the Smart City concept.

The designation of areas describing Smart City leads to the definition of indicators (criteria) providing information about the maturity of the city in terms of a given category. Next, to assess the extent to which the city is smart (Sharifi, 2020). By its very nature, this assessment is multi-criteria (Halepoto et al., 2015; D'Alpaos, Andreolli, 2020; Ogrodnik, 2020; Carli et al., 2018).

One of the key elements of the evaluation system are data that can be obtained from publicly available databases (Sojda, Wolny, 2020), own research, expert opinions or from various sources, depending on the evaluation system. Smart City evaluation initiatives are usually related to an objective approach (independent of residents or city authorities) or refer to a survey of the opinion and situation of residents (e.g., the source of the Urban Audit survey). On the other hand, research involving the assessment of Smart City from the perspective of the administration and city authorities is relatively rare (Ligarski, Wolny, 2021).

A separate issue is research related. This is due to the occurrence of interdependencies between areas, sub-areas and categories defining Smart City. There are numerous studies identifying the occurrence of correlations between individual categories (Moustaka et al., 2017, 2018; Theng, Kanokkorn, 2016; Neirotti, 2014, Cagliero et al., 2016). However, there are no results showing the interdependencies directly between the main areas of Smart City.

Researchers generally agree that Smart City development should be sustainable (Honarvar, Sami, 2019; Silva et al., 2018; Khan et al., 2020; Heitlinger et al., 2019), although the difference between a sustainable and a smart city is recognized (Ahvenniemi et al., 2017). Therefore, a sustainable Smart City should be characterized by a significant interdependence between the main areas defining the Smart City.

Taking into account the presented considerations, Smart City research was undertaken from the point of view of the administration and city authorities. The following main areas of Smart City were considered: social, logistic, economic, managerial, technical, IT, ecological, and additionally evaluative (readiness to evaluate Smart City solutions). In addition to the above-mentioned research areas, cities were asked to assess the functioning strictly in IT aspects aimed at residents (functionality of the e-office, scope of use of the e-office, availability of IT infrastructure, IT equipment of the e-city hall, and educational activities related to IT going beyond the curriculum). The main objective of the research was to determine the interdependencies between Smart City areas and between these areas and the IT aspects of the city aimed at residents.

2. Methods

The collected data come from a random sample of 287 Polish cities. The draw was layered, so that each of the voivodships was represented by at least 10 cities. The study was addressed to people responsible for the preparation of strategies and urban development plans. It concerned the assessment of cities in the area of IT infrastructure and the perception of the city in the context of being "smart". Questions related to IT infrastructure covered the following 5 aspects:

- e-office functionality,
- e-office usage,
- access to IT infrastructure for residents,
- e-office equipment,
- IT education.

Questions about the perception of the city as a Smart City related to the following areas:

- social,
- logistical,
- economical,
- managerial,
- technical,
- IT,
- ecological,
- evaluative.

For each question, respondents answered on a 5-point Likert scale. A detailed description of the research sample and the results of the answers to individual questions can be found in (Sojda et al., 2020).

Since the aim of the study was to determine the interdependencies between Smart City areas and between these areas and the IT aspects of the city aimed at residents, it was necessary to select appropriate measures of interdependence.

The first measure was Pearson's linear correlation coefficient defined by the formula:

$$r_{xy} = \frac{\sum_{i=1}^{n}(x_i-\bar{x})(y_i-\bar{y})}{\sqrt{\sum_{i=1}^{n}(x_i-\bar{x})^2}\sqrt{\sum_{i=1}^{n}(y_i-\bar{y})^2}} \quad (1)$$

Due to the fact that this coefficient measures the degree of linear dependence, while the answers were measured on a 5-point ordered scale, it was feared that the values obtained with this coefficient would not be reliable. Taking this into account, it was also decided to determine the Kendall's tau correlation coefficient (Kendall's tau), which measures the monotonic relationship between the two X i Y variables. It can be interpreted as the probability that the X variable Y will also increase as it increases – with this probability being scaled to a range from –1 to 1 (Arndt et al., 1999).

The third measure chosen was Cramér's V-statistic given by the formula:

$$V_{xy} = \sqrt{\frac{\chi_{xy}^2}{n\min\{p-1,s-1\}}}, \quad (2)$$

where χ_{xy}^2 is the value of the chi-squared statistic calculated from the contingency table for variables X i Y with dimensions p and s.

It measures the relationship between nominal variables and takes values from 0 (no dependencies) to 1 (variables are mutually unambiguous) (Rayward-Smith, 2007).

Based on the selected measures, correlation coefficients between the variables were calculated. Then, using the Spearman rank correlation coefficient, the correspondence of the order of strength of the compounds determined by each of these measures was checked. The results are presented in Table 1.

The results clearly indicate a high compatibility of the strength quantity of the compounds determined by each of these measures. The Pearson correlation coefficient showed the greatest consistency with other measures, which is why it was the relationship sizes determined by this measure that were selected for detailed analysis.

Table 1.
Spearman's rang coefficient between three correlation measures

	Pearson'sr	Kendall's tau	Cramér's V
Pearson'sr	1.0000	0.9867	0.9488
Kendall's tau	0.9867	1.0000	0.9165
Cramér's V	0.9488	0.9165	1.0000

In addition to correlation analysis, it was also decided to perform a principal component analysis (PCA) to determine the main directions of volatility (the evaluative aspect was omitted as the least correlated with the rest of the variables). Bartlett's test of sphericity was performed, the result of which confirmed the occurrence of correlations between variables and the possibility of PCA analysis ($\chi^2(66) = 3008.86, p < 0.001$). The eigenvalues of the first 10 components obtained with the PCA are represented by figure 1.

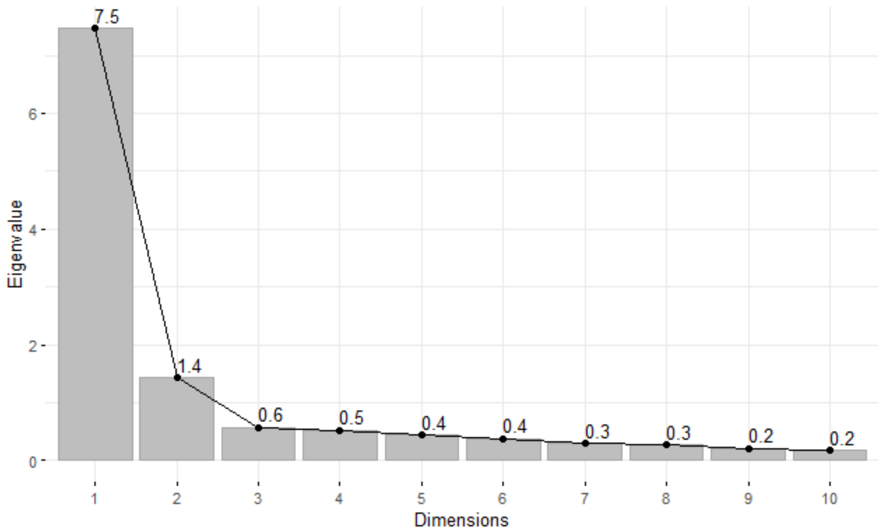

Figure 1. Eigenvalues of first 10 principal components.

Based on the Kaiser criterion and the scree plot, it was decided to choose 2 components that explain 74% of the variability of the entire set.

3. Results

Analysis

Firstly, the correlations between infrastructure aspects were checked. The obtained values are represented by figure 2.

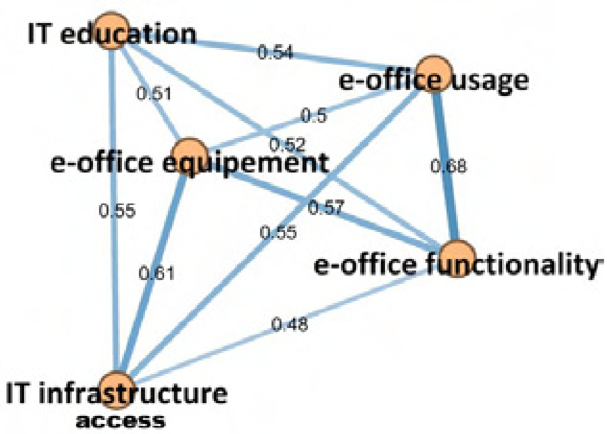

Figure 2. Correlations between the IT infrastructure aspects.

There are positive correlations between all variables, but the strongest is between e-office usage and e-office functionality. The second strongest correlation is between IT infrastructure access and e-office equipment. There are also clear correlations between additional IT education activities and access to IT infrastructure and the scope of using the e-office.

Next, the correlations between the areas of urban perception in Terms of Smart City (figure 3) were checked. All correlations are high here, but among them it is possible to distinguish the strongest and the weakest.

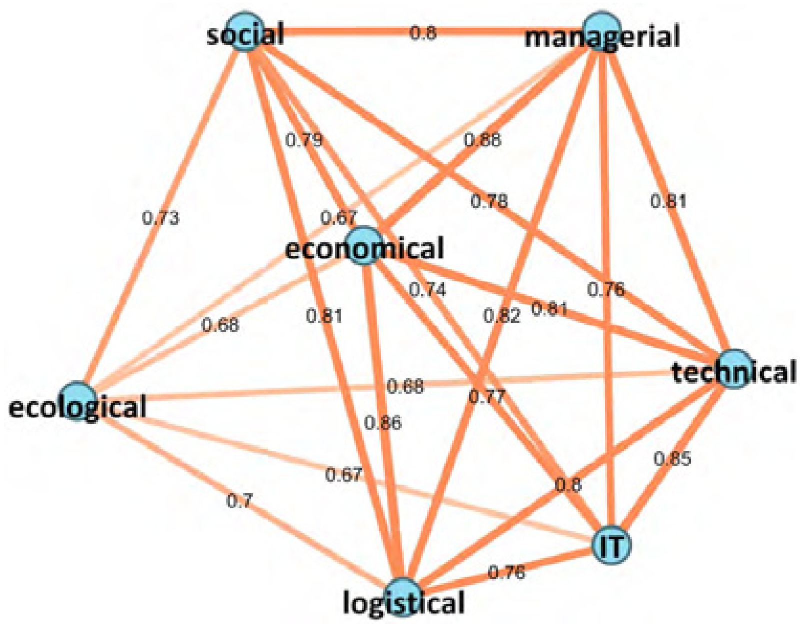

Figure 3. Correlations between the perceived Smart City aspects.

The strongest relationship here is between the economic and managerial areas. High correlations also characterize the economic and logistic area as well as technical and IT areas. The economic area seems to be the most closely related to the others. The weakest relationships occur in the case of an ecological area (it is most strongly related to the social aspect).

The relationships between the Smart City areas and additional IT education and access to IT infrastructure were also checked (figure 4).

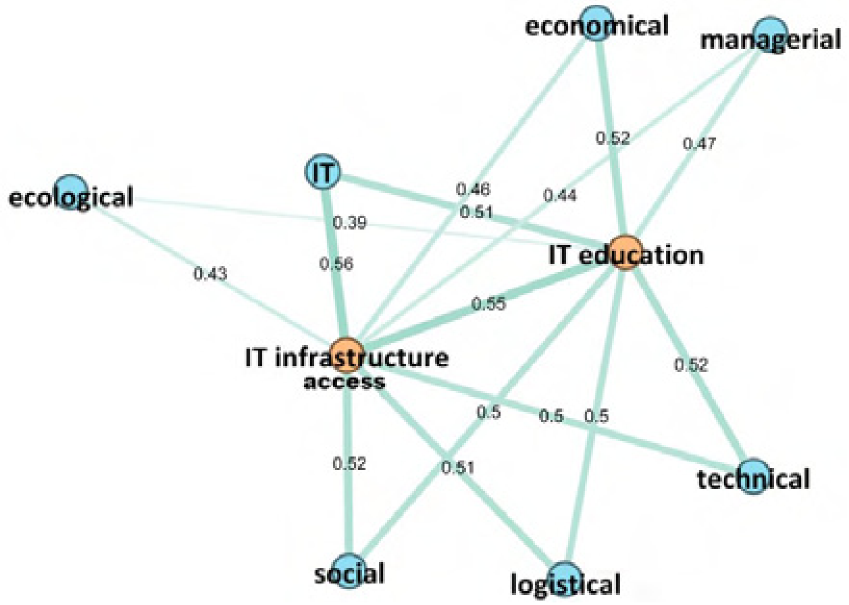

Figure 4. Correlations between ID infrastructure access and IT education with the perceived Smart City aspects.

Both of these areas are most strongly related to the IT aspect, and least to the ecological and managerial area.

Analysis of the principal components

For further analysis, the first two components were selected. Due to the positive correlations between all variables, in order to better interpret the obtained dimensions, it was decided to carry out an additional *oblimin* rotation. The factor loadings of the individual variables are shown in Table 2.

Table 2.
Factor loadings between variables and rotated components

variable	principal 1	principal 2
social aspect	**0.862**	0.059
logistical aspect	**0.913**	0.007
economical aspect	**0.936**	-0.022
managerial aspect	**0.972**	-0.088
technical aspect	**0.872**	0.069
IT aspect	**0.790**	0.152
ecological aspect	**0.844**	-0.050
e-office functionality	-0.058	**0.873**
e-office usage	-0.090	**0.901**
e-office equipment	0.251	**0.613**
IT infrastructure access	0.138	**0.696**
IT education	0.159	**0.661**

Factor loadings indicate two clearly separated dimensions of data: the perception of the city in terms of being "smart" (Smart City dimension) and IT infrastructure (IT dimension). These values for individual variables are presented in a two-dimensional space determined by these dimensions (figure 5).

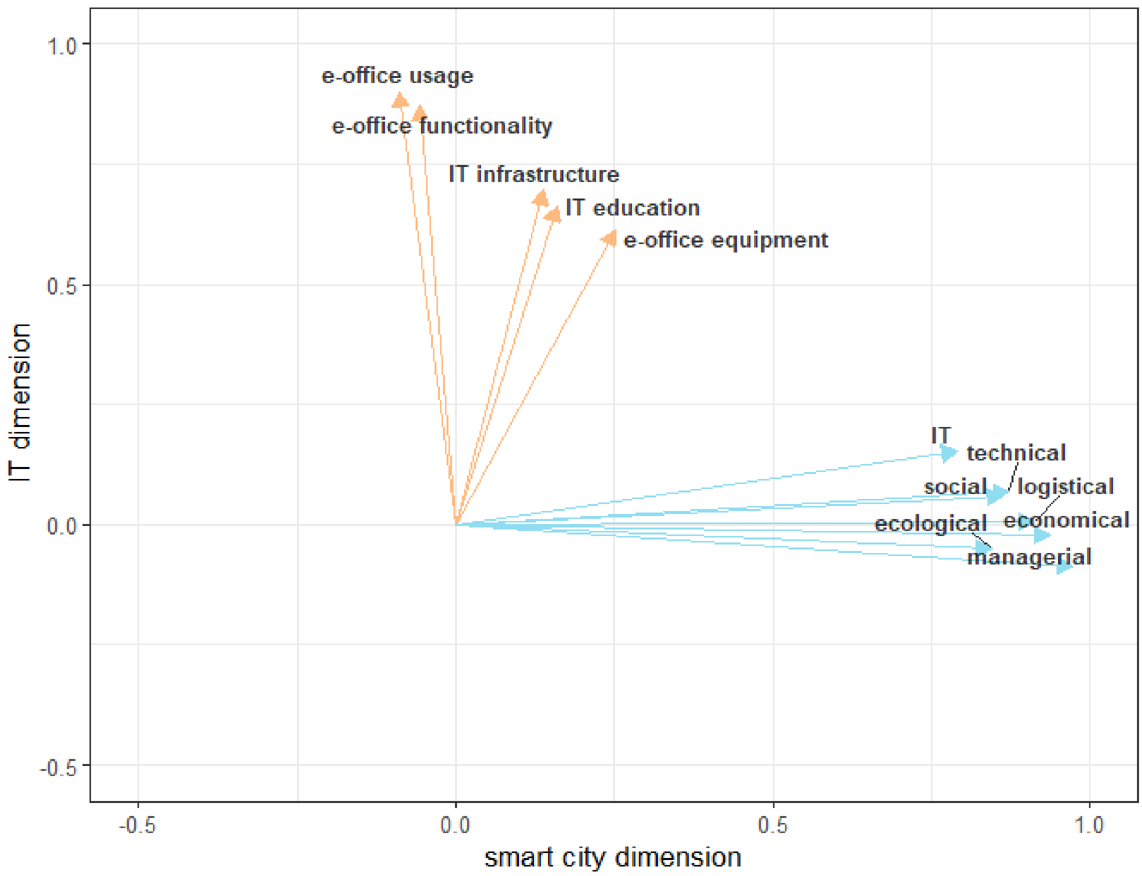

Figure 5. Variables' factor loadings in 2-dimensional space.

Figure 6 shows the component coefficients of all cities broken down by city size. X points indicate group centers (i.e., average values obtained by cities of a given size). It is clear that the largest cities (over 100,000 inhabitants) perform best due to the two analyzed dimensions, while the lowest are cities with a size of up to 10,000 inhabitants.

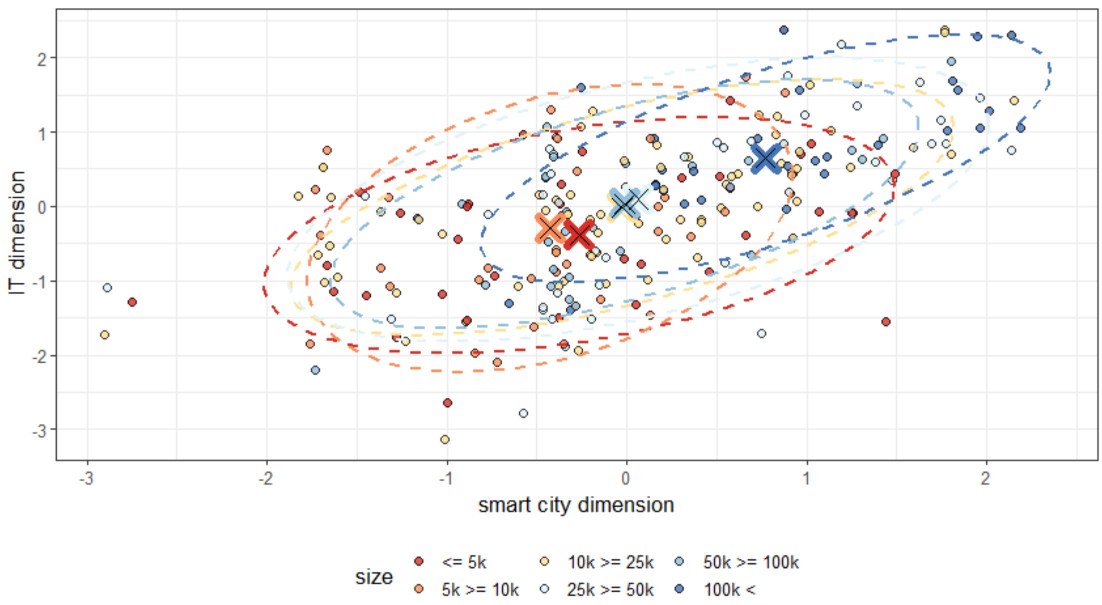

Figure 6. Cities' results according to their size.

The next figure shows the coefficients of cities broken down according to the answers given to the question about the evaluation aspect, i.e., conducting a self-assessment in the field of smart solutions (figure 7). A clearly positive relationship can be seen between the answers given and the values obtained in the two analyzed dimensions.

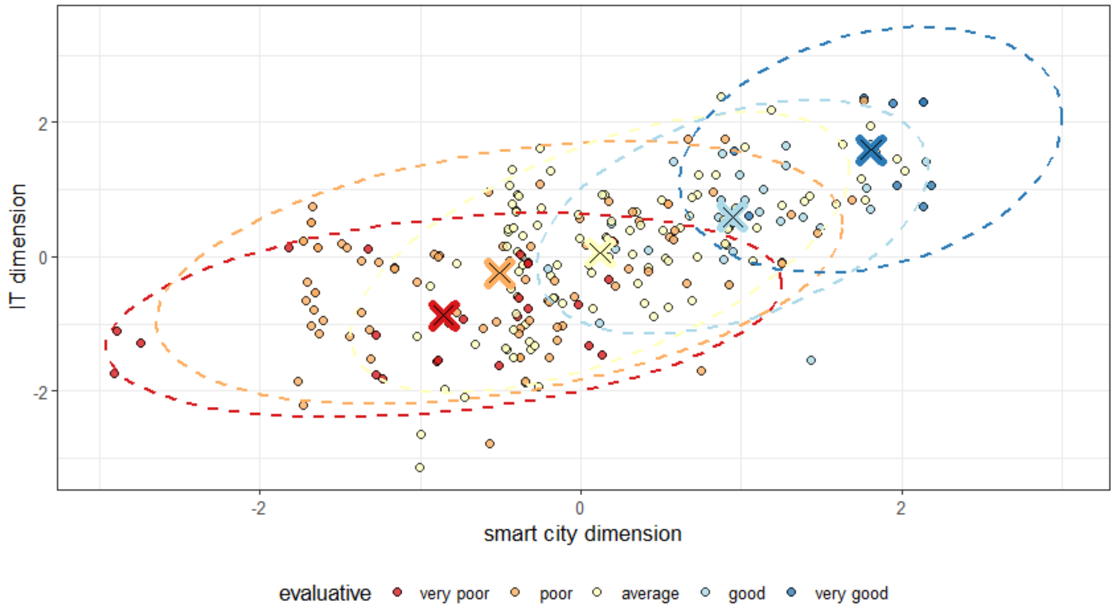

Figure 7. Cities' results according to self-evaluative aspect.

Figure 8 presents the results of cities depending on the answer to the question about interest in the overall evaluation of the city in terms of Smart City evaluation.

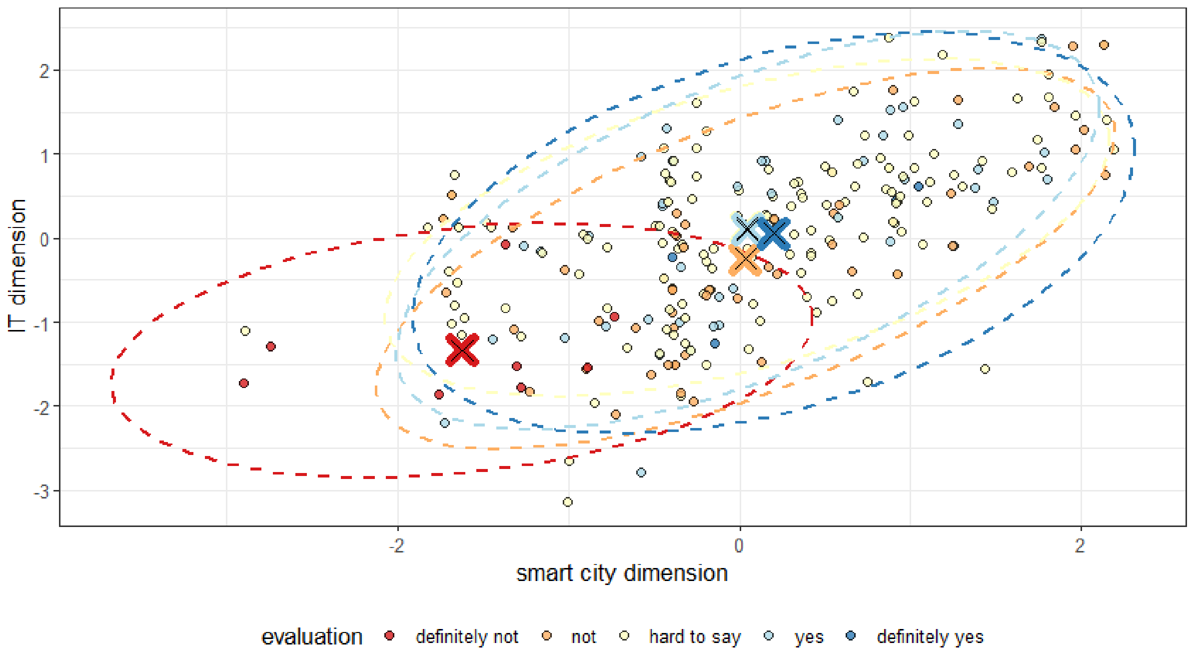

Figure 8. Cities' results according to their interest in evaluation of being "smart".

It points to clear differences between the cities that have strongly refused to be the subject of such evaluations and the others.

4. Discussion

The following conclusions can be drawn from the presented research results. Firstly, the scope of using the services made available as part of the e-city hall is strongly related to their functionality, and to a lesser extent to the IT equipment of the office itself (figure 2). The degree of use of the services offered by the e-office is clearly related to the additional education of residents in the field of IT. Both of these areas are strongly linked to access to IT infrastructure by residents. This indicates a complex relationship between the studied areas in terms of IT infrastructure of cities. This corresponds with the conclusions of (Kashnar et al., 2021), who recommend treating the entire smart cities infrastructure as an "emergent socio-technological topic", which can only be well understood using a holistic and comprehensive approach.

Secondly, the economic area seems to play a major role in the context of being smart. It is located at the center of the network of connections with all other components of Smart City (figure 3). The management area is most closely related to this area. Therefore, it can be hypothesized that efficient management has a positive effect on the economic results of being “smart”, which in turn translates into other areas. Similar results are presented in the work (Giovannella et al., 2014). The management area is strongly correlated with other smart city areas. On the other hand, the economic area is most strongly correlated with the management area. The impact of the economic aspect on other areas of smart cities is similarly recognized in (Jonek-Kowalska, Wolniak, 2021).

Thirdly, the IT aspect is strongly linked both to access to infrastructure, but also to education in the use of this infrastructure (figure 4). Both of these aspects should therefore be developed simultaneously. This confirms the extreme relevance of education in the context of smart cities, which has been highlighted before (Garg et al., 2017; Molnar, 2021).

Fourthly, the awareness of being "smart" is clearly correlated with the size of cities (figure 6) and self-esteem in the field of "smart" solutions (figure 7). In terms of city size, similar results are provided by the PCA from the study (Giovannella et al., 2014), where the second principal component distinguishes large cities and shows the impact of city size on the assessment of being "smart". It is interesting, however, that the interest declared by the representatives in the overall external evaluation of the city in terms of Smart City evaluation does not seem to be related to how cities perceive themselves. For example, among the cities that have chosen the answer "not" there are both cities from leading positions in both dimensions, as well as those below the average value (figure 8).

5. Summary

The Smart City concept is related to the development of cities, which means that it is constantly being developed. It is a utilitarian concept aimed at indicating the areas in which the city should develop. The overwhelming number of research/works tries to assess the city with objective measures based on indicators of its development. In a few studies you can see the use of residents' opinions. There was a lack of investigation of Smart City from the perspective of city managers.

The paper uses the results of surveys from a sample of 287 cities relating to five aspects of IT infrastructure and eight areas defined within the Smart City concept itself. The survey was addressed to people responsible for preparing the city's development strategy. A detailed description of the research sample and the results of the answers to individual questions can be found in (Sojda et al., 2020).

Based on the answers, dependency measures based on the linear correlation coefficient of Pearson's, Kendall's tau, Cramér's V-statistic were determined. All the meters gave similar results. The Pearson correlation coefficient was the most consistent with the other measures. The PCA analysis indicated the main directions of volatility.

On the basis of the correlation analysis, positive relationships between aspects of the IT infrastructure (figure 2) were found. Positive relationships were observed for the areas of understanding the Smart City concept (figure 3). The study of the relationship between IT aspects and Smart City areas showed the existence of positive relationships between them (figure 4).

Analysis of the main components (PCA) allowed to distinguish two components (figure 1, 5). In addition, the dependence of individual components on the size of the city (figure 6) and the willingness to evaluate in the field of Smart City (figure 8) were checked.

It can be concluded that the scope of using services within the e-office is more strongly related to functionality than to IT equipment. The economic area plays a fundamental role in the perception of the city as a Smart City. The IT aspect is related to the infrastructure and education of how to use this structure.

The presented research results allows us to look at the smart city concept from an individual's perspective managing the city and therefore deciding on the directions of its development.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

ENVIRONMENTAL SUSTAINABILITY ORIENTATION FROM A DYNAMIC CAPABILITIES PERSPECTIVE – A CONCEPTUAL APPROACH

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Purpose: The environmental problems which have been deepening in recent decades, i.e. climate change or the degradation of the biosphere, are creating a new reality of pursuing business activity. On the one hand, firms – by their nature – seek to maintain the efficiency and to gain a competitive advantage, on the other hand – they are more and more often obliged to balance environmental goals with economic goals. Although there are opinions that these goals are competitive in themselves, it is possible for firms to reconcile them effectively by adopting Environmental Sustainability Orientation. Since this orientation is analysed in the literature from various research perspectives, this paper attempts to conceptualise it from a Dynamic Capabilities perspective.
Design/methodology/approach: The paper is theoretical and based on an in-depth review of the literature. The developed conceptual model includes the direct and indirect relations among dynamic capabilities formulated in multidimensional terms, Environmental Sustainability Orientation and organisational outcomes. Embedding considerations in resource-based theories, three key processes (organisational learning, integration and reconfiguration of resources) have also been analysed, which, as necessary for building dynamic capabilities, make it easier for firms to adopt strategic Environmental Sustainability Orientation.
Findings: The considerations included in the paper complement the literature in the area of strategic management and make it easier to understand Environmental Sustainability Orientation at the organisational level. They also point to a need to undertake further scientific work, the authors of which can use the research propositions elaborated in the paper and thus empirically verify the proposed conceptual model.
Originality/value: The key scientific contribution of the paper is the development of a research framework formulating Environmental Sustainability Orientation from a Dynamic Capabilities perspective, i.e., respectively: (1) the capability to identify opportunities and/or threats (sensing), (2) the capability to use these opportunities and/or cope with threats (seizing) and (3) the capability to reconfigure the firm's resources and competences (reconfiguring). The logic of this approach results from the fact that the three fundamental processes underlying the building of dynamic capabilities – organisational learning, integration and reconfiguration of resources – supported by the conscious action of CEO, make it easier for firms to adopt strategic Environmental Sustainability Orientation.

http://dx.doi.org/10.29119/1641-3466.2022.161.15 http://managementpapers.polsl.pl/

Keywords: Environmental Sustainability Orientation, dynamic capabilities, theoretical framework.

Category of the paper: Research paper.

1. Introduction

Just like any new concept, Environmental Sustainability Orientation (ESO) is based on solid research foundations rooted in management sciences. In the literature regarding strategic choices, the best known is Market Orientation, to which thousands of studies, both theoretical and practical, have been dedicated (Gupta et al., 2019). Similarly, researchers are highly interested in Entrepreneurial Orientation, i.e. a strategic attitude of an organisation which combines the aspects of proactiveness, risk-taking, and innovativeness (Covin and Slevin, 1989) and allows firms to gain a competitive advantage in an uncertain environment (Simpson and Sariol, 2022). In view of the key role of the environment, including its characteristic set of features (variability, complexity and hostility), researchers focused on Innovation Orientation, including interrelations and interactions between innovations and the above-mentioned strategic orientations (Ejdys, 2014). The capability of enterprises to generate, adapt and implement innovations (Subramanian and Nilakanta, 1996), embedded in their organisational culture, structure and strategy (Siguaw et al., 2006), has been considered the most important determinant of maintaining a relatively sustainable competitive advantage.

The growing popularity of Environmental Sustainability Orientation points to a paradigm shift in management sciences (Khizar et al., 2022). Researchers identify many benefits associated with implementing an environmentally friendly strategy by firms (Hart, 1995; Aragón-Correa and Sharma, 2003; Roxas et al., 2017; Danso et al., 2019), and the results of these studies may dispel the doubt which still bothers practitioners – does it pay to be sustainable? However, such a strategy is not always a firm's own choice, because – increasingly – it results from the need to meet the requirements of, e.g., customers, suppliers or business partners (Claudy et al., 2016; Cheng, 2020). In addition, regulatory (environmental legislation) and market (taxes, subsidies) instruments implemented in many countries (Idoko et al., 2013) make firms include environmental issues in their business activity (Amankwah-Amoah et al., 2019; Khizar et al., 2022). In this way, reconciling business goals with taking environmental activities becomes – more and more often – simply a necessity rather than a choice, which explains the growing popularity of the Environmental Sustainability Orientation in the literature on strategic management (Khizar et al., 2022).

Among the numerous studies attempting to conceptualise ESO, we can identify two different research perspectives. On the one hand, researchers analyse the Environmental Sustainability Orientation at the individual level, referring it to the intentions, values, aims, attitudes, and beliefs of individuals (Kuckertz and Wagner, 2010; Sung and Park, 2018; Abdulaziz-al-Humaidan et al., 2021). A different view suggests that ESO should be expressed at the organisational level (Roxas and Coetzer, 2012; Roxas et al., 2017). In this perspective, it is seen as *the overall proactive strategic stance of firms towards the integration of environmental concerns and practices into their strategic, tactical and operational activities* (Roxas and Coetzer, 2012, p. 464; Amankwah-Amoah et al., 2019; Cheng, 2020). In addition, researchers argue that adopting Environmental Sustainability Orientation requires a significant involvement of resources (Adomako et al., 2019) and the development of specific capabilities and leads to gaining a competitive advantage and higher efficiency (Claudy et al., 2016). Taking both assumptions into account at the same time embeds the concept of ESO not only in the Resource-Based View (RBV), but also in the theory of Dynamic Capabilities.

The objective of the paper is an attempt to conceptualise Environmental Sustainability Orientation from a Dynamic Capabilities perspective. Starting with a comparison of two different formulations of ESO and a synthetic presentation of resource-based theories, the paper raises the issue of a conceptual connection between Environmental Sustainability Orientation and dynamic capabilities formulated in multidimensional terms. This orientation of the conducted considerations allows to avoid criticism related to limiting the analysis only to the classical resource-based concept, understood as a static and balance-based model (Easterby-Smith et al., 2009). Although the dynamic nature of Environmental Sustainability Orientation has already been highlighted in the literature (Claudy et al., 2016; Criado-Gomis et al., 2017), still there are no research works that would explain even not the consequences but the processes facilitating the adoption of ESO at the organisational level. The considerations presented in this paper are aimed at filling this research gap.

The analysis carried out – based on an in-depth review of the literature – indicates that dynamic capabilities support the adoption of ESO, which leads to achieving better organisational outcomes. The logic of this approach results from the fact that the three fundamental processes underlying the building of dynamic capabilities – organisational learning, integration and reconfiguration of resources – supported by the conscious action of CEO, make it easier for firms to adopt strategic Environmental Sustainability Orientation. In other words, it is the potential of dynamic capabilities that makes a firm more sensitive to environmental problems, which is conducive to pursuing business activity for the environment, while allowing to improve the efficiency and/or to gain a competitive advantage.

2. Theoretical Background

Among researchers analysing environmental sustainable orientation, two different research perspectives dominate (individual level vs organisational level). In the first perspective, researchers define ESO as the underlying attitudes and convictions (Kuckertz & Wagner, 2010), that refer to the level of concern about the environmental protection and social responsibility of individuals (Sung & Park, 2018), regardless of the business's circumstances, issues, profits and so on (Abdulaziz-al-Humaidan et al., 2021). As a theoretical framework, the authors mainly use the Upper Echelon Theory (UET), justifying the need to study ESO from the perspective of actions taken by the top management.

In the second perspective, researchers argue that Environmental Sustainability Orientation is a strategic concept at the organisational level, illustrating the firm's commitment to sustainability activities, programmes and practices (Roxas and Coetzer, 2012; Roxas et al., 2017). The logic of this approach points to the fact that firms should take environmental issues into account in their business activity, and thus pursue business goals in an environmentally and socially responsible manner (Claudy et al., 2016; Danso et al., 2019). Research in this area refers directly to resource-based theories popular in the literature, i.e.: the Resource-Based View of the Firm (RBV), Natural Resource-Based View of the Firm (NRBV) and Dynamic Capabilities Theory (DCT).

The creators of RBV (Wernerfelt, 1984; Barney, 1991) formulate a firm as a set of various resources distinguishing it from its competitors, which – according to the logic of the resource-based concept – should be valuable, rare and/or firm-specific, as well as difficult to replace and imitate (Wernerfelt's VRIN framework, 1984). In addition, it is assumed that organisations differ from each other in a fundamental way not only in terms of their resources, but also in the context of their effective use (Barney's VRIO framework, 1991). Therefore, the conceptualisation of Environmental Sustainability Orientation from the RBV perspective indicates that it is a unique organisational resource determining gaining a competitive advantage (Cheng, 2020).

The positive relation between Environmental Sustainability Orientation and firm outcomes has been theoretically described by Hart (1995), who made gaining a competitive advantage conditional upon meeting the challenges posed by the natural or biophysical environment. This approach – known in the literature as NRBV – stresses the importance of strategic capabilities aimed at prevention of pollution, product management and sustainability, treating them as a key condition for gaining a long-term competitive advantage (Hart, 1995).

An important issue that escapes the resource-based perspective is the need to dynamically adjust resources in a firm to the changing conditions of the environment. This assumption made researchers (Teece et al., 1997; Teece, 2007) complement the RBV concept with the dynamics of introducing organisational changes (Easterby-Smith et al., 2009). The DCT, developed on the basis of the pioneering study by Teece et al. (1997), points to the need to build specific capabilities – also formulated as higher-order capabilities (Winter, 2003) or meta-capabilities (Collis, 1994) – which lead to the continuous creation, expansion, updating and protection of the resource base, in order to gain a relatively sustainable (in the context of generating values) competitive advantage.

Although the literature has shown empirically that firms with greater dynamic capabilities are characterised by the higher efficiency (Wilden et al., 2013; Wang et al., 2015; Pichlak, 2021) and a significant competitive advantage (Fainshmidt and Frazier, 2017), we cannot a priori reject an assumption that this relationship is specific, contextual and situational. This is consistent with the statements by Bowman and Ambrosini (2003), Zahra et al., (2006), and Shamsie et al. (2009). Researchers point to an indirect relation between dynamic capabilities and efficiency, while highlighting the key role of the organisational context in which these capabilities are developed. When being guided by the arguments of Barreto (2010), the study of dynamic capabilities should be focused, first of all, on analysing the directions of using their potential. Therefore, the conceptual framework developed in this paper is based on the assumption that dynamic capabilities facilitate the adoption of Environmental Sustainability Orientation, which leads to achieving better organisational outcomes.

Referring to the most popular literature formulation of dynamic capabilities by Teece (2007), the model takes into account three components (dimensions) of them: sensing, seizing and reconfiguring. Sensing is about identifying opportunities and/or threats; seizing – about mobilising organisational resources and competences in order to use these opportunities and/or cope with threats; reconfiguring boils down to reorganisation, as well as – if necessary – to reconfiguring resources and competences in order to achieve organisational renewal.

In addition, the multidimensional formulation of dynamic capabilities indicates that they are interrelated. This is consistent with the arguments by Danneels (2016), who points out that abilities to detect and use opportunities determine the reconfiguration of resources and with the studies by Wilden and Gudergan (2015) and Fainshmidt and Frazier (2017), who confirm this empirically. Sensing generates the emergence of new streams of knowledge and information, which may result in recombining existing and/or developing new resources and competences. Similarly, seizing may change the base of resources held in a firm, and thus extend the scope of their reconfiguration and – if necessary – protect against path dependency.

3. Conceptual framework and research propositions

Despite many discrepancies in relation to the conceptualisation of dynamic capabilities – cf. literature reviews by Wang and Ahmed (2007); Ambrosini et al. (2009) and Barreto (2010) – most researchers agree with two fundamental issues related to the nature of these capabilities.

The first one is the priority role of organisational learning processes in building and developing dynamic capabilities (Teece et al., 1997; Zollo and Winter, 2002; Teece, 2007; Lin et al., 2016; Fainshmidt and Frazier, 2017). Teece et al. (1997) also identify two other organisational and managerial processes, i.e.: coordination/integration of resources, as a result of which a new resource base is created, and reconfiguration (transformation and recombination) of resources, while Teece (2007), elaborating the above-mentioned concept, indicates that they constitute asset ‘orchestration’ processes and are necessary for building dynamic capabilities.

The second issue is the key role of management team members in creating and developing dynamic capabilities, and this role is stressed by many researchers (Eisenhardt and Martin, 2000; Helfat et al., 2007, Teece, 2007). The way management team members perceive the environment of an organisation (Ambrosini and Bowman, 2009), whether they notice its uncertainty and complexity (Aragon-Correa and Sharma, 2003) and finally, what their motivations, skills and experiences are (Zahra et al., 2006) determines not only the acquisition of new knowledge, but also its inclusion in organisational systems and procedures. Similarly, management team members must formulate a clear vision of the development of the organisation and an effective motivation system that will be conducive to integrating and reconfiguring resources and competences, both in an enterprise itself and in its relations with the environment.

According to the theoretical model presented in Figure 1, the three fundamental processes – organisational learning, integration and reconfiguration of resources – underlying the building of dynamic capabilities facilitate the adoption of strategic Environmental Sustainability Orientation.

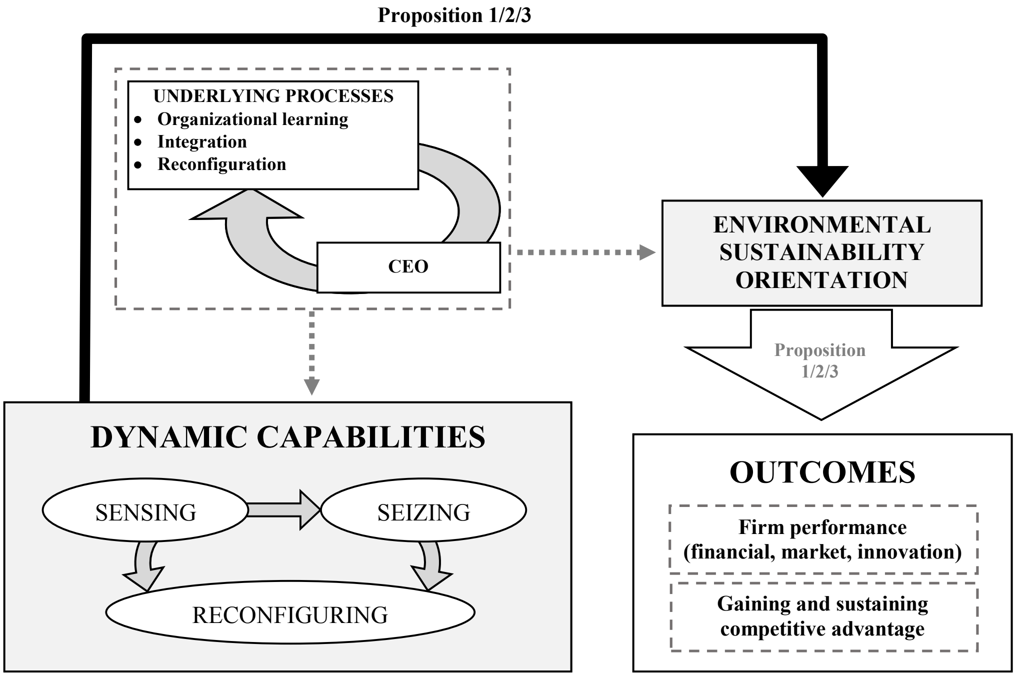

Figure 1. Theoretical framework.

It is obvious that meeting new (environmental) challenges requires firms not only to have significant resources, but also to develop new knowledge through organisational learning processes. These processes manifest themselves both in the form of individual skills of members of an organisation and in the form of organisational knowledge, which is embedded in routines, in new patterns of activity or in a new logic of organisational activities (Teece et al., 1997). Researchers stress primarily the social nature of these processes, pointing out that individual learning leads to organisational learning by modifying the attitudes, behaviour and beliefs of members of an organisation (Bloor, 1999).

As noted by Roxas et al. (2017), firms having strong strategic Environmental Sustainability Orientation are characterised by the greater capability to learn constantly and to conduct innovative activities. Similarly, Hult et al. (2004) confirm empirically that learning orientation, as a cultural concept, is positively related to innovativeness. Thus, it can be assumed that considering ESO from the perspective of organisational learning processes associates it directly to organisational culture. It happens so because organisational learning processes are immanently embedded in organisational culture (Hurley and Hult, 1998), and in addition, organisational culture may both influence and be influenced by individual and organisational learning (Bloor, 1999). For example, Lin and Kunnathur (2019) point out that strategic orientations manifest themselves per se in organisational culture, Claudy et al. (2016) refer Environmental Sustainability Orientation directly to organisational culture, for Roxas and Coetzer (2012) the development of ESO takes place by including environmental issues primarily in corporate culture, and Jin et al. (2019) demonstrate empirically that innovation culture (as a key element of organisational culture) is positively related to adopting Environmental Sustainability Orientation in such a way that the stronger it is, the more likely it is that a firm will be environmentally oriented.

Another bundle of processes facilitating the adoption of strategic Environmental Sustainability Orientation is undoubtedly the integration of resources. The importance of these processes results from the existence of enormous pressure on the part of stakeholders who make firms include environmental issues in their activity (Khizar et al., 2022). One of the ways to cope with such pressure is to initiate, maintain, and use intra- and inter-organisational relations. By establishing these relations, a firm may intensify the exchange and integration of environmental knowledge within a firm (thanks to interdisciplinary cooperation of various organisational units) and acquire and integrate new environmental knowledge held by external entities. This perspective refers directly to the concept of absorptive capacity, defined in the literature as *an ability to recognize the value of new information, assimilate it, and apply it to commercial ends* (Cohen and Levinthal, 1990, p. 128). Dangelico et al. (2013) indicate that pursuing eco-innovative activity in an effective manner requires the implementation of organisational procedures facilitating the acquisition of new external knowledge, while using internal knowledge held in a firm. Establishing intra-organisational relationships is essential to integrate sustainability issues into a firm's strategic and operational activities (Dangelico et al., 2017). Establishing inter-organisational relations enables – in turn – access to environmental knowledge held by customers and suppliers (Melander, 2018), competitors (Horbach, 2016) and R&D units, institutes and universities (Triguero et al., 2013). Researchers prove that building such relations improves the efficiency of pursued eco-innovative activity by adopting a Environmental Sustainability Orientation (Cheng, 2020).

The complexity of environmental problems and challenges faced by modern enterprises may be a reason for which, despite previously chosen strategic Environmental Sustainability Orientation, the continuation of pro-environmental activity will require recombination or reconfiguration of corporate resources and competences. As knowledge and resources can lose their value over time (Zhou et al., 2019), excessive attachment to their base can prevent a firm from overcoming the problem of inertia (Huang and Li, 2017) – understood even not as the lack of change, but rather as a too slow response to emerging opportunities and threats – as well as overcoming path dependency (Teece, 2007). Finally, the importance of reconfiguration processes for the adoption of Environmental Sustainability Orientation is also supported by the very nature of ESO, which (just like all other strategic orientations) is immanently embedded in the reconfiguration of the organisational system, structure and activities (Roxas et al., 2017).

Summing up, both organisational learning processes and processes of integration of knowledge (internal and external) result in the adoption of strategic Environmental Sustainability Orientation. These processes intensify the creation of new knowledge and its assimilation and application in an enterprise, which translates directly not only into the faster and more effective capture of opportunities (and/or threats) emerging in the environment, but also into the use of these opportunities and/or coping with these threats. In addition, the inclusion of environmental issues at the strategic level significantly increases the complexity of organisational change (Hart, 1995; Dangelico et al., 2017), and therefore must be supported not only by the acquisition and assimilation of new knowledge, but also by a periodic renewal of the corporate base of resources and competences. Finally, taking into account the fact that the growing awareness of environmental problems determines the decision of firms to reorient strategically towards taking activity for the benefit of the environment (Shahidi, 2020), it can be assumed that:

- **Proposition 1.** Sensing determines the sensitivity of a firm to environmental problems, facilitating the adoption of strategic Environmental Sustainability Orientation, which leads to achieving better organisational outcomes.
- **Proposition 2.** Seizing determines a firm's readiness to cope with environmental problems, facilitating the adoption of strategic Environmental Sustainability Orientation, which leads to achieving better organisational outcomes.
- **Proposition 3.** Reconfiguring determines a firm's capability to renew necessary resources and competences, facilitating the adoption of strategic Environmental Sustainability Orientation, which leads to achieving better organisational outcomes.

The research propositions suggested in this paper clearly indicate that the inclusion of environmental issues in pursued business activity translates into gaining a competitive advantage by firms and is reflected in a higher level of their efficiency. This assumption is consistent with the results of many empirical studies (Roxas et al., 2017; Amankwah-Amoah et al., 2019; Danso et al., 2019; Adomako et al., 2021) and points to the existence of real benefits (i.e., e.g., increased efficiency, cost savings or improved repute) which can be brought to firms by adopting Environmental Sustainability Orientation.

4. Discussion and Conclusion

The validity and necessity of pursuing environmentally friendly activity, as stressed by many researchers, results in the growing importance of Environmental Sustainability Orientation and justifies taking scientific research in this area. On the one hand, the adoption of such orientation can contribute to solving environmental problems, among others, through the design and implementation of eco-innovations. On the other hand, the analysis carried out shows that this adoption requires the significant involvement of resources (including, first of all, knowledge resources) and the development of specific capabilities (formulated in the literature as dynamic capabilities).

The main objective of the paper was to develop a research framework that takes into account not only the consequences, but also processes and capabilities making it easier to adopt Environmental Sustainability Orientation at the organisational level. Based on the studies by Teece et al. (1997) and Teece (2007), dynamic capabilities have been defined in a multidimensional manner, taking into account, respectively: (1) the capability to identify opportunities and/or threats (sensing), (2) the capability to use these opportunities and/or cope with threats (seizing) and (3) the capability to reconfigure the firm’s resources and competences (reconfiguring).

A developed conceptual framework (as well as research propositions) indicates that all three dimensions of dynamic capabilities can support the adoption of Environmental Sustainability Orientation, which leads to achieving better organisational outcomes. Such theoretical assumptions are supported by the results of empirical studies existing in the literature, indicating that: there is a positive relation between recognition of opportunities and Environmental Sustainability Orientation (Sung and Park, 2018); ability to conduct R&D activities (thus activities directly related to the use of opportunities) strengthens the impact of involvement of suppliers on the relation between Environmental Sustainability Orientation and organisational outcomes (Cheng, 2020) and that building and reconfiguring resources has a positive impact on an organisation’s ability to integrate environmental issues into the development of new eco-products (Dangelico et al., 2017).

In addition, as it results from the presented considerations, the development of ESO is based on the same processes in which dynamic capabilities are embedded. Both organisational learning processes and integration processes facilitate pursuing environmentally friendly activity on the basis of previously developed procedures and intensify the acquisition of new knowledge, supporting the development of capabilities to detect and use new opportunities and/or cope with new environmental threats. In turn, recombination and reconfiguration of resources allows firms to continuously improve existing capabilities and introduce new ones and thus to respond to changing environmental challenges.

Summing up, although the considerations contained in this paper are limited by their nature (theoretical analysis) and – by definition – are not exhaustive, they may constitute the basis for conducting pioneering empirical studies (verifying the proposed conceptual model) in enterprises operating in the Polish economy. This would be valuable not only for the theory, but, above all, for the practice of management. The developed research framework indicates that ESO is strategic, and thus manifests itself at almost every level of an organisation's functioning. Therefore, its development requires having specific capabilities (higher-order capabilities), thanks to which organisations will be able to build and integrate their skills, resources and competences, adapt them to changes taking place in their environment and transform them into efficiency.

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SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

DISPARITIES IN REGIONAL DEVELOPMENT ON THE EXAMPLE OF POLISH PROVINCES BETWEEN 2000 AND 2020

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Purpose: The purpose of this article is to present the disparities of Poland's economic development in 2000-2020 by NUTS-2 units, using selected economic indicators.
Design/methodology/approach: The following methods are used in the article: critical literature analysis and statistical data analysis using selected statistical tools. Based on data obtained from the Local Data Bank of Statistics Poland (GUS), the level of regional characteristics is calculated such as: the output of production (GDP), GDP per capita and the value and share of the industrial sector in the total output. The analysis covered 16 Provinces in the period of 2000-2020.
Findings: The analysis of selected variables in the analyzed years confirmed the regional disparities in Poland between Provinces, and the leading role of the Mazowieckie Province.
Research limitations/implications: The research performed in the article represents only one aspect of the assessment of regional disparities. The complete research picture can be obtained by using other tools of statistical analysis and additional variables of socio-economic and environmental development.
Practical implications: Knowledge of the mechanisms and regularities of regional development is the basis for the formation of policies that would ensure, on the one hand, high and sustainable development dynamics and, on the other, lead to the reduction of regional inequalities.
Social implications: Regional inequalities, manifested through social inequalities, are a natural and – to some extent – acceptable phenomenon. However, excessive economic inequalities lead to conflicts and tensions in societies. Therefore, one of the objectives of economic and social policy of the state should be the reduction of regional inequalities to achieve sustainable development and improvement of the quality of life in the country.
Originality/value: The analysis herein used the most recent statistical data of selected variables and statistical tools. Thus, it can be another element towards recognizing the regularities of regional disparities in the Polish economy at the regional level.

Keywords: regional disparities, regional GDP, changes in industrial sector.

Category of the paper: Research paper.

1. Introduction

The issue of development, including regional development, has been the subject of numerous theoretical analyses and research studies for many years. Globalization processes, as well as the concomitant increased flows of goods, services and production factors, seem to lead to an increasing homogeneity of the world economy. This should be reflected in the increasing uniformity of the level of wealth of countries and the convergence of the values of macroeconomic indicators. However, when reviewing the literature, can be observed the variety of definitions and methods of studying convergence and divergence, and the different results of empirical studies and theoretical considerations. The concept of convergence was introduced to the literature by R. Barro and X. Sala-i-Martin, in the context of economic growth theory (Barro, Sala-i-Martin, 1991). It is most often defined as a process of narrowing the gap in the level of development of different countries, or as a leveling of differences between countries and regions as well. The opposite process to convergence is divergence, which means the persistence or increase of these differences. The literature review indicates that there are many models and theories presenting a variety of concepts and views explaining the causes and mechanisms of development, including regional development (Dyjach, 2013). Initially, a certain division became apparent between theories studying convergence processes and divergence theories. Supporters of convergence, derived from classical theories, interpreted development as a process that aims, through market forces, to achieve a level of equilibrium (Barro, Solow, Swan, Lucas). According to these economists, at the equilibrium point there is an efficient allocation of resources and there is an even distribution of factors of production, which contributes to establishing a similar level of development between regions. On the side of divergence, on the other hand, stands the Keynesian school, which assumes not only the persistence, but also deepening of differentiation between regions (Myrdal, Hirschman, Perroux). However, today, with advanced mathematical methods available, the potential of each theory can be used to create instruments to diagnose the process of regional development (Łaźniewska et al., 2011). Simultaneously, there is an ongoing discussion in the literature addressing the issue of explaining the universal causes and mechanisms of economic growth differentiation and its spread both between and within countries. Long-term research has made it possible to identify direct factors of economic growth, also called first order factors, which include: capital, labor, as well as technical and organizational progress (Zienkowski, 2005). Nevertheless, as the author suggests, for these factors to have an effective impact on the economy, thus contributing to economic development and improving the quality of life of the population, they should be supported by the so-called indirect factors. Such factors may include business conditions, socio-economic policy, innovation or knowledge capital in society. It should be noted that it is very rare that the specified determinants are distributed evenly, both in time and areas. In particular, technological progress, which is considered by many economists as the main factor of structural change and long-term economic growth, may lead to an increase, rather than decrease in regional inequalities (Barrios, Strobl, 2009). Consequently, as suggested by these authors, it may mean that economic growth will promote divergence rather than convergence or confirm the thesis of the self-reinforcing nature of economic inequality, or the nonlinear development of convergence. Concepts about the nonlinear evolution of regional inequality appeared in the literature as early as the 1950s. One of the economists addressing this issue was S. Kuznets, who, in his analysis of income inequality, suggested the existence of a "long swing" in regional income inequality, i.e., firstly that there is an increase and then there is a decrease in income disparity (Kuznets, 1955). It is caused by the process of industrialization, which means an increase in the share of the industrial sector in the volume of global output (GDP), along with a decrease in the share of the agricultural sector. The concepts of linking economic development with changes in economic structure have their origin in the theory of three sectors, created in the 1930s by A. Fisher and developed by S. Clark and J. Fourastie (Swadźba, 1994). They formulated the thesis that, in the first stage of development (in a backward society, according to C. Clark), the dominant sector is agriculture. As economic development progresses, the proportion of people working in the agricultural sector decreases, in favor of the industrial sector. Then, in the further course of economic development, the importance of the sector of industry decreases, while the service sector increases. Also S. Kuznets (together with Rostow, Chenery, Schumpeter, Hoffman and others) emphasizes the close relationship between economic growth and industrialization of the economy. Most studies, including those by Polish authors (Karpiński, Kempny, Klamut, Lipiński, Swadźba, Lisikiewicz, Ciamaga) point to the occurrence of certain characteristic phenomena in the industrial sector. It is possible to name such processes as industrialization, deindustrialization and reindustrialization. Their distinction is associated with specific changes observed in the share of the industry structure in total global output. Development researchers have transferred this concept to the regional context, suggesting the existence of a bell-shaped curve of spatial development, where inequality should first increase as developed areas benefit from the external economy, better location of decision-makers, mobility of capital and labor (Myrdal, Hirschman, Williamson). A notable study is available by Williamson, who analyzes in quite some detail the driving changes in regional inequality, also depending on the stage of development of the country during industrialization (Williamson, 1965). He finds some evidence of a nonlinear relationship between regional inequality and national development. His conclusions are based on two main empirical facts: first, that regional inequality is higher in less developed countries and lower in more developed countries, and second, that regional disparities increase over time in less developed countries and decrease in more developed countries. Thus, regional income inequality can be regarded, in a sense, as a by-product of the process of development and industrialization, and any attempt to reduce its level may ultimately inhibit this process. Kim and Margo, through their research, present similar findings (Kim and Margo, 2003). They demonstrate that, in the United States, the rise of industrialization in the second half of the 19th century increased regional income differences between regions. More recent studies of the European economy can also be considered quite significant in terms of the extent, to which regional inequality dynamics depend on national catch-up processes (in particular, the poorest member states of the European Union). In this context, D. Quah notes that Spain and Portugal, which achieved the highest economic growth rates in the 1980s, are also the countries that experienced the most striking increase in regional imbalances (Quah, 1996). Petrakos and Saratsis also find similar findings for Greece, finding that during the same 1980s, the most developed regions of that country experienced great difficulties due to intensified foreign competition (Petrakos and Saratsis, 2000). Other studies (Davies and Hallet, Petrakos et al.) also provide evidence of rising regional income inequalities in the poorest EU countries. It is also confirmed by the 2004 European Commission's report, which indicates that the then newly admitted countries, such as the Czechia, Hungary, Poland and the Slovak Republic, where the need to quickly catch up with the highly developed countries resulted in an upward trend of regional inequalities (European Commission, 2004). The authors of the report also indicate that regional inequalities tend to increase as the relative level of national GDP per capita increases, and then they start to have a decreasing tendency, after reaching a certain relative level of national GDP per capita. The issue of convergence is also taken up by Polish economists (Malaga, Łaźniewska et al.; Smętkowski, Gorzelak, Malina). The authors publish literature studies and empirical analyses to explain the processes of convergence and divergence, both at the international and regional level, using various statistical tools. The conclusions of those studies, which with their time span stop, at the latest, in the first decade of the 21st century, also confirm the existing thesis in the foreign literature about the existence of processes of regional divergence rather than convergence. Thus, the question arises whether the contemporary years of the 21st century are an illustration of economic convergence, or further divergence, leading to increase in disparities in the level of regional development in Poland. Therefore, this article attempts to analyze the issue of changes in regional disparities based on data on the Polish economy in the first twenty years of the 21st century. It can be argued that the Polish economy is a rather interesting case study in this time frame, during Poland's accession to the European Union, the financial crisis and the beginning of the COVID-19 pandemic. Structural and economic changes that Poland has faced in the last two decades may have had a significant impact on the dynamics of regional inequality. This issue is important because the knowledge of mechanisms and regularities of regional development is the basis for shaping a regional and national policies, that would ensure high and sustainable economic growth rate on the one hand, and on the other, would lead to a reduction in regional inequalities. This issue is also aligned with Article 174 and 178 of the Treaty on the Functioning of the European Union, which formulates the pursuit of regional policy to “reduce disparities between levels of development in the various regions” (Treaty on the Functioning of the European Union, 2012).

2. Methods

The research in this article is based on annual indicators of the level and growth rate of gross domestic product (GDP) and GDP per capita. These are the main indicators used to measure economic growth and development, despite their criticism and imperfections (Łaźniewska, et al, 2011). The statistical data, presented according to NUTS-2 classification, comes from 16 Polish Provinces (also called regions): Dolnośląskie, Kujawsko-Pomorskie, Lubelskie, Lubuskie, Łódzkie, Małopolskie, Mazowieckie, Opolskie, Podkarpackie, Podlaskie, Pomorskie, Śląskie, Świętokrzyskie, Warmińsko-Mazurskie, Wielkopolskie and Zachodniopomorskie. The main source of data is the Local Data Bank of Statistics Poland (GUS-Local Data Bank). Moreover, the values of shares of the industrial sector in provinces are compared. To analyze changes in the selected indicators, statistical data are collected for over twenty years, from 2000 to 2020. Only statistics for industry sector cover only the 2000-2019 period, due to the lack of homogeneity of their calculations in Statistics Poland. The different authors propose various statistical tools that describe and measure differences between variables. In this study, the selected element of descriptive statistics and the classical coefficient of variation (cv) has been chosen. This coefficient is calculated as the quotient of the standard deviation and the mean value for variables, in each province during the analyzed period. If the value of this coefficient exceeds 40%, it means high diversity. And accordingly, the more the values are below 40%, the smaller the variation of the variables is. These elements are used for presentation and interpretation of changes in selected indicators, in the context of regional disparities and convergence or divergence processes. A histogram will also be used as one of the graphical means of visualizing the distribution of variables under study. It is used to present the frequency of occurrence of a given analyzed variable in selected period. All own calculation results are presented in the Appendix in Tables.

3. Results and discussion

Analyzing the 2000-2020 GDP values, it could be noticed a regular growth of production in all provinces. Figure 1 shows the GDP in subsequent years (vertically) in each province. In the analyzed period, Mazowieckie, Śląskie and Wielkopolskie provinces are the ones with the highest GDP level. 20 years later, they are still the leaders.

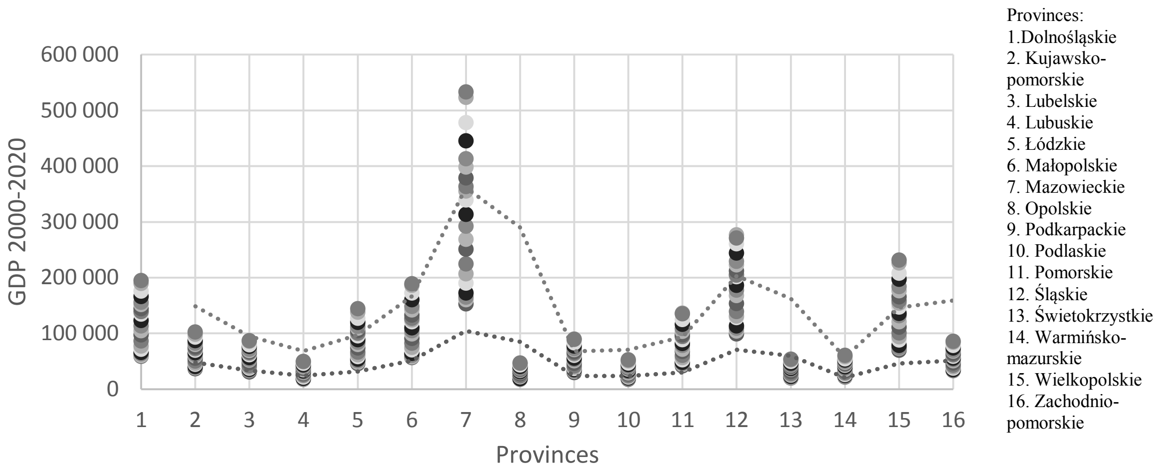

Figure 1. GDP in 2000-2020 by province. Own analysis based on data from Statistics Poland.

As seen in Table 1 and Table 2 (Appendix) some of the provinces that multiplied the GDP level the most in 2022, compared to 2000, are Mazowieckie (248%), Małopolskie (235%) and Dolnośląskie (231%). At the end of analyzed time period (at the beginning of pandemic), the Śląskie Province has the largest decrease while the Łódzkie Province has the highest increase. Yet all provinces record a decline, but not the same for all of them in GDP growth rate at the end of the period. The presented statistical data indicates that there are disparities in the GDP level in the analyzed provinces. In the discussed period the distance between the Mazowieckie Province and the other provinces is increasing. This province has not only the highest growth since 2000, but also the highest average annual GDP growth (over 6% on average). The lowest growth increase (below 5% on average per year) is characteristic for Zachodniopomorskie Province. The biggest gap compared to the Mazowieckie Province is recorded for the Opolskie Province, both at the beginning and at the end of the analyzed period. The highest variability of the value and of the GDP growth in the analyzed 20 years period is observed in the Opolskie (about 85%), Świętokrzyskie (67%) and Śląskie (66%) provinces. The lowest coefficient of variation is found for the Łódzkie Province (37%). However, such high coefficients of variation for almost all the regions may indicate a lack of tendency to balance the level of GDP.

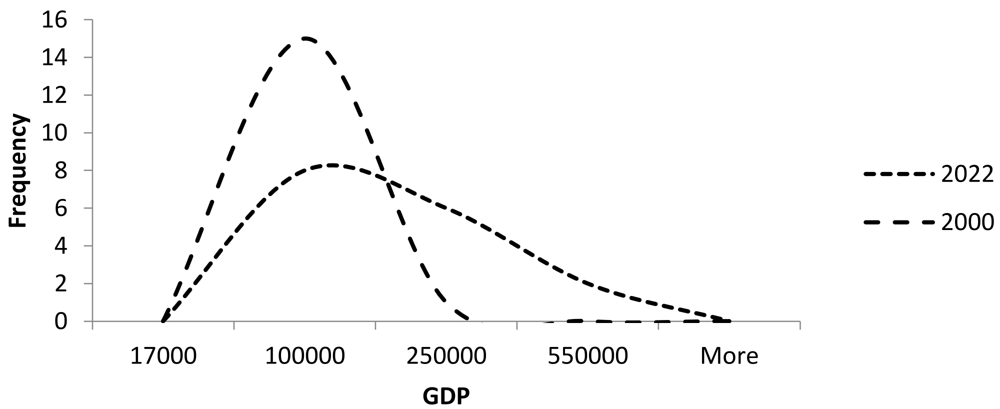

Figure 2. GDP histogram for 2000 and 2020. Own analysis on data from Statistics Poland.

The plotted lines on Figure 1 graphically indicate greater diversity of the analyzed variable in 2020 compared to 2000. While grouping provinces by GDP levels, it can be assumed the division into three groups (Table 7, Appendix). The first group, with the highest GDP level (over or almost 200 billion PLN), includes the following provinces: Mazowieckie, Dolnośląskie, Śląskie and Wielkopolskie. The second group comprises Małopolskie, Łódzkie and Pomorskie Provinces. The remaining provinces, with GDP below 100 billion PLN, are classified in the third group. The graph presented in Figure 2 shows a flattening and a slight shift to the right of the 2020 graph compared to 2000. This indicates an improving situation, in which more regions have a higher level of GDP. However, along with the increase in the level and of GDP growth, there is an increase in the diversification of this indicator between regions.

When analyzing the GDP per capita, also as in the case of GDP, an upward trend can be observed in all provinces (Figure 3) and (Table 3 and 4, Appendix). Only at the end of the analyzed period, at the turn of 2019-2020, several provinces (Śląskie, Podkarpackie and Pomorskie) record a decrease in this variable. The highest level at the beginning of the analyzed period is shown in the following provinces: Mazowieckie, Śląskie and Wielkopolskie. The lowest level is evidenced in Lubelskie, Podkarpackie and Podlaskie provinces. At the end of the analyzed period, there is a change in the leading position, where Dolnośląskie Province took the second place after Mazowieckie. Wielkopolskie and Śląskie provinces still showed high GDP per capita values.

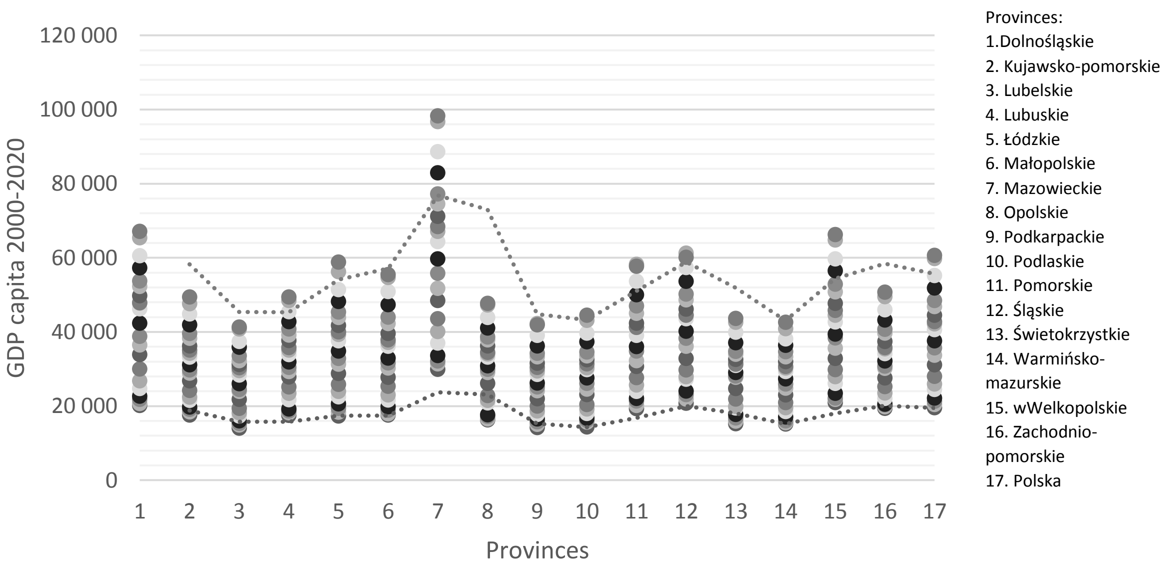

Figure 3. GDP per capital in 2000-2020 by province and in Poland. Own analysis based on data from Statistics Poland.

The lowest values are observed in the following provinces: Lubelskie, Podkarpackie and Warmińsko-Mazurskie. On the other hand, the Wielkopolskie Province recorded a fairly large increase in GDP per capita, the highest of all analyzed regions. The unquestionable, independent leader in terms of GDP per capita throughout the studied period is still the Mazowieckie Province. An interesting situation can be observed where only three provinces at the beginning of the analyzed period have a higher GDP per capita than the size of this indicator for the whole country: Dolnośląskie, Mazowieckie and Śląskie, but at the end of this period only two provinces, i.e. Dolnośląskie and Mazowieckie. Compared to the Mazowieckie Province, the Lubelskie Province was the farthest behind. If categorize provinces into groups by this indicator, it can be divided into four groups, assigning the Mazowieckie Province to the first group (Table 7, Appendix). The second group includes provinces with GDP per capita above 60 thousand PLN, i.e.: Dolnośląskie, Śląskie and Wielkopolskie. These are also the regions with higher or equal to Polish GDP per capita. The provinces with GDP per capita between 50 and 60 thousand PLN are: Małopolskie, Łódzkie, Pomorskie and Zachodniopomorskie, which can be assigned to the third group. In the group of regions with the lowest level (below 50 thousand PLN) of GDP per capita are the Kujawskie, Lubuskie, Opolskie, Podkarpackie, Podlaskie, Świętokrzyskie and Warmińsko-Mazurskie. Coefficient of variation of this parameter for all provinces are less than 40%, which can be interpreted as an average level of variation. The highest average growth can be observed in Dolnośląskie and Mazowieckie provinces. However, the greatest coefficient in the growth of GDp per capita occurs in the Opolskie Province. Differences in changes in GDP per capita growth are also another argument for the existence of disparities between provinces and a deepening of this disparity at the end of the analyzed period. This is also confirmed by the graphic lines (upper for 2020, lower for 2000) on Figure 3.

Comparing both indicators GDP and GDP per capita, the differences between the provinces are smaller for the latter variable, compared to the corresponding period of change in total GDP. Thus, it could be concluded that the distribution of GDP per capita across regions is less skewed.

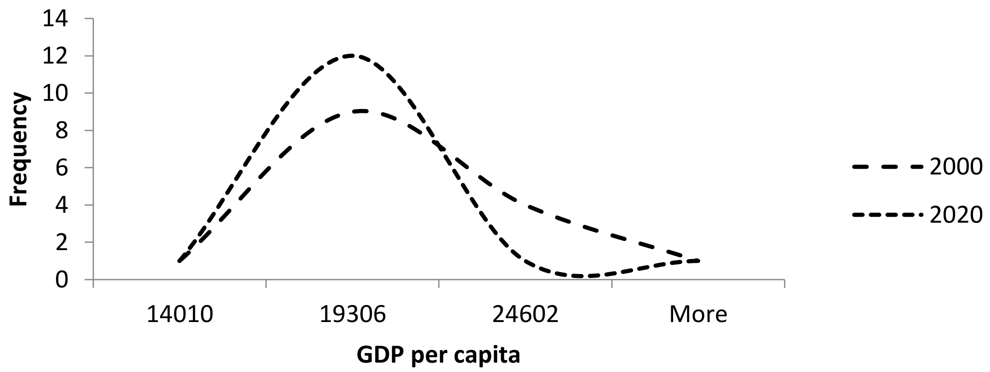

Figure 4. GDP per capita histogram for 2000 and 2020. Own analysis based on data from Statistics Poland.

The interpretation of the GDP per capita histogram is, in fact, the same as for GDP (Figure 4). The flattening and slight rightward shift of the 2020 graph compared to 2000 indicates an improvement, more regions having a higher level of GDP per capita. Thus, it can be concluded that, with the increase in the level and growth of GDP per capita, there is a slight increase in variation and disparities of this indicator among provinces.

Another parameter compared is the share of the industrial sector in GDP (Figure 5) and (Table 5 and 6, Appendix). The highest share of the total value added of industrial production at the beginning of the analyzed period is notable for the Śląskie Province (17.37%), and a slightly lower share for the Mazowieckie Province (15.05%). However, at the end of the analyzed period both provinces' values are at almost the same level. However, in the case of the Mazowieckie Province, a decrease in this share in 2000-2011 is noticeable, followed by an increase. In the Śląskie Province, however, an increase in the share of the industrial sector until 2004 is noticeable, and then after Poland's accession to the European Union, its systematic decline. The following provinces are also in the lead in terms of the value added of industrial production throughout the analyzed period (apart from Mazowieckie and Śląskie): Dolnośląskie and Wielkopolskie. Comparing the coefficient of variation, it can be stated that the greatest variation in changes occurs in Lubuskie and Dolnośląskie, and the smallest in Podlaskie. This fact is graphically confirmed by the curves on Figure 5.

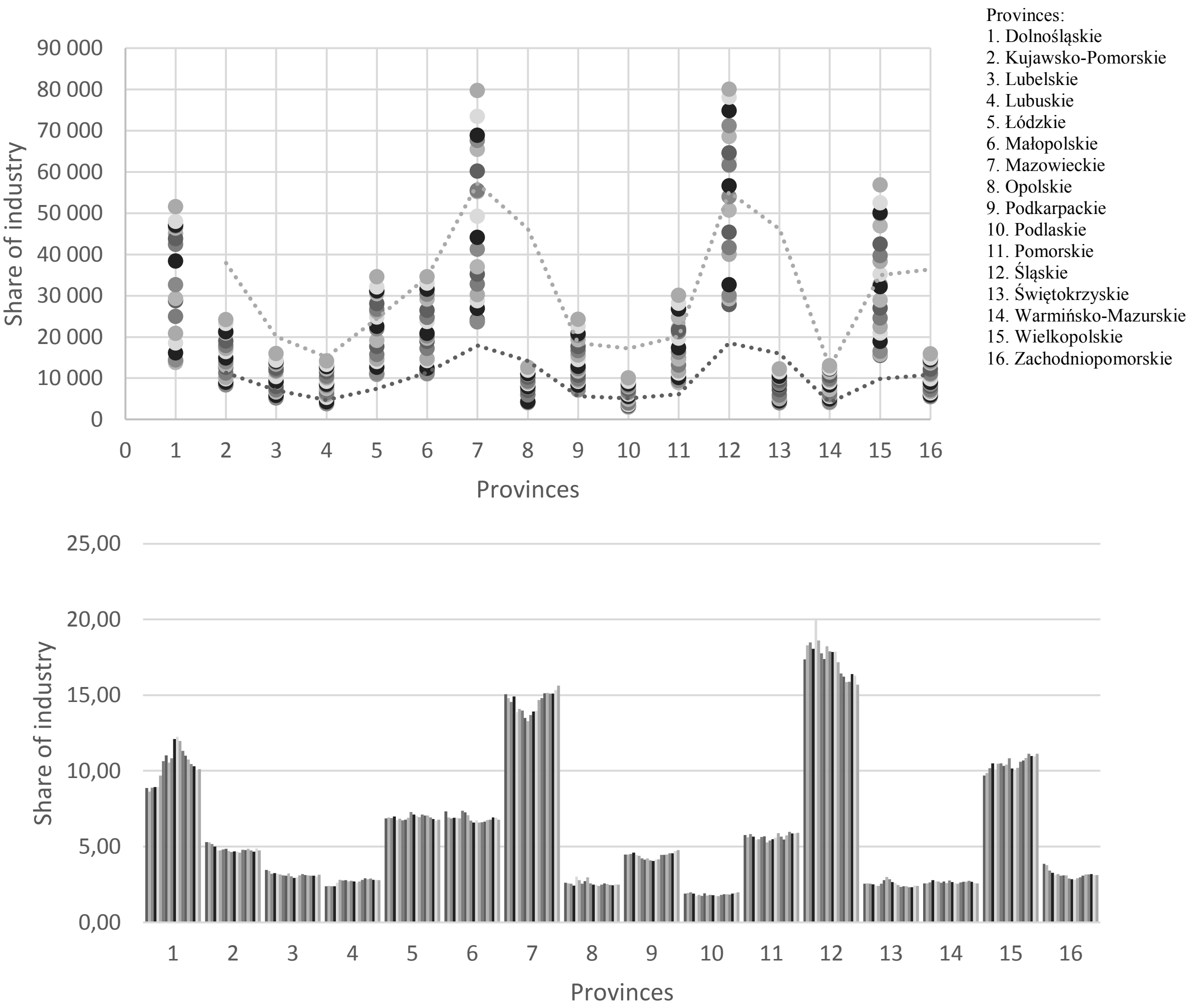

Figure 5. Value added and share of industry sector in GDP in 2000-2019 by province. Own analysis based on data from Statistics Poland.

On the other hand, the highest increase in the share of the industry sector in the analyzed period can be observed in Lubuskie Province (16.7% in 2019 compared to 2000), and the highest decrease in Zachodniopomorskie Province (-19%). A characteristic phenomenon for this parameter is also a rather large irregularity of values in the analyzed period in all provinces and a lack of clear trend. In most regions, the decline in the share of industry took place mostly in 2009-2011. The opposite trend is characteristic, as already mentioned, for Śląskie Province, as well as for Dolnośląskie Province. Thus, it can be concluded that some provinces experienced reindustrialization (Mazowieckie), while others were deindustrialized (Kujawsko-Pomorskie, Lubelskie, Łódzkie, Opolskie, Śląskie, Świętokrzyskie and Zachodniopomorskie). Coefficients of variation for this variable were in the range of 30-40%. The highest value was found for the following provinces: Dolnośląskie, Lubuskie, Mazowieckie and Wielkopolskie. When analyzing this variable, it can be also created certain groups (Table 7, Appendix). The first group includes the leading provinces with the highest share of the industrial sector (over 10%): Śląskie, Mazowieckie, Wielkopolskie and Dolnośląskie. The second group (with the share of this sector in the range of 5%-10%): Łódzkie, Małopolskie and Pomorskie. The third group, with the lowest shares of industrial manufacturing, comprises the following provinces: Kujawsko-Pomorskie, Lubelskie, Lubuskie, Opolskie, Podkarpackie, Podlaskie, Świętokrzyskie, Zachodniopomorskie and Warmińsko-Mazurskie. Interpretation of the histogram of industrial sector share in GDP differs slightly from that for previous variables (Figure 6). The graph is shifted strongly to the right, while, at the same time, it is flattened. This indicates that more of the analyzed regions were characterized by a higher share of the industrial sector in 2019 than in 2000. Some provinces experienced reindustrialization (Mazowieckie), while others were deindustrialized (Kujawsko-Pomorskie, Lubelskie, Łódzkie, Opolskie, Śląskie, Świętokrzyskie and Zachodniopomorskie).

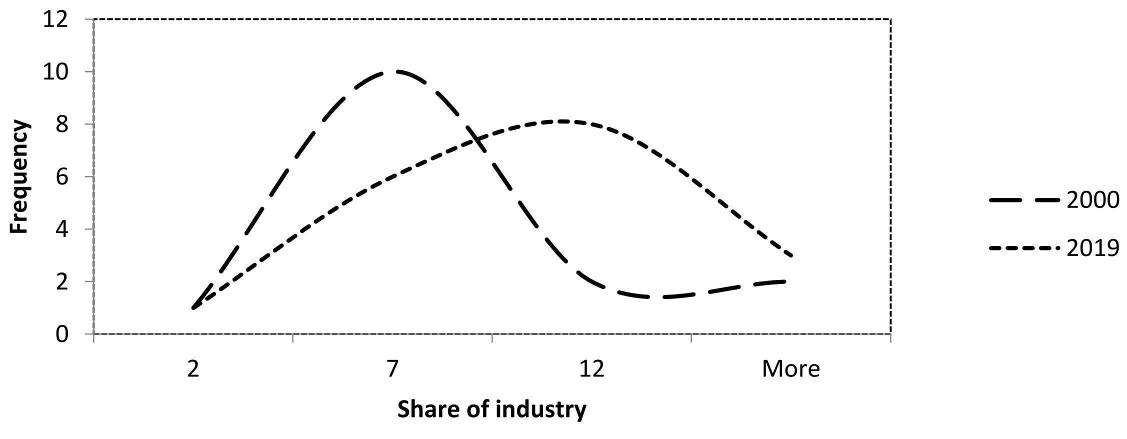

Figure 6. Industrial sector share histogram for 2000 and 2019. Own analysis based on data from Statistics Poland.

4. Summary

The paper attempts to analyze the changes in regional disparities and variation between the levels and growth rates of GDP, GDP per capita and the share of the industrial sector in total output, at the level of NUTS-2 classification. The collected data from the first two decades of the 21st century allow to formulate several conclusions. As can be seen from the presented results, at the regional level of the Polish economy can be observed a process of divergence rather than convergence. The analysis allows to conclude that there are disproportions between the size and growth rates of both GDP and GDP per capita, despite their increase during the entire period under analysis. Coefficients of variation calculated for consecutive years indicate that the rate of divergence after 2004 decreases slightly, which may indicate the spread of economic development throughout the country. Smaller disproportions occur in the values of GDP per capita than GDP, which is not surprising. The highest values of all analyzed indicators can be found in Mazowieckie Province. The distance between this province to other regions in the values of analyzed variables is greater at the end of the analyzed period. This conclusion is consistent with the previously mentioned research (e.g., Smętkowski, Malina). The share of the industrial sector in GDP, in all analyzed provinces increases. However, that changes in the share of the industrial sector in total value are not so ambiguous. Some provinces experience reindustrialization, while others are deindustrialized. The study of selected variables also does not indicate that the occurrence of characteristic events in the Polish economy (accession to the European Union, the financial crisis, the beginning of COVID-19) caused the same effects in individual regions. The comparison of the value of the share of industrial sector in GDP and the change in GDP per capita growth rates, gives rise to the following conclusions. The greater the share of the industrial sector in GDP, the higher the values of GDP and GDP per capita occur in a region, while contributing, according to the thesis indicated in the literature, to the further increase in their divergence of these parameters.

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Appendix

Table 1.
Descriptive Statistics of GDP for Polish Provinces in the period 2000-2020

PROVINCE	DESCRIPTIVE STATISTICS					
	Mean	**Standard Deviation**	**Kurtosis**	**Skewness**	**Coefficient of variation**	**Confidence level (95%)**
POLSKA	1448423.90	505012.43	-1.10	0.20	43.45	229878.90
DOLNOŚLĄSKIE	119726.57	44211.57	-1.24	0.09	51.74	20124.86
KUJAWSKO-POMORSKIE	65383.62	20618.41	-1.06	0.20	40.79	9385.39
LUBELSKIE	56659.05	18060.90	-1.22	0.12	52.36	8221.22
LUBUSKIE	32472.38	10354.84	-1.13	0.10	50.71	4713.47
ŁÓDZKIE	88666.86	30150.12	-1.01	0.20	37.08	13724.17
MAŁOPOLSKIE	113187.14	42505.27	-1.00	0.31	42.34	19348.17
MAZOWIECKIE	315526.10	121477.15	-1.04	0.28	42.00	55295.73
OPOLSKIE	31073.71	9463.24	-1.09	0.04	85.78	4307.61
PODKARPACKIE	56762.76	19223.96	-1.12	0.22	45.23	8750.64
PODLASKIE	32890.90	10786.43	-1.04	0.21	48.36	4909.92
POMORSKIE	83323.43	30219.53	-1.05	0.27	49.18	13755.76
ŚLĄSKIE	182791.90	56813.94	-1.18	0.07	66.29	25861.40
ŚWIĘTOKRZYSKIE	35921.52	10578.24	-1.08	-0.02	67.88	4815.16
WARMIŃSKO-MAZURSKIE	39116.24	12346.32	-1.19	0.09	41.17	5619.98
WIELKOPOLSKIE	139342.00	51695.55	-1.06	0.28	43.49	23531.53
ZACHODNIO POMORSKIE	55579.81	17020.15	-1.07	0.23	51.24	7747.48

Table 2.
GDP characteristics for Polish Provinces in the period 2000-2020

PROVINCE	CHARACTERISTICS				
	Minimum	**Maximum**	**Growth 2000-2020**	**Average growth**	**Change in relation to Mazowieckie 2000-2020**
	[mln PLN]	[mln PLN]	[%]	[%]	
POLSKA	748483.00	2326656.00	210.85	5.87	
DOLNOŚLĄSKIE	58630.00	194631.00	231.96	6.23	1.87
KUJAWSKO-POMORSKIE	36272.00	102302.00	182.04	5.34	4.55
LUBELSKIE	30925.00	86899.00	181.00	5.34	3.94
LUBUSKIE	17641.00	49897.00	182.85	5.37	2.19
ŁÓDZKIE	45657.00	144082.00	215.57	5.94	2.86
MAŁOPOLSKIE	56433.00	189295.00	235.43	6.27	1.43
MAZOWIECKIE	152817.00	533233.00	248.94	6.48	0.00
OPOLSKIE	17476.00	46805.00	167.82	5.14	2.66
PODKARPACKIE	29882.00	89832.00	198.35	5.65	2.83
PODLASKIE	17431.00	52383.00	200.52	5.69	1.58
POMORSKIE	41914.00	136063.00	222.88	6.08	2.05
ŚLĄSKIE	99189.00	277029.00	173.11	5.21	14.11
ŚWIĘTOKRZYSKIE	19891.00	53686.00	169.90	5.15	2.95
WARMIŃSKO-MAZURSKIE	21620.00	60465.00	179.67	5.30	2.81
WIELKOPOLSKIE	69838.00	231752.00	231.84	6.22	2.24
ZACHODNIOPOMORSKIE	32867.00	85846.00	161.19	4.95	5.41

Table 3.
Descriptive Statistics of GDP per capita for Polish Provinces in the period 2000-2020

PROVINCE	DESCRIPTIVE STATISTICS					
	Mean	Standard Deviation	Kurtosis	Skewness	Coeffcient of variation	Confidence level (95%)
POLAND	36602.40	12302.54	-1.05	0.20	33.61	5757.76
DOLNOŚLĄSKIE	39946.15	14372.72	-1.25	0.08	35.98	6726.64
KUJAWSKO-POMORSKIE	30521.15	9197.10	-1.03	0.20	30.13	4304.38
LUBELSKIE	25537.30	8226.87	-1.14	0.17	32.22	3850.29
LUBUSKIE	31109.35	9566.60	-1.06	0.12	30.75	4477.31
ŁÓDZKIE	33963.70	11730.58	-1.03	0.19	34.54	5490.08
MAŁOPOLSKIE	32816.85	11375.91	-0.93	0.30	34.66	5324.09
MAZOWIECKIE	57719.20	20487.12	-1.04	0.23	35.49	9588.27
OPOLSKIE	29774.10	9570.89	-1.08	0.08	32.15	4479.31
PODKARPACKIE	26028.85	8450.49	-1.01	0.25	32.47	3954.95
PODLASKIE	26705.35	8609.32	-1.02	0.20	32.24	4029.29
POMORSKIE	35583.10	11715.60	-0.95	0.25	32.92	5483.07
ŚLĄSKIE	38596.90	12344.88	-1.07	0.14	31.98	5777.58
ŚWIĘTOKRZYSKIE	27570.40	8253.64	-1.03	0.03	29.94	3862.82
WARMIŃSKO-MAZURSKIE	26468.00	8050.35	-1.17	0.10	30.42	3767.68
WIELKOPOLSKIE	39181.40	13507.35	-1.02	0.26	34.47	6321.64
ZACHODNIOPOMORSKIE	31664.80	9281.39	-0.98	0.26	29.31	4343.82

Table 4.
GDP per capita characteristics for Polish Provinces in the period 2000-2020

PROVINCE	**CHARACTERISTICS**				
	Minimum	**Maximum**	**Growth 2000-2020**	**Average growth**	**Change in relation to Mazowieckie 2000-2020**
	[PLN]	[PLN]	in %	in %	
POLAND	19565.00	59741.00	210.06	5.90	
DOLNOŚLĄSKIE	20116.00	65392.00	233.80	6.34	-1.07
KUJAWSKO-POMORSKIE	17530.00	47558.00	182.03	5.41	8.31
LUBELSKIE	14010.00	40771.00	194.90	5.65	4.80
LUBUSKIE	17495.00	48499.00	182.33	5.42	8.24
ŁÓDZKIE	17345.00	56209.00	239.23	6.34	-1.88
MAŁOPOLSKIE	17552.00	54678.00	215.91	6.00	2.26
MAZOWIECKIE	29898.00	96725.00	228.57	6.18	0.00
OPOLSKIE	16294.00	47272.00	192.89	5.54	5.92
PODKARPACKIE	14225.00	42225.00	194.81	5.65	4.89
PODLASKIE	14387.00	43128.00	209.46	5.91	2.80
POMORSKIE	19328.00	58202.00	198.37	5.74	5.94
ŚLĄSKIE	20769.00	61234.00	189.33	5.51	8.30
ŚWIĘTOKRZYSKIE	15260.00	42608.00	186.02	5.51	6.61
WARMIŃSKO-MAZURSKIE	15167.00	40883.00	180.65	5.41	7.40
WIELKOPOLSKIE	20897.00	64763.00	216.83	6.01	2.50
ZACHODNIOPOMORSKIE	19361.00	49496.00	161.87	5.05	13.15

Table 5.
Descriptive Statistics of share of industry sector in GDP for Polish Provinces in the period 2000-2019

PROVINCE	DESCRIPTIVE STATISTICS					
	Mean	Standard Deviation	Kurtosis	Skew-ness	Coefficient of variation	Confidence Level (95%)
POLSKA	295610.00	103504.31	-1.38	0.14	35.01	51471.48
DOLNOŚLĄSKIE	31523.67	12880.40	-1.70	-0.15	40.86	6405.27
KUJAWSKO-POMORSKIE	14141.06	4665.98	-1.37	0.26	33.00	2320.34
LUBELSKIE	9223.78	3071.58	-1.38	0.24	33.30	1527.46
LUBUSKIE	8046.89	3166.91	-1.26	0.14	39.36	1574.87
ŁÓDZKIE	20574.33	7328.55	-1.52	0.09	35.62	3644.40
MAŁOPOLSKIE	20201.50	6776.33	-1.18	0.17	33.54	3369.79
MAZOWIECKIE	42814.56	16011.83	-1.33	0.38	37.40	7962.50
OPOLSKIE	7582.56	2462.42	-1.24	-0.05	32.47	1224.53
PODKARPACKIE	12859.11	4647.30	-1.13	0.43	36.14	2311.05
PODLASKIE	5386.00	1876.97	-1.23	0.31	34.85	933.40
POMORSKIE	16711.56	6123.34	-1.24	0.32	36.64	3045.06
ŚLĄSKIE	51049.28	15467.16	-1.36	-0.11	30.30	7691.64
ŚWIĘTOKRZYSKIE	7414.56	2382.30	-1.59	-0.26	32.13	1184.69
WARMIŃSKO-MAZURSKIE	7852.39	2778.48	-1.23	0.19	35.38	1381.70
WIELKOPOLSKIE	31047.61	11690.91	-1.16	0.26	37.65	5813.75
ZACHODNIO POMORSKIE	9181.00	2989.36	-0.96	0.56	32.56	1486.57

Table 6.
Share of industry sector in GDP characteristics for Polish Provinces in the period 2000-2019

PROVINCE	CHARACTERISTICS				
	Minimum	**Maximum**	**Growth 2000-2019**	**Average industry share**	**Change in share 2000-2019**
	[mln PLN]	[mln PLN]	[%]	[%]	
POLSKA	159812	456771	218.54		
DOLNOŚLĄSKIE	13802	47113	263.13	10.36	14.00
KUJAWSKO-POMORSKIE	8415	21302	186.02	4.83	-10.21
LUBELSKIE	5201	14084	188.64	3.14	-9.39
LUBUSKIE	3822	12934	271.77	2.69	16.71
ŁÓDZKIE	10983	31185	215.34	6.92	-1.00
MAŁOPOLSKIE	11055	31595	195.00	6.87	-7.39
MAZOWIECKIE	23651	68939	230.61	14.53	3.79
OPOLSKIE	4092	11150	202.81	2.58	-4.94
PODKARPACKIE	7129	20826	238.30	4.39	6.20
PODLASKIE	3022	8616	234.75	1.84	5.09
POMORSKIE	8980	26824	226.25	5.66	2.42
ŚLĄSKIE	27848	74882	187.67	17.39	-9.69
ŚWIĘTOKRZYSKIE	4079	10538	200.51	2.52	-5.66
WARMIŃSKO-MAZURSKIE	4113	12266	217.63	2.65	-0.28
WIELKOPOLSKIE	15524	50128	266.27	10.48	14.98
ZACHODNIOPOMORSKIE	5547	14507	157.84	3.15	-19.06

Table 7.
Groups of provinces by indicators

INDICATOR	PROVINCES			
	Group 1		**Group 2**	**Group 3**
GDP	Mazowieckie	Śląskie, Wielkopolskie, Dolnośląskie	Małopolskie, Łódzkie, Pomorskie	Kujawsko-pomorskie, Lubelskie Lubuskie, Opolskie, Podkarpackie, Podlaskie, Świętokrzyskie, Warmińsko-mazurskie Zachodnio-pomorskie
GDP PER CAPITA	Mazowieckie	Śląskie, Wielkopolskie, Dolnośląskie	Małopolskie Łódzkie, Pomorskie Zachodnio-pomorskie	Kujawsko-pomorskie, Lubelskie, Lubuskie, Opolskie, Podkarpackie, Podlaskie, Świętokrzyskie, Warmińsko-mazurskie
SHARE OF INDUSTRY IN GDP	Mazowieckie	Śląskie, Wielkopolskie, Dolnośląskie	Małopolskie Łódzkie, Pomorskie	Kujawsko-pomorskie, Lubelskie, Lubuskie, Opolskie, Podkarpackie, Podlaskie, Świętokrzyskie, Warmińsko-mazurskie, Zachodnio-pomorskie

SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

GREEN FINANCE TO COMBAT CLIMATE CHANGE

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Purpose: The aim of this paper is to analyze the importance of finance for climate change.
Design/methodology/approach: The paper attempts to answer the question: what is the meaning of finance in the processes related to environmental protection, what is the development trend in the field of the so-called instruments of green finance and what are the purposes of the particular instruments. The following research methods were used: literature review, desk research (UNCTAD reports, GIIN, Sustainable Debt, Green Finance in Poland,) and deductive reasoning.
Findings: The market for green finance instruments is growing rapidly. For both green bonds and sustainable funds and impact investments, the growth rate in the number and value of instruments has been the highest in recent years. The analysis of investment directions indicates that they are related to activities concerning environmental protection or other aspects of sustainable development.
Practical implications: The importance and need for creating conditions (legislative, technical, educational) for the development of green finance instrument market was indicated.
Originality/value: The paper offers cognitive value as it contributes to the body of knowledge regarding the relevance of green in addressing climate change.

Keywords: green finance, green bonds, sustainable funds, impact investments.

Category of the paper: Conceptual paper.

1. Introduction

The climate change is no longer just a distant future scenario, it is a reality. Since the beginning of measurements, approximately 150 years ago, the effects associated with climate change have not been as severe as in recent years. The summer of 2019 was, in accordance with the Zentralanstalt für Meteorologie und Geodynamik in Vienna (ZAMG), the second warmest summer in terms of temperatures, approximately 2.7°C above the long-term average. Furthermore, it was one of the seven driest years since the measurements began (1767) (https://www.zamg.ac.at/cms/de/klima).

The Global Risks Report presented at the 2019 World Economic Forum in Davos states that environmental risks are ranked highest by companies and their importance will continue to grow, especially those related to climate change (The Global Risks Report, 2019). This is due to the fact that hot weather, crop failures, and storms cause damage to property as well as fatalities. In 2018, there were already approximately twice as many heat-related deaths as traffic fatalities. Frequent and extreme flooding, increased numbers of hurricanes and increasingly prolonged droughts, as well as rising sea levels pose threats of ecological disaster on a global scale. In addition, they are causing permanent damage to ecosystems. The 2019 report of the World Biodiversity Council (Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services) (IPBES, 2019) states that the Earth is heading towards ecological collapse and, if climate change is not stopped quickly, many animal and plant species will become extinct. Higher temperatures are causing species to die off because numerous living beings can only survive within a certain temperature range. In particular, a worrying phenomenon is the extinction of pollinating insects. This poses threats to the plant reproduction processes, as well as to the animal food chain, and also threatens food security.

In order to curb drastic climate change and its consequences, the United Nations Paris Agreement on Climate Change, which entered into force on November 4, 2016, has set a major goal. It is to limit the global temperature rise to below two Celsius degrees by the end of this century compared to pre-industrial levels and to make efforts to keep the temperature rise below 1.5 degrees. In order to comply with the 1.5 standard, it is necessary to achieve a net zero level of greenhouse gas emissions by 2050 at the latest. This means that a climatic balance between greenhouse gas emissions and their absorption will be achieved, among other things, by creating forests that absorb CO2. Structural transformations such as phasing out the burning of coal, oil and natural gas are also prerequisites.

The European Union and a number of UN member states made a commitment in September 2019 to achieve climate neutrality by 2050. To achieve this goal, financial resources are required to be allocated to pro-environmental investments. Article 2, section 1c of the Paris Agreement explicitly formulates the link between financial flows and climate-friendly actions (https://unfccc.int/…). Worldwide, around EUR 82,500 billion have already been invested in environmentally friendly and climate protection-related investments. This is because the financial sector is a lever for climate action.

The purpose of this paper is to analyze the importance of climate change finance, specifically the role of so-called green finance in environmental finance.

2. The rationale for the emergence of green finance

The economic and financial systems have a key role in combating climate change. On the one hand, they involve channeling financial flows into sustainable development investments, e.g. for energy and transport transformation in order to achieve climate neutrality. On the other hand, it is necessary to reduce climate-damaging activities in order to limit climate risks. This is essential for the financial system itself.

The entry into force of the Paris climate policy is associated with a relatively rapid process of phasing out the use of fossil fuels. This means that energy sources, which provide the basis for numerous industrial processes, services and infrastructure, as well as some areas of daily life (transport, diets, etc.), should undergo structural changes. All sectors of the economy are affected, however, some will be transformed to a greater extent and others to a lesser extent (Rydzewska, 2021). The key sectors that should be transformed are greenhouse gas emitters such as power plants, mining and fossil fuel industries, the transport sector and agriculture. The steps developed for structural transformation are diverse in nature. They involve, among others, the reconstruction of the energy system based on renewable energy, the creation of climate-friendly transport. The presented areas create a huge investment potential. At present, about 2% of EU GDP is invested in the energy system and related infrastructure. If the economy is to become greenhouse gas neutral, investment must rise to 2.8% of GDP, or about EUR 520 to 575 billion per year. In terms of the baseline, these are additional investments of between EUR 175 and 230 billion per year. Similar figures are presented by the IPCC's special report on 1.5°C temperature change, which predicts that the value of investments to limit temperature rise should amount to 2.5% of global GDP between 2016 and 2035. In contrast, the renewable energy report, “Clean Energy Investment Trends 2018”, puts global investment in 2018 at USD 332.1 billion. This amount excludes large hydroelectric plants (hydroelectric projects), though it also includes energy storage and the electric mobility sector, with the vast majority of investments in solar and wind (Clean Energy Investments Trend, 2018). The financial data presented shows the values of financial resources, but the most important point is that both investments already made and future investments should be allocated to achieve the climate goals set in Paris. As published in Nature, climate-friendly investments must overtake fossil fuel technologies by 2025 at the latest. (McCollum et al., 2018).

Climate protection measures, the implementation of which requires investment, simultaneously support the economic and financial systems. The Report of the Global Commission on the Economy and Climate of 2018 has calculated that climate-friendly infrastructure (transport, energy, etc.) will have an additional positive impact on the economy, amounting to about EUR 23,000 billion by 2030. These investments would not only reduce the risk of damage from climate change, but also make the air cleaner, create millions of new jobs, improve quality of life, and provide an opportunity for the economy to grow.

3. The essence and instruments of green finance

The concept of so-called green finance is an ambiguous term. It is used interchangeably with such terms as sustainable finance, ethical finance, sustainable and responsible investment, green bonds.

In a narrow sense, green finance is identified with financing of pro-environmental activities. In a broad sense, it is associated with funds allocated for investment in environmental protection, as well as aimed at preventing, minimizing and compensating for environmental and climate damage. These actions will have to involve changes in legal (regulatory), economic and institutional terms that will take on a character, shape and size that serves to redirect capital to a green, environmentally sustainable economy (Zielone Finanse w Polsce, 2021, p. 5).

Within the framework of green finance, various types of instruments may be distinguished. The difference between them and traditional forms is that in most cases, in addition to classic financial criteria, they take into account categories of ecological, social and ethical evaluation. These instruments are of different nature.

The first instrument discussed, the most well-known, is green bonds, also known as green loans. Their structure coincides with the general essence of bonds. The issuer, by issuing a debt security, borrows and then redeems the paper from the creditor (bondholder) at an agreed date, with interest. In turn, the funds obtained through the issue are used directly for investments in green projects: e.g. to improve energy efficiency, to expand renewable energy sources or to develop environmentally friendly transport infrastructure. Issuers of green bonds can be international institutions (supranational, quasi-governmental and agency green bonds (SSA bonds), the state (treasury/governmental green bonds), municipalities (municipal green bonds), companies (corporate green bonds) and financial institutions (financial sector green bonds).

Another instrument is sustainable funds. They are a type of investment funds which, in addition to generating a financial return, are also aimed at ethical, ecological and social objectives. These investments can include both companies with green operations and countries that meet specific sustainability requirements. The investment strategies of sustainable investment funds are highly diversified. One of them is targeting problems related to the SDG strategy (Sustainable Development Goals) (www.un.org./sustainabledevelopment/…).

Impact investing is investing funds in projects that generate profits and have a positive environmental or social impact. They mainly include projects where the social effect is in the foreground, i.e. social benefit that exceeds the business goal. The emergence and growing popularity of this instrument is related to the popularization of the ESG concept, i.e. socially responsible investment taking into account the needs of the environment, social responsibility and corporate governance. The impact investment market provides equity to fund activities that help solve some of the world's most pressing problems. These include sectors such as sustainable agriculture, renewable energy, conservation, microfinance, and affordable and accessible basic services, including housing, healthcare and education.

The last of the described instruments is crowdfunding. This instrument involves collecting funds from a great number of small investors (mainly Internet users) and using them to finance projects. In most cases, the goal of financing is determined to encourage maximum participation. With regard to green finance, numerous climate protection projects as well as social initiatives are currently financed by this means.

4. Analysis of the use of green finance instruments in financing pro-environmental goals

In accordance with the theoretical considerations presented, the instruments that are recognized as means of financing climate protection goals are green bonds, sustainable funds, impact investments and crowdfunding funds.

One of the most dynamic financial instrument markets in the world is the green bond market. In 2021, the annual value of issuance of these instruments reached USD 522.7 billion and exceeded the threshold of half a trillion USD. This represents an increase of 75% over the previous year and an increase of over 1250% with respect to 2015 (Fig. 1). The green bond market is currently estimated to be worth about USD 1.6 tn.

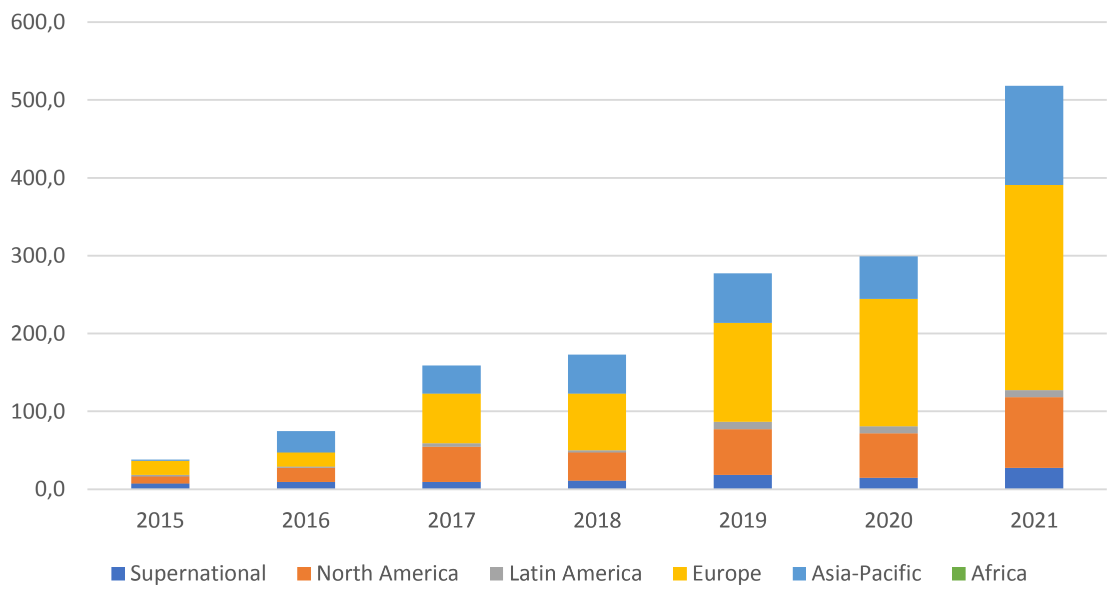

Figure 1. Green bond issuance volume by region (USD billions) Adapted from: Sustainable Debt, Global State of Market 2021, Climate Bonds Initiative.

The most active region for green bond issuance was and still is Europe. In 2021, half of the issuance volume came from Europe (USD 265 billion). The most dynamic growth in this region was in corporate (136%) and sovereign (103%) financial bonds. The next region in terms of issuance volume was Asia Pacific (USD 129.5 billion). North America, on the other hand, declined in importance (issuance volume of USD 92 billion in 2021). SNAT issuers were the fourth largest source of green bonds, with annual volume doubling to USD 27.3 billion. This increase may be explained by a USD 13.9 billion debut from European Union (EU) green bonds. The lowest volume of green debt securities was recorded by Latin America and Caribbean (USD 8.2 billion).

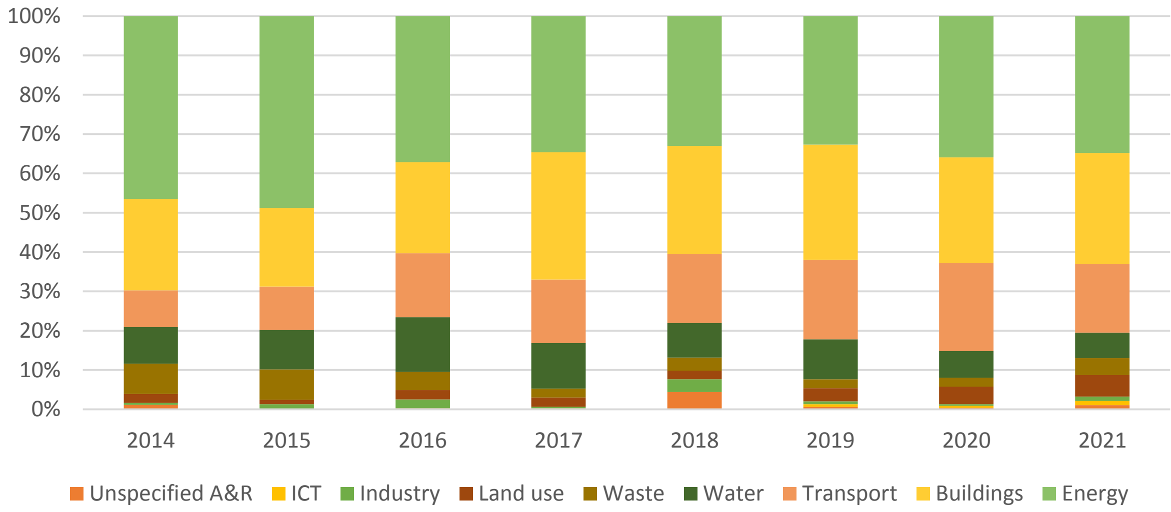

Figure 2. Use of Green Bond proceeds Adapted from Sustainable Debt, Global State of Market 2021, Climate Bonds Initiative.

Funds from green bond issuance were primarily used to finance the needs of 3 sectors: Energy, Tansport and Buildings. This trend is evident throughout the period under study (Fig. 2). In 2021, these three sectors together accounted for 81% of the total amount of issuance. Energy and Transport were the most supported by issuers from the non-financial corporate sector providing 40% and 27% of total capital respectively. Construction received the most support from financial corporations (37.5%).

Sustainable funds are another instrument analyzed. Due to the trend of increasing interest in the issue of sustainable development, one can observe in recent years that investments of funds are directed towards this type of activities.

As shown in Figure 3, the number of balanced funds, i.e. (investment funds and ETFs), has grown rapidly since 2016. As reported by Morningstar and TrackInsight, the total number of balanced funds from 2016 to 2020 nearly doubled, while asset values more than quadrupled from USD 405 billion to more than USD 1.7 trillion. This pace has accelerated significantly over the past two years, particularly in terms of AUM, which grew by more than 50% in 2019 and then nearly doubled in 2020. The majority of balanced funds are located in Europe (73%), followed by North America (18%). Other regions, including developing countries, account for less than 10% of funds located in Europe.

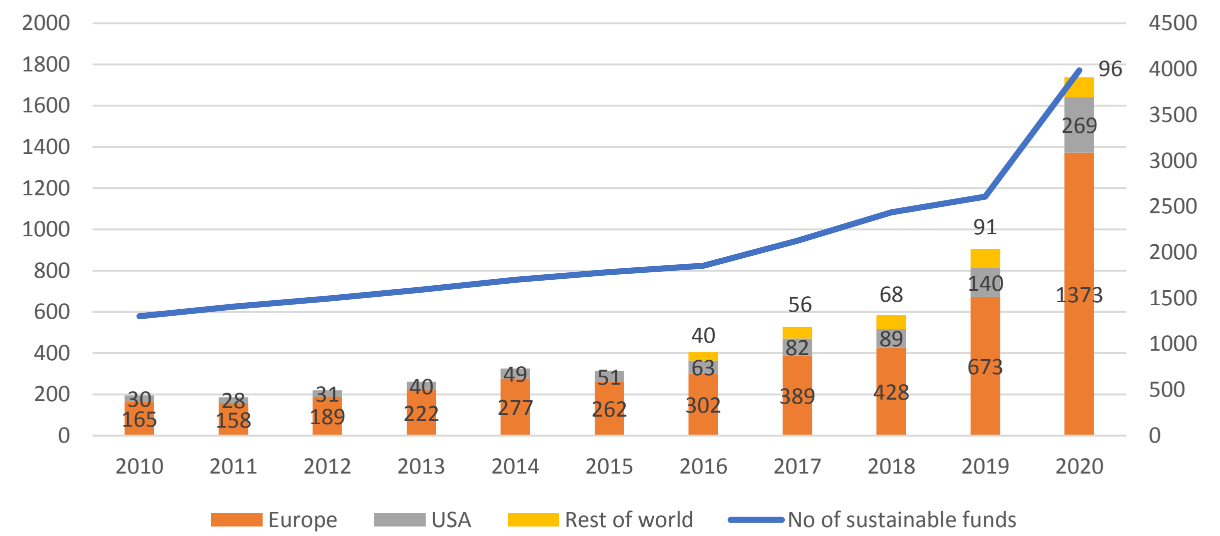

Figure 3. Number of sustainable funds and assets under management, 2010-202, Adapted from: The rise of the sustainable fund market and its role in financing sustainable development, UNCTAD 2021, p. 6.

One of the investment strategies of sustainable funds is to target sustainability themes or sectors, including the SDGs. UNCTAD's analysis of 800 sustainable equity funds showed that approximately 27 percent of them (USD 145 billion of their total assets (AUM)) are invested in eight key SDG sectors (Figure 4). Health sector, is the most invested SDG sector for sustainable funds (USD 77 billion). These were followed by renewable energy (USD 32 billion), food and agriculture (USD 19 billion), and water and sanitation (USD 9 billion).

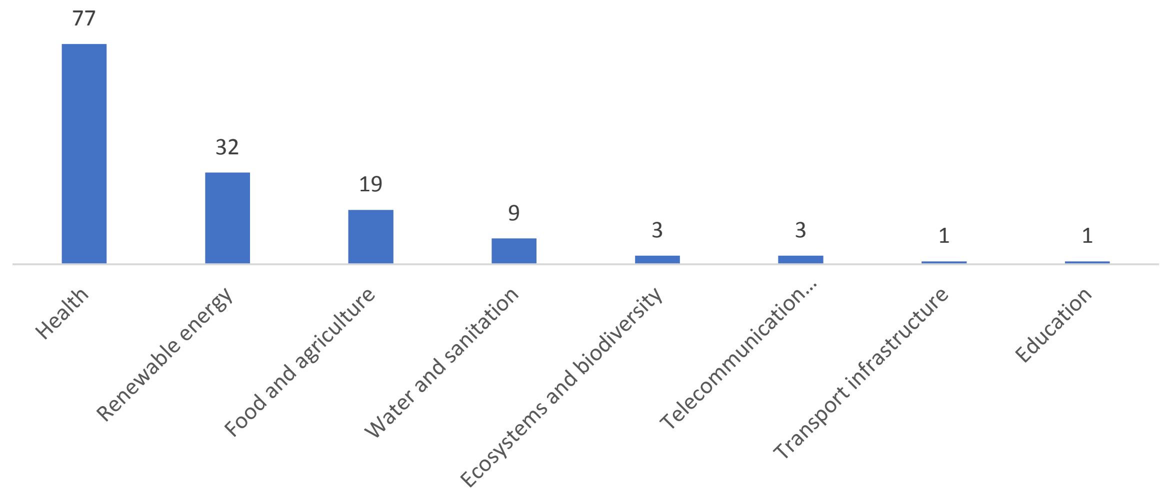

Figure 4. Deployed assets across eight SDG sectors, 2020 (billions of dollars), Adapted from: World Investemen Report 2021, Investing In Sustainable Recovery, UNCTAD, p. 221 (pdf).

In terms of climate impact, sustainable fund stocks tend to outperform the overall fund market. Compared to the MSCI ACWI index, they have higher exposure to cleantech (about 3.5 percentage points higher) and water treatment (about 2.5 percentage points higher), and lower exposure to fossil fuels (excluding coal) (over 3 percentage points lower) and coal (over 1.5 percentage points lower) (UNCTAD 2021, p. 13).

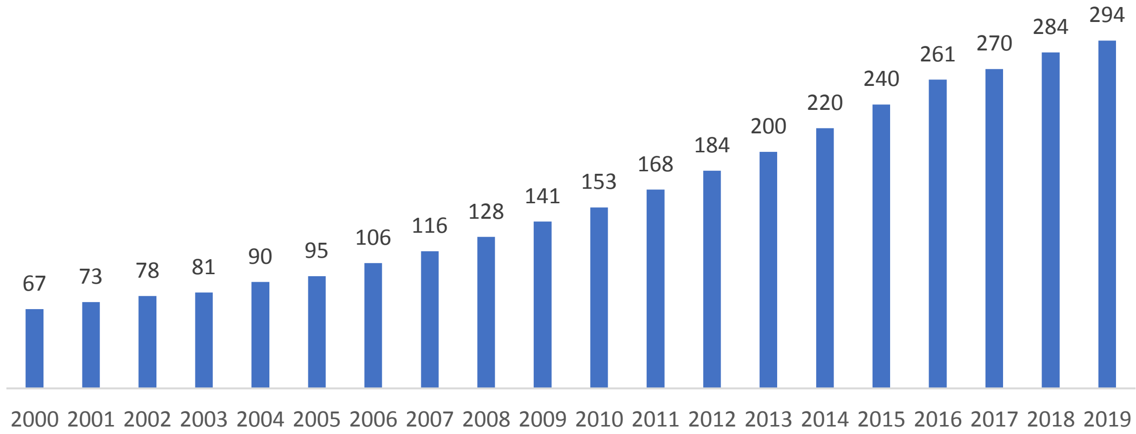

Figure 5. Cumulative number organization making impact investments, Adapted from: GIIN, Annual Impact Investor Survey 2020.

With respect to the impact investment market, a study conducted among 294 organizations that invest in environmental and social impact activities shows that just over half of all respondents (52%) began investing in impact projects within the last decade. More than three-quarters of respondents (77%) are based in developed markets, with another 21% in emerging markets. Seven percent of impact investments are based in SSA (Sub-Sahara Africa), 6% in LAC (Latin America and the Caribbean), and 3% in Southeast and South Asia. Most respondents are based in the United States, followed by the United Kingdom, Canada and the Netherlands.

The motives for impact investments vary. However, it is worth noting that the fourth most important goal is “contribution to a global agenda, such as the UN Sustainable Development Goals or the Paris Climate Agreement” (62% indicated as very important and 30% somewhat important). This indicates that impact investors are becoming increasingly aware that significant capital flows are needed to address the climate crisis.

While as reasons for undertaking impact investments focused on climate protection, most respondents (83%) do so in order to “address an urgent, significant global challenge”. More than two-thirds seek to ‘mitigate against the physical risks caused by climate change’ (Fig. 6), such as droughts, storms, and floods, among other natural disasters resulting from increased temperatures, rising sea levels, and changes in weather patterns. By contrast, only 54% address climate change through impact investments in order to mitigate against the transition risks caused by climate change—that is, unplanned or abrupt changes to businesses or assets that may occur after an investment transaction—such as changes in policies, shifts to low-carbon technologies, or other liabilitiesMore than one-third of respondents address climate change in response to client interest, while just 15% do so in response to regulations.

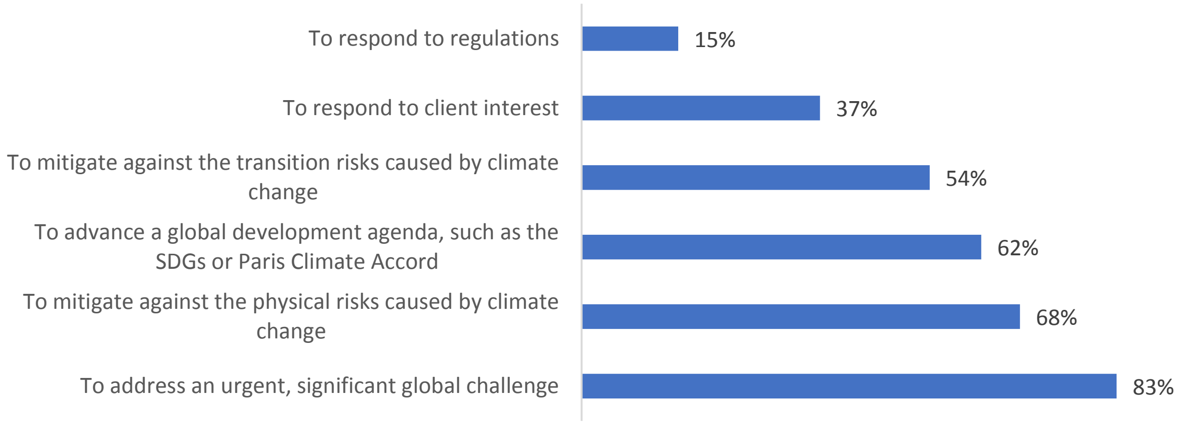

Figure 6. Reasons for addressing climate change through impact investments. Adapted from: GIIN, Annual Impact Investor Survey 2020.

Respondents take various approaches to address climate change through their investments. Most commonly, impact investors seek investments that mitigate climate change by reducing greenhouse gas emissions (84%). Meanwhile, close to the same proportion of respondents (82%) seek investments that prevent future greenhouse gas emissions. Perhaps unsurprisingly, 78% of those that seek to reduce greenhouse gas emissions also seek to prevent future emissions (GIIN, 2020).

The last green finance instrument analyzed is crowdfunding. Unfortunately, there is no data on collections organized for the purpose of financing environmental protection activities. However, based on data concerning the entire crowdfunding market, it can be concluded that the same tendencies are observed on the market related to financing pro-ecological investments.

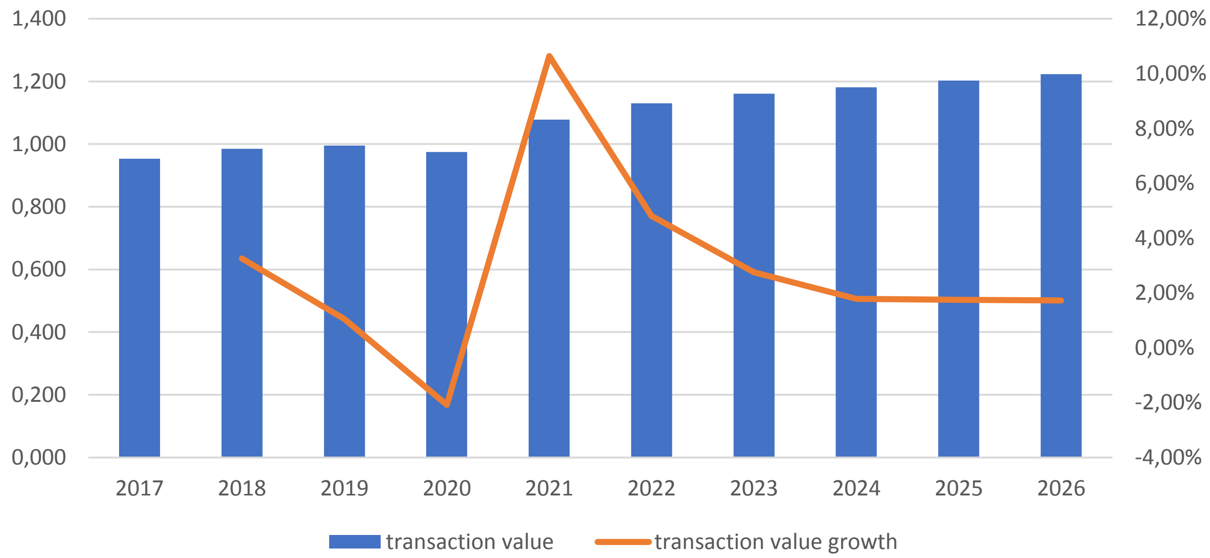

Figure 7. Transaction value and annual growth rate of crowdfunding transactions (forecast) from 2017 to 2026. Adapted from: Sources: https://www.statista.com/outlook/dmo/fintech/alternative-financing/crowdfunding/worldwide.

Figure 6 shows that the value of crowdfunding transactions is growing through 2017 (except for the exceptional year of 2020), and the growth rate is projected to continue at 2% through 2026. The value of transactions in crowdfunding is projected to reach USD 1.13 billion in 2022, rising to USD 1.22 billion in 2026. The average funding per campaign in the crowdfunding segment amounts to US$6.15k in 2022.

In 2020, the global crowdfunding market was valued at 12.27 billion U.S. dollars and was forecast to double by 2027, growing at compound annual growth rate (CAGR) of 11 percent (https://www.statista.com/outlook/…).

5. Conclusions

Financing climate protection and other pro-environmental activities faces a significant challenge. It is only by mobilizing additional capital, including private capital, that climate challenges may be financially addressed. This is why the term "green finance" was developed to refer to the financial streams for climate protection.

The presented analysis of the development trends of selected green finance instruments shows that this market is developing rapidly. For both green bonds and sustainable funds and impact investments, the growth rate in the number and value of instruments has been the highest in recent years. The main issuers of these instruments are developed countries. This is due to both the wealth of these countries and their awareness of the need for climate investment. The analysis of investment directions indicates however that they are related to activities concerning environmental protection or other aspects of sustainable development.

At the same time, it should be emphasized that the potential of green finance is not exhausted. In order to achieve the EU's environmental goals of climate neutrality by 2050, more, and above all private, capital urgently needs to be mobilized and directed towards climate-related investments. To this end, action must be taken at supranational as well as national level to develop sustainable development measures. These actions should address four areas: a stable institutional environment (e.g. changes in regulations), systemic market education (e.g. available platforms for sharing knowledge and experience), competitive financing (e.g. new financial instruments to support the transition and provide funding for innovation); technological and expert support (e.g. availability of knowledge and materials, tools to support analysis of available ESG factors) (Zielone Finanse w Polsce, 2020, p. 93).

The considerations conducted in the paper and the conclusions formulated:

- contribute to the development of theory on instruments supporting climate protection actions, in particular financial instruments included in the so-called green finance,
- in the management aspect, they indicate the need to improve the processes related to the development of legal frameworks, technological and expert support, education and development of financial instruments for activities related to sustainable development,
- from the social point of view, they indicate the need for further support for activities, including those of a financial nature, in the field of pro-ecological activity, due to their social importance.

The limitation of this paper is the lack of data on the use of the whole range of instruments that finance investments related to sustainable development. However, it should be mentioned that the green finance market is developing and new tools are still being created. The paper may therefore serve as a basis for further analysis in the development of instruments used to finance pro-ecological activities.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

PROJECT MANAGEMENT IN TURBULENT TIMES OF COMPLEXITY OF SOCIAL AND TECHNOLOGICAL SYSTEMS

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Purpose: The aim of the article is a Viewpoint based on the General Review of the state of knowledge regarding current trends in project management, taking into account the high volatility of the environment and the increasing complexity of social and technological systems.
Design/methodology/approach: The article presents a narrative review of the literature and refers to the results of the author's own research.
Findings: With the increasing volatility of the environment and the increasing complexity of social and technological systems, the importance of using hybrid project management and the process approach to management in organisations will increase.
Practical implications: Nowadays, a vast majority of organisations manage projects in a traditional way. Observations contained in the article will contribute to the potential attention of decision-makers and the implementation of new management methods in organisations.
Social implications: Projects are not only inscribed in the activities of the organisation but also their results affect the quality of life of the population. By improving the efficiency of project management activities, it is possible to significantly affect the quality of people's lives.
Originality/value: The article presents the significance of hybrid project management and the process approach in turbulent times of complexity of social and technological systems in a systematic and review way.

Keywords: Project management, new technologies, uncertainty, complex environment.

Category of the paper: Viewpoint.

1. Introduction

Over the years, project management has been subject to constant changes (Kerzner, 2013; Spalek, 2013c; Trocki, Bukłaha, 2016). These changes were undoubtedly related to the need to improve the organisation's activities (Trocki et al., 2012, p. 15; Spalek, 2016a) in order to build a competitive advantage (Martens, Franklin, Mauro, Silva, De Freitas, 2018). As results of the author's previous research have shown[1], the improvement of project's activities can be considered in terms of process and structure. The first is related to the dynamic functioning of the organisation, while the other is relevant to the static functioning. Recently, the importance of the process approach to project management has increased, as enterprises are experiencing a far-reaching dynamisation of activities linked to the introduction of breakthrough technological changes. Therefore, it may be concluded that technological progress plays and will continue to play an increasingly important role in creating changes in project management. However, it may take a moderating and mediating or inductive form. The moderating and mediating character becomes apparent in situations where the development of new technologies affects the modification of the methods used so far (Davidson, Chiasson, 2005; Yen, Li, Niehoff, 2008) or their wider dissemination (Tiwana, McLean, 2005; Wang, Wang, 2019). Moreover, technological progress imposes the emergence of new ways of project management, an example of which may be an agile approach to project management (Wyrozębski, 2016).

The subject of the influence of modern technologies on project management has already been elaborated by researchers, although it was mostly focused on information systems and their application possibilities to improve tools and techniques in project management (Liberatore, Pollack-Johnson, 2003; Sambamurthy, Zmud, 1999). It was only at the constituting of the last decade that attention began to be more closely paid to the impact that technological progress may have on the activities of the organisation, including project management (Kwak, Anbari, 2009). With the further development of modern technologies and their wider use in enterprises, determining this impact becomes more and more desirable (Gomes, Oliveira, Chaves, 2018; Roberts, Piller, Luttgens, 2016). This was confirmed by the author's research[2] carried out in 2019, which reveals that currently, technologies associated with social media and Industry 4.0, including those very closely linked to modern technologies, have the greatest potential impact on project related activities in enterprises.

Summing up, it should be noted that contemporary project management should take into account far reaching changes in the activities of enterprises, which are brought about by the expansive development of modern technologies, with particular emphasis on those related to social changes.

[1] The research was conducted as part of NCN grant no. N504 678740 and cooperation with the Project Management Institute, the key conclusions were published in: Spalek, 2012, 2013a, 2013b, 2014.

[2] International empirical research was carried out on a sample of 264 respondents (project managers or members of project teams) from enterprises running IT, production and construction projects. The research results are presented in the article: Spalek, S. (2020). Współczesne wyzwania technologiczne a zarządzanie projektami w organizacjach. In: E. Sońta-Drączkowska, I. Bednarska-Wnuk (eds.), *Wybrane aspekty zarządzania procesami, projektami i ryzykiem w przedsiębiorstwach* (pp. 103-114). Łódź: Publishing House of the University of Łódź.

2. The impact of environmental variability on project management

As it has already been addressed, along with a growth in the dynamics of activities in organisations, the importance of the process approach to project management has increased. The high volatility of the environment has also resulted in the emergence of the concept of Agile Project Management (APM) alongside traditional (waterfall) project management and Hybrid Project Management (HPM) combining the two previously mentioned approaches. Moreover, the concept of projectification (Maylor, Turkulainen, 2019) was introduced, associated with an increase in the number of projects and their importance in the activities of the organisation. Therefore, there was a need to define a system framework for project activities in organisations.

Along with the ongoing dynamisation of the organisation's activities, the process approach more and more often constitutes the basis for the functioning of the organisation (Nowosielski, 2009, p. 11), with particular emphasis on project management (Trocki, 2012a, pp. 66-67). This statement is of particular importance in the context of project management in turbulent times of complexity of social and technological systems. Moreover, the latest international scientific studies indicate the important role of processes in project management (Antony et al., 2019; Bordley, Keisler, Logan, 2019; Crama, Sting, Wu, 2019; da Costa, Amaral, Fernandes, Rozenfeld, 2019; De Benedittis, 2019; Dolata, 2019; Jalocha, 2019; Karlsson, Kurkkio, Hersinger, 2019; Li, Hall, 2019; Midler, 2019; Tarraco, Bernardes, Borini, Rossetto, 2019). Therefore, it is advisable to focus on the process aspect of project management, as a response to the increasing dynamics of activities undertaken in organisations.

Following Michał Trocki (2019a, pp. 10-11) and following the provisions of ISO 21500:2012 *Guidance on project management* (ISO, 2012) standard, project activities should be defined in terms of processes as a complete and coherent set of processes that create three groups:

- project management processes,
- product processes,
- support processes.

It is significant that only the first group of processes, i.e. project management processes, is the exclusive domain of project management, the other two are not unique to project management (ISO, 2012, p. 8; Trocki, 2012, p. 68).

The structure of management processes can be considered from two perspectives (ISO, 2012; PMI, 2017): as groups of processes occurring at different stages of the project execution and as groups of subject related processes, which are processes reflecting homogeneous issues (Trocki, 2012b) also referred to in the literature as areas of knowledge in project management (Wyrozębski, 2017, p. 101; Nogalski, Szpitter, Jabłoński, 2016, p. 21). The first group includes processes related to management in the key areas of the project, i.e. integration, stakeholders, scope, resource, time, cost, risk, quality, procurements and communication. The other group includes processes related to stages of the project management cycle, i.e. initiating, planning, implementing, controlling and closing.

When analysing the intensity of the occurrence of processes at individual stages of the project management cycle, it may be noticed that the particular intensity of management processes occurs at the stages of planning and then successively for controlling and executing. This observation shows the importance of organising, which is largely related to the three stages mentioned. While, organising is understood as: (1) planning and coordinating individual stages of activities, (2) creating a team for joint action or establishing an institution, organisation, etc., (3) being a factor determining the arrangement and functioning of the elements of a whole (PWN, 1997-2019). In the context of changes brought about by complex social and technological systems, organising as part of the project management processes has a special place in them. The importance of organising was already indicated by Tadeusz Kotarbiński (1999, p. 348), who stated that organising is a combination of elements of collective actions (subjects, things, purposeful processes and actions) into a whole, so that the structure of the resulting entity contributes to the achievement of the common goal of these items. In this way, Kotarbiński foresaw the 'material and immaterial' idea of organising that is focused on creating value for the customer, which can be successfully implemented in a symbiosis of modern social and technological systems. The current trends in management also indicate the important role of organising, and it is precisely with the use of the relationship between the various resources of the enterprise (Pabian, 2017; Rokita, 2009; Zakrzewska-Bielawska, 2012).

3. Multiple complexity of systems and project management

It is assumed in the literature that Traditional Project Management (TPM) means the use of tools and techniques in the waterfall management of project stages, with particular emphasis on scheduling as well as budget and quality management in the project (Masciadra, 2017; Spalek, 2016b). As Manfred Saynisch (2010) pointed out in their 2010 article, traditional project management (TPM) cannot autonomously meet the challenges of increasing complexity in social, economic and technological systems. This statement is also very relevant today. This does not mean that the use of waterfall project management should be discontinued. As yet, in some types of projects it works perfectly. However, over the years, traditional project management has also undergone significant modifications. In its constituting, special attention was paid to the triangle of constraints, also known as iron or gold, which included managing time, costs and the scope of the project. Currently, this concept is still the focus of researchers (Pollack, Helm, Adler, 2018), although it is often extended to the business aspects of projects (Kloppenborg, Tesch, 2015). In addition, increasing attention is paid to managing change

(Ansari, 2019), stakeholders (Toor, Ogunlana, 2010), communication (Yang, Chen, An, Cui, 2015) and project integration (Marques, Gourc, Lauras, 2011), with particular attention on knowledge management in these areas (Camison-Haba, Clemente-Almendros, Gonzalez-Cruz, 2019).

The concept of agile project management (APM) was born on the wave of criticism from traditional project management. The turning point in the emergence of the concept of agile project management is the 2001 Agile Manifesto (Cohen, Lindvall, Costa, 2004). However, both before and after that date, researchers focused on agility beyond the framework of information systems (Thomke, Reinertsen, 1998; Ramesh Devadasan, 2007). It should be noted that in its assumptions, APM rejects the main role of the triangle of constraints. In this concept, it is assumed that the most important aspect is to match the product or service to the customer's requirements in the best possible way. Therefore, the most important issues are: communication with the customer, interactions in the project team, functionality of the solution and flexible response to changes in requirements. Other aspects of project management are subordinated to them. At the same time, while being part of IT project management, commonly accepted methods of agile project management have been developed – such as SCRUM (Santos, Flentge, Begin, Navarro, 2011) – in other industries, agile project management may take various forms (Conforto et al., 2014). As such, it still remains a more general concept that is adapted to specific enterprise applications (Nicholas, Steyn, 2017).

Comparing the principles of traditional and agile project management, it can be concluded that TPM is better based on a *hard* (tools and techniques) approach to project management, while APM emphasises the *soft* aspects of cooperation between people in the project. It is worth emphasising that both approaches are aimed at providing a solution for the customer. The application of TPM or APM may be limited by the environment in which the project is operating. However, projects implemented with the use of agile methods are more suitable for implementation in dynamic project environments (Serrador, Pinto, 2015).

After the initial period of an uncritical approach to agile project management and attempts to popularise this practice, voices appeared pointing out the limitations of this concept (Boehm, Turner, 2005; Katayama, Goldman, 2011). It is especially difficult to apply the principles of agile project management in large and very formalised organisations. Problems with the appropriate selection of members for project teams should also be indicated, who, having the appropriate knowledge and experience, would be ready to work in very dynamic, self-organising teams. Moreover, in agile project management we deal with a very high degree of trust between the project team and the customer, while in many organisations there is a high level of distrust resulting from previously implemented projects or business relationships.

Trying to meet the challenges resulting from the dynamisation of the environment, increasing variability of customer requirements and technological progress, the organisations were also forced to adapt the way of project management to the new realities. When the TPM adaptation possibilities and limitations in the application of APM reached the limit, selected solutions from TPM and APM were used. This approach offered an opportunity, especially for large enterprises outside the IT industry, to adapt products and services faster without the need to introduce deep and costly organisational and personnel changes. This was made possible by the use of agile practices for selected product elements or stages in the project life cycle, while applying an overall flowchart of the traditional approach to project management. Over time, this approach became popular under the name of hybrid project management (HPM) (Wysocki, 2011, pp. 405-408). It can be concluded that the organisation using HPM derives solutions from both TPM and APM, and the scope of their application may differ depending on the enterprise and the specifics of the project.

It is worth noting the results of international longitudinal research conducted since 2012 by Ayelt Komus of the University of Koblenz on the use of individual project management methods in companies (Komus et al., 2020). The results of this research clearly show the growing importance of HPM. Thus, in 2012, 27% of all researched projects were managed in a hybrid way, and in 2019 as much as 43%. It is significant that HPM is also more frequently adapted in sectors other than IT. Its importance in the new products development is also growing – this level is currently estimated at 20%.

HPM can be both used at the project and programme or project portfolio level. Whilst, the project portfolio is understood as a set of projects grouped in terms of benefits for the organisation, as a result of the implementation of these projects various products or services are created. The programme is understood as a set of projects whose common goal is to provide a given product or service. As part of a single project, it is possible to apply TPM and use APM only for the implementation of selected tasks for which there is a significant variation in customer requirements or there is a high uncertainty of the methods and tools used. On the other hand, utilisation at the portfolio or programme level is the selection of those component projects that will be implemented using agile methods, while using TPM at the programme or portfolio level.

4. Conclusion

Summing up, it should be noted that with the increasing complexity of modern social and technological systems, hybrid methods of project management, combining traditional and agile project management approaches, are growing and will continue to grow in importance. Moreover, the high volatility of the environment imposes the combining of process and project related approaches in organisations increasingly often.

The above observations constitute a strong premise for project managers in organisations to redefine the existing traditional approaches to project management in organisations.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

ONLINE FORMS AND SPREADSHEET AS MEANS TO SUPPORT QUALITY MEASUREMENT BY THE SERVQUAL METHOD

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Purpose: The main purpose of the research is to devise and present a concept for a solution enabling integration of popular off-the-shelf online forms with a tool aligned with the MiRel concept used for quality measurement by application of the SERQUAL method.
Design/methodology/approach: The analysis performed by the author comprised various possibilities of using standard features of popular online forms to store data for purposes of the SERVQUAL method. This involved identification of several potential layouts of the master table where the answers previously received are kept. The analysis concerned the data structure applied in the tool designed, as proposed in the literature, in accordance with the MiRel concept, to support the method in question. The elements identified in this structure were the attributes whose values should be entered directly and manually in tables as well as those whose values should be added automatically on the basis of the answers previously received. Solutions were developed to enable automatic data migration from the master table to the tool's respective tables.
Findings: The data required for purposes of the SERVQUAL analysis, supported by a tool created in a spreadsheet according to the MiRel concept, can be successfully stored by means of commonly available online forms. What proves to be problematic is the impossibility of verifying the correctness of the answers in terms of the relevance of individual dimensions, yet in this respect both the verification and potential adjustment of the answers received can be inherent in the mechanism responsible for data migration from the master table to the tool's tables. A fully functional solution enabling data to be retrieved from the master table and moved to the tool's tables can be developed using built-in spreadsheet features only, without the need for any code created in any programming language.
Practical implications The solution proposed in the paper can be used in practice when measuring quality using the SERVQUAL method.
Originality/value: The concept described in the paper is the author's original solution.

Keywords: spreadsheet, database, MiRel, data processing, quality management.

Category of the paper: Conceptual and technical paper.

1. Introduction

Day-to-day operations require every contemporary organisation to process massive amounts of information. It is obvious that more or less complex IT solutions must also be used on an ongoing basis. Despite the continuous evolution of already extensive and highly integrated systems, much of the data stored in organisations is still processed using one of the most popular of the available tools, which a spreadsheet most certainly is. There are various concepts mentioned in the literature as to how this group of tools can be put into practical use in different operating areas of organisations. These include finance, sales and marketing, or HR management. Many of the solutions proposed require data processing to be supported for the sake of quality management. The suggested solutions include using spreadsheets to support the ABC method (Szczęśniak, 2010), the Suzuki method (Szczęśniak, 2020b), quality control (Carlberg, 2007), or statistical process control (Knight, 2009; Szczęśniak and Molenda, 2013). A part of this domain is a tool intended to support data processing in quality measurement using the SERVQUAL method (Szczęśniak, 2021). It was designed by Parasuraman, Zeithaml, and Berry (Parasuraman et al.,1995; Parasuraman et al., 1998) to measure the discrepancies between the quality perceived and the quality expected of a service delivered to customers. This measurement is conducted by means of a questionnaire whose main part prompts customers to assess the extent to which they agree or disagree with individual statements. The questionnaire statements make references to items associated with the quality of the service being surveyed. For each item, the form provides a statement pertaining to the expected quality and one concerning the perceived quality. According to the original approach, this assessment is based on a 7-point Likert scale (Ulewicz, 2014; Pradela, 2015; de la Cruz del Río Rama et al., 2014), where 1 means that the respondent strongly disagrees with a given statement, and 7 – that they strongly agree. Next to the original seven-point scale, a five-point variation is also in use (Luke and Heyns, 2020; Aghamolaei and Zare, 2008). In a decided majority of cases, statements concerning a certain item are positive in their overtone, which means that a higher number of points given is correlated with a higher assessment of the service level. However, a survey questionnaire may well comprise items linked with negative statements. Where this is the case, the answers thus obtained should be modified by reversing the scale prior to further analysis. Each item linked with a given statement is assigned to one of key dimensions. Those defined in the original version of the method are empathy, reliability, tangibles, assurance, and responsiveness (Zeithaml et al, 1990; Dalrymple et al., 1995), but this set is sometimes modified (Nowacki, 2005; Chatzoglou et al., 2014; Pakdil and Aydın, 2007). When filling in the questionnaire, the customer decides on the relevance of individual dimensions by distributing 100 points among them (Zeithaml et al., 1990; Dalrymple et al., 1995). The dimensions which have received the highest number of points are those the customer considers the most relevant. Additionally, the questionnaire can be used to collect supplementary information which characterises the customer. Based on the data thus acquired, one can establish the value of individual indices which make it possible to assess the perceived vs the expected quality. Since there are no explicit guidelines as to the indices that can be calculated, different studies mention various kinds of approach. Papers commenting on studies performed using the SERVQUAL method mention 14 identified indices which one can calculate (Szczęśniak, 2021). There is also a tool proposed as a means to support the SERVQUAL method in practice (Szczęśniak, 2021), developed in a spreadsheet in accordance with the MiRel concept (Szczęśniak, 2017, 2018a, 2018b, 2020a). One of the assumptions underpinning this tool is that data are collected using a questionnaire created in a spreadsheet. However, what seems to be considerably more convenient in this respect is to use online forms, which are growing in popularity. The following sections of this paper discuss a concept of using such forms to collect data for purposes of the SERVQUAL method, as well as a concept of their integration with the tool proposed.

2. Data collection using online forms

When assessing the possibility of integrating the tool supporting the SERVQUAL method with online forms, it was assumed that one should use the most popular free-of-charge forms, i.e. the solutions provided by Microsoft and Google, referred to as variant 1 and variant 2, respectively, in this paper. The functionality range of both solutions is very similar.

The entire form was divided into 4 parts. Part one contained information about the respondent, part two concerned the relevance of individual dimensions, part three – the respondent's expectations as to the service subject to assessment, and part four – the actual assessment. Each part was defined using the *Section* type item, available in both solutions. The questions contained in the first part of the form allowed the respondent to choose one among several options. In Microsoft forms, this is the *Choice* type question, while in those from Google – the *Multiple choice* type. In the form's second part, the best solution would be to pose a question which makes it possible to assign a specific number of points to individual answers, and where all answers are taken into consideration collectively, enabling verification if the total score is consistent with the assumptions previously adopted. Unfortunately, none of the solutions analysed offers such a question type. With regard to the foregoing, it was decided that the relevance of individual dimensions would be assessed in separate questions by assigning a number from 0 to 100 to each of them, with an explicit reservation that the sum of all points given must be 100. In Microsoft forms, the *Text* type question was used, while in Google forms – that of the *Short answer* type. In both cases, a limitation was imposed on the values to be entered so that one could only enter numbers from the 0-100 range. The sum condition is not verified in the form, and one can submit a filled-in questionnaire if the values entered sum up to a number different than 100. Consequently, as the form was being integrated with the tool intended to support the processing of the data acquired, it was necessary to propose a mechanism that would proportionally adjust the values being entered in such a manner that the result to be obtained complied with the premises of the SERVQUAL method.

Based on an analysis of the available types of questions, it was concluded that there were two options which could be applied in the third form part where the persons surveyed were expected to state whether or not, and if so to what extent, they agree with individual statements.

The first option entails providing multiple statements in a single question. This being the case, consecutive questions are presented in a concise form, one below another, with the rating scale displayed next to each question. The question type which one should apply in the form to make use of this option is:

- *Likert* – when using Microsoft forms.
- *Multiple choice grid* – when using Google forms.

In both cases, the main phrase used in the question does not refer to the statement being assessed, but only provides additional information. According to variant 1, individual statements are put in the question as consecutive *Statement* type items, while in variant 2 – as type *Row* items. On account of the restriction in place as to the number of type *Statement* items in a single question of the *Likert* type, when using Microsoft forms, one must add two *Likert* type questions in order to provide the standard number of 22 questions.

Option two assumes that there is a separate question for each statement in the form. With this variant in place, statements are presented in the form's consecutive paragraphs, while the rating scale is always to be found under the statement being assessed. The question type which one should apply in the form to make use of this option is:

- *Rating* – when using Microsoft forms.
- *Linear scale* – when using Google forms.

In both cases, the main phrase used in each question is invariably the statement subject to assessment.

The layouts of the third and fourth part are identical, which makes it possible to use exactly the same question types in the form's last part as in the third.

The answers obtained when using the forms in question can be automatically added to a spreadsheet as a single master table. In the consecutive rows of this table, answers given by consecutive respondents are provided, and each column contains answers to one specific question or those concerning a given statement. Column headers are consistent with the main phrases used in the questions retrieved from parts 1 and 2, as well as from parts 3 and 4, where the form has been created according to option 2. If the form has been created as per option 1, the headers of the columns where the answers to questions from parts 3 and 4 are kept depend on the brand whose forms are in use. When using Microsoft forms, these headers are consistent with the text entered as consecutive items of the *Statement* type. In the case of the forms from Google, these headers contain text which combines the question's main phrase and the text entered in square brackets as another item of the *Row* type. In Microsoft forms, the sequence of the master table columns containing answers can be random. Additionally, the columns which come first in this table are the technical ones, such as *ID, Start time, Completion time, Email* and *Name*. In Google forms, the sequence of the columns containing answers matches the sequence in which questions appear in the form, while the initial one is a single technical column *Timestamp*. The layout of columns in master tables has been depicted in Figures 1 and 2.

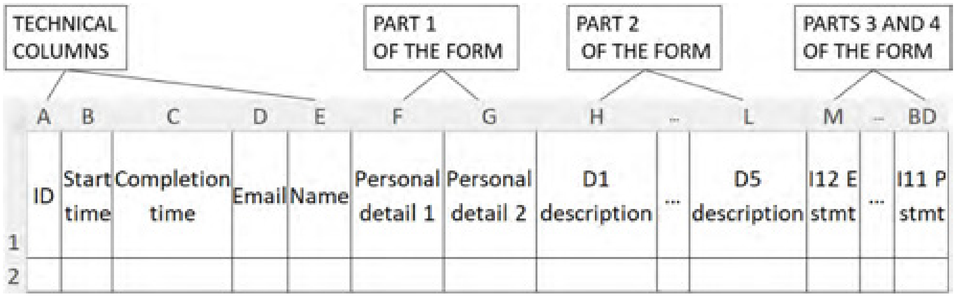

Figure 1. Layout of columns in a master table generated when using Microsoft forms.

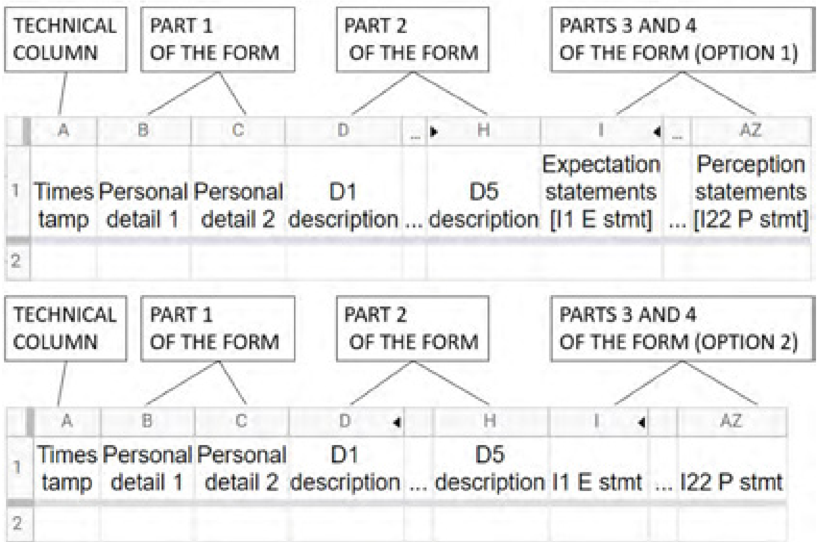

Figure 2. Layout of columns in a master table generated when using Google forms.

3. Form and tool integration in a spreadsheet

The tool proposed in the literature makes it possible to retrieve values of all the identified basic indices taken into account when using the SERVQUAL method. In this tool, data are stored in tables representing entities such as *Respondent, Personal detail 1* and *Personal detail 2, Item, Statement, Statement answer, Dimension, Dimension answer*. The links between individual entities as well as the attributes identified for them are consistent with the model depicted in Figure 3.

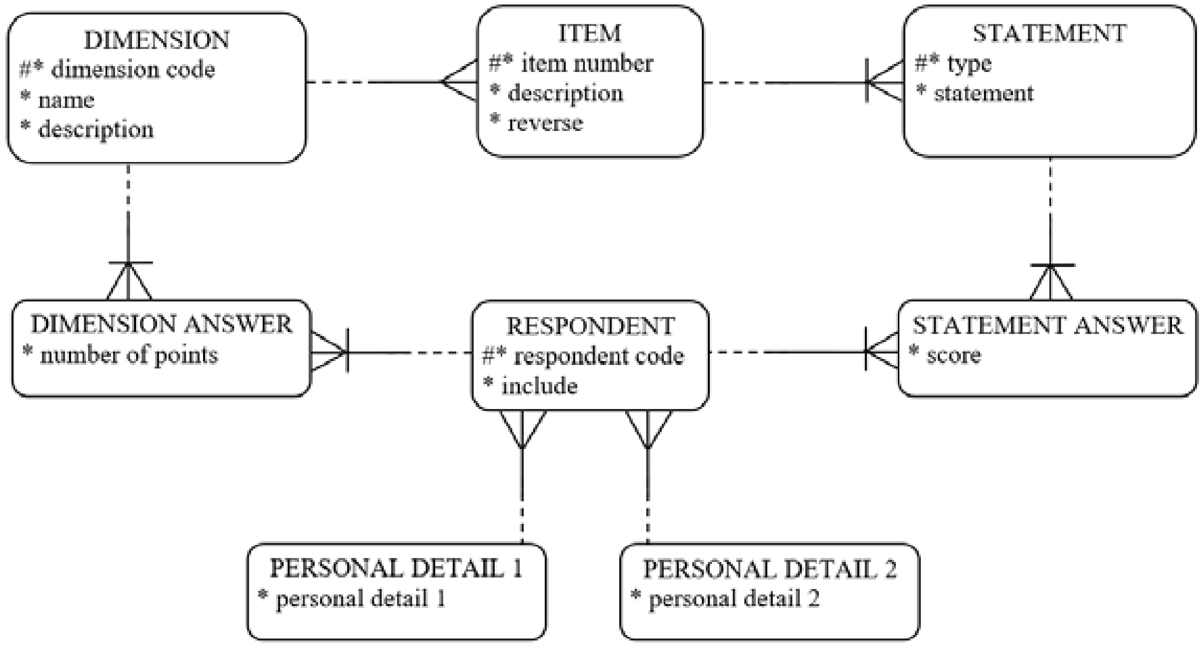

Figure 3. CASE Method-compliant model of relationships between entities for the tool supporting the SERVQUAL method.

Entities such as *Dimension, Dimension answer, Item, Statement, Statement answer, Respondent* are represented as tables placed in separate worksheets titled *Dimensions, DAnswers, Items, Statements, SAnswers,* and *Respondents,* respectively. It was assumed that the table titles should be consistent with the titles of the worksheets. Entities *Personal detail 1* and *Personal detail 2* are represented as one-column tables performing dictionary functions, and consequently, they were placed in consecutive columns of a shared worksheet titled *Dict*. Using external forms, part of the data acquired is manually entered directly in individual tables, while another part is extracted from a master list generated on the basis of the answers previously received. The manual keying of data pertains to the following attributes:

- *Item No, Dim Code, Description, Reverse* in table *Items*.
- *Dim Code, Dimension, Description* in table *Dimensions*.
- *Item No, Type, Statement* in table *Statements*.
- *Include* in table *Respondents*.
- *Personal detail 1, Personal detail 2* in worksheet *Dict*.

Using the answers previously acquired, values of the following attributes are entered automatically:

- *Code, ItemNo, Type, Score* in table *SAnswers*.
- *Code, Dimension Code, Points* in table *DAnswer*.
- *Code, Personal detail 1, Personal detail 2* in table *Respondents*.

The layout of the tables, including the breakdown into attributes whose values are manually keyed in and the attributes whose values are automatically retrieved, has been shown in Figure 4.

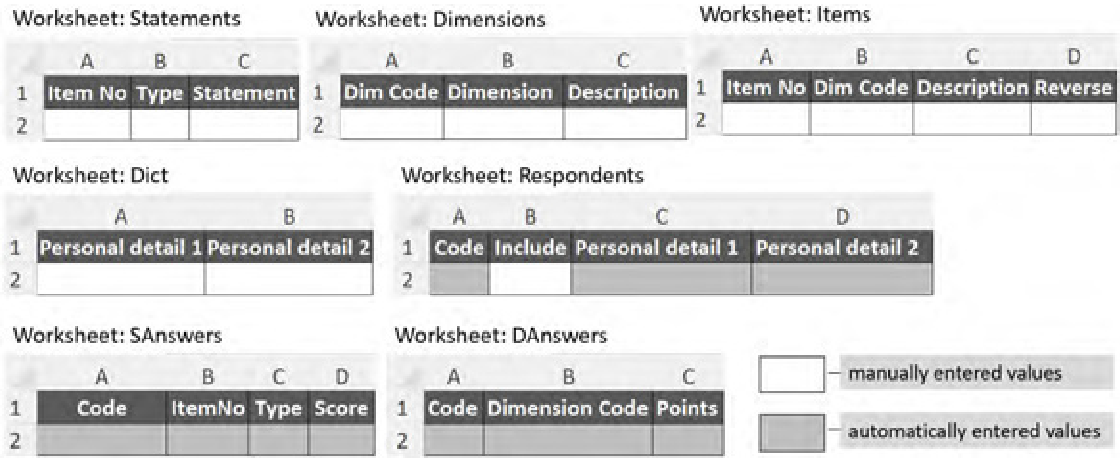

Figure 4. Layout of tables in the analysed tool.

The existing set of worksheets was complemented with worksheet *FormsIn*, containing all the answers obtained, representing a master table matching Figure 1 or 2, depending on the variant and option applied. For the data layout shown, a mechanism was developed to automatically enter values of corresponding attributes in tables with reference to the existing master table. The following assumptions were made for purposes of the said mechanism:

- the main phrases used in the questions contained in part 1 of the form must correspond to the names of the attributes characterising a given respondent in table *Respondents*, and in the structure proposed, these attributes are *Personal detail 1* and *Personal detail 2,*
- the main phrases used in the questions contained in part 2 of the form must correspond to the values of attribute *Description* in table *Descriptions*,
- where option 1 is applied for parts 3 and 4 of the form, the main phrases used in the questions must correspond to the values of attribute *Statement* in table *Statements*,
- where option 2 is applied for parts 3 and 4 of the form, the phrases entered as type *Statement* items in variant 1 and those entered as type *Row* items in variant 2 must correspond to the values of attribute *Statement* in table *Statements.*

If one uses Microsoft forms, regardless of the option applied in parts 3 and 4 of the form, the solution proposed is identical. In step one, with reference to the master table, values of the corresponding attributes are entered in table *Respondents*. Values retrieved from consecutive rows of the master table are migrated to consecutive rows of the former table. The solution which migrates the consecutive values in worksheet *Respondents* features the formulas shown in Figure 5. The principle followed when presenting formulas in individual columns is that the formula shown in the figure is the one from the top cell of a given column. The form taken by the formulas in consecutive cells is a resultant of the visible formula copied into these cells, and this stems from the master addressing principles which apply in spreadsheets.

	A	B	C	D
1	Code	Include	Personal detail 1	Personal detail 2
2	1	Y	A	CC
3	2	Y	B	BB

Column	Formula
Code	=IF(FormsIn!A2<>"";FormsIn!A2;"")
Personal detail 1	=IF($A2<>"";INDEX(FormsIn!$A2:$BD2;1; MATCH(C$1;FormsIn!$A$1:$BD$1;0));"")
Personal detail 2	=IF($A2<>"";INDEX(FormsIn!$A2:$BD2;1; MATCH(D$1;FormsIn!$A$1:$BD$1;0));"")

Figure 5. Formulas entered in the columns of worksheet *Respondents.*

The formula in column *Code* checks if there is any value in the given row of column *ID* of the master table in worksheet *FormsIn*. If so, this value is migrated to table *Respondents*. If any value has been entered in the given row in column *Code*, the formula in column *Personal detail 1* identifies the right column in the master table and retrieves from it the value of attribute *Personal detail 1*. The value of attribute *Personal detail 2* is retrieved in the same manner. In the rows where the corresponding values have been entered by way of the formulas, one must key in the value of attribute *Include* which defines if the answers provided by a given respondent are to be taken into consideration in further analysis.

Once the right values have been entered in table *Respondents*, values of attributes are entered in tables *DAnswers* and *SAnswers*. The mechanism which fills in the former of these tables with values adds 1 auxiliary column in worksheet *Dimensions* and 4 auxiliary columns in worksheet *DAnswers*. The layout of these columns, along with the formulas applied in individual worksheets, has been shown in Figures 6 and 7.

	A	B	C	D	E
1	Dim Code	Dimension	Description		H1
2	REL	Reliability	D1 description		7
3	ASR	Assurance	D2 description		8

Column	Formula
H1	=IF(A2<>"";MATCH(C2;FormsIn!$B$1:$BD$1;0);"")

Figure 6. Auxiliary column in worksheet *Dimensions.*

The formula in auxiliary column *H1* returns a number which designates the master table column where the answers concerning the given dimension are to be found. In consecutive rows of table *DAnswers*, all possible combinations of the respondent code and dimension code pair must appear. The values generated in auxiliary columns *H2* and *H3* are the numbers of the rows in table *DRespondent* and table *Dimension*, respectively, from which values of individual codes are to be retrieved.

	A	B	C	D	E	F	G	H
1	Code	Dimension Code	Points		H2	H3	H4	H5
2	1	REL	35		1	1	7	35
3	1	ASR	25		1	2	8	25

Column	Formula
H2	=IF(ROW(A1)<=(COUNTA(Dimensions!$A$2:$A$10)*(ROWS(Respondents!$A$2:$A$120)-COUNTBLANK(Respondents!$A$2:$A$120)));QUOTIENT(ROW(A1)-1; COUNTA(Dimensions!$A$2:$A$10))+1;"")
H3	=IF(E2<>"";MOD(ROW(A1)-1;COUNTA(Dimensions!$A$2:$A$10))+1;"")
H4	=IF(E2<>"";INDEX(Dimensions!$E$2:$E$10;DAnswers!F2;1);"")
H5	=IF(E2<>"";VALUE(INDEX(FormsIn!$B$2:$BD$120;E2;G2));"")
Code	=IF(E2<>"";INDEX(Respondents!$A$2:$A$120;E2;1);"")
Dimension Code	=IF(E2<>"";INDEX(Dimensions!$A$2:$A$10;F2;1);"")
Points	=IF(E2<>"";(H2/SUMIF($E$2:$E$600;E2;$H$2:$H$600))*100;"")

Figure 7. Auxiliary columns and formulas in worksheet *DAnswers.*

The formula in auxiliary column *H2* generates consecutive numbers in accordance with the following expression:

$$r_r = \left\lfloor \frac{i-1}{d} \right\rfloor + 1 \tag{1}$$

and the formula in auxiliary column *H3* operates in accordance with the following expression:

$$r_d = \big((i-1)\ mod\ d\big)\ + 1 \tag{2}$$

where:

r_r – number of the row in table *Respondents* from which the respondent code is to be retrieved and, at the same time, number of the master table row from which the given respondent's answers are to be retrieved,

r_d – number of the row in table *Dimensions* from which the dimension code is to be retrieved,

i – index of the current row in table *DAnswers* (index starting with the value 1),

d – number of dimensions entered in table *Dimensions*.

Depending on the value returned by the formula in columns *H2* and *H3*, the formulas in columns *Code* and *Dimension Code* return the respondent code and the dimensions code, respectively, while the formula in auxiliary column *H4* retrieves the master table column number pre-established for the given dimension. In the next step, based on the value retrieved from columns *H2* and *H4*, the formula in column *H5* returns the number of points the given respondent has assigned to the given dimension. Since the total number of points the given respondent has assigned to all dimensions is not verified at the form filling stage, any potential adjustment of the answers provided takes place when values are migrated from column *H5* to column *Points*. According to the assumptions of the SERVQUAL method, the sum of the points in column *Points*, in the rows which contain the same respondent code, always equals 100.

The mechanism which enters values in table *SAnswers* adds 1 auxiliary column in worksheet *Statements* and 5 auxiliary columns in worksheet *SAnswers*. The layout of these columns, along with the formulas applied in individual worksheets, has been shown in Figures 8 and 9. The formula in auxiliary column *H11* returns a number which designates the master table column where the answers concerning the given statement are to be found.

	A	B	C	D	E
1	Item No	Type	Statement		H11
2	1	EXP	I1 E stmt		13
3	2	EXP	I2 E stmt		14

Column	Formula
H11	=IF(A2<>"";MATCH(C2;FormsIn!$B$1:$BD$1;0);"")

Figure 8. Auxiliary column in worksheet *Statements*.

In consecutive rows of table *SAnswers*, all possible combinations of the respondent code paired with the item number and type must appear. The values generated in auxiliary columns *H12* and *H13* are the numbers of the rows in table *DRespondent* and table *Statements* from which the respondent code as well as the item number and item type are to be retrieved, respectively. The formula in column *H12* generates consecutive numbers in accordance with the following expression:

$$r_r = \left\lfloor \frac{i-1}{s} \right\rfloor + 1 \tag{3}$$

and the formula in auxiliary column *H13* operates in accordance with the following expression:

$$r_s = \big((i-1)\ mod\ s\big) + 1 \tag{4}$$

where:

r_r – number of the row in table *Respondents* from which the respondent code is to be retrieved and, at the same time, number of the master table row from which the given respondent's answers are to be retrieved,

r_s – number of the row in table *Statements* from which the item number and type are to be retrieved,

i – index of the current row in table *SAnswers* (index starting with the value 1),

s – number of statements entered in table *Statements*.

Depending on the number in auxiliary column *H12*, the formula in column *Code* retrieves the right respondent code from table *Respondents*. Making use of the number in auxiliary column *H13*, the formula in column *ItemNo* retrieves the corresponding item number from table *Statements,* while the formula in column *Type* retrieves the corresponding statement type from the same table. The formula in auxiliary column *H14* retrieves the pre-established master table column number from the same row in table *Statements*. This column always contains answers concerning the given statement. Depending on the numbers in columns *H12* and *H14*, the formula in column *H15* retrieves the right answer from the master table. Additionally, the formula in column *H16* retrieves the value of attribute *Reverse* of the item to which the given statement pertains. This attribute determines if the statement associated with the given item is positive or negative, and whether or not it is necessary to reverse the rating scale prior to the analysis. Taking the value of this attribute into account, the formula in column *Score* puts an adjusted answer into the table.

	A	B	C	D	E	F	G	H	I	J
1	Code	ItemNo	Type	Score		H12	H13	H14	H15	H16
2	1	1	EXP	5		1	1	13	5	0
3	1	2	EXP	5		1	2	14	5	0
4	1	3	EXP	7		1	3	21	7	0

Column	Formula
H12	=IF(ROW(A1)<=(COUNTA(Statements!$A$2:$A$80)* (ROWS(Respondents!$A$2:$A$120)- COUNTBLANK(Respondents!$A$2:$A$120))); QUOTIENT(ROW(A1)-1;COUNTA(Statements!$A$2:$A$80))+1;"")
H13	=IF(F2<>"";MOD(ROW(A1)-1;COUNTA(Statements!$A$2:$A$80))+1;"")
H14	=IF(F2<>"";INDEX(Statements!$E$2:$E$80;G2;1);"")
H15	=IF(F2<>"";VALUE(INDEX(FormsIn!$B$2:$BD$120;F2;H2));"")
H16	=IF(F5<>"";VLOOKUP(B5;Items!$A$2:$D$31;4;FALSE);"")
Code	=IF(F2<>"";INDEX(Respondents!$A$2:$A$120;F2;1);"")
ItemNo	=IF(F2<>"";INDEX(Statements!$A$2:$A$80;G2;1);"")
Type	=IF(F2<>"";INDEX(Statements!$B$2:$B$80;G2;1);"")
Score	=IF(F2<>"";IF(J2=0;I2;8-I2);"")

Figure 9. Auxiliary columns and formulas in worksheet *SAnswers.*

The above solution must be slightly modified if one intends to use Google forms. In the event that Google forms are used in line with option 1, two adjustments should be introduced in parts 3 and 4 to ensure that the solution proposed works properly. One pertains to the respondent code, which the master table simply lacks in this case. For that reason, the formula presented in Figure 5 and found in column *Code* should generate the code as a sequence of consecutive integers, instead of retrieving it from the master table. This effect can be achieved by adding the ROW() function to the formula. The second modification is connected with the extended form of the headers of the master table columns which contain the answers to the questions from the form's parts 3 and 4. In order that the number of the column containing answers provided against a certain statement to be identified correctly, the formula in auxiliary column *H11* requires a considerable adjustment. Both the column in question and its modified formula have been shown in Figure 10.

	A	B	C	D	E
1	Item No	Type	Statement		H11a
2	1	EXP	I1 E stmt		9
3	2	EXP	I2 E stmt		10

Column	Formula
H11a	`{=IF(A2<>"";MATCH(C2;IF(ISERROR(FIND("[";FormsIn!$A$1:$BC$1));FormsIn!$A$1:$BC$1;MID(FormsIn!$A$1:$BC$1;FIND("[";FormsIn!$A$1:$BC$1)+1;LEN(FormsIn!$A$1:$BC$1)-FIND("[";FormsIn!$A$1:$BC$1)-1));0);"")}`

Figure 10. Auxiliary column in worksheet *Statements* along with its modified formula.

What the formula does in the first place is create a one-row table containing master table headers. They become modified to the point that, as far as the questions from parts 3 and 4 are concerned, they are only left with the text which can be found in square brackets. With reference to the row containing the headers, modified as above, the next step consists in establishing the number of the column which contains the answers provided against a given statement. For the mechanism proposed to work properly, it is assumed that no square brackets should appear in the main phrases used in the form's questions. When using Google forms according to option 2, one must only modify the formula in column *Code* of worksheet *Respondents* in parts 3 and 4 of the form.

4. Conclusions

The solutions proposed and discussed above demonstrate that the data needed for purposes of the SERVQUAL analysis, supported by a tool created in a spreadsheet according to the MiRel concept, can be successfully acquired by means of commonly available online forms from providers such as Microsoft or Google, representing variants 1 and 2. The features of the solutions analysed in the paper make it possible to build forms capable of collecting all the required data. In both variants, two form options were taken into consideration, differing in terms of the items used to acquire answers concerning expected and perceived quality. The structure of the data obtained in all cases was very similar, save for certain minor differences. The basic structure was assumed to be that which variant 1 yielded. Irrespective of the option chosen, it was precisely the same, enabling the least complicated data migration from the master table to the tool's tables. In variant 2, there is no answer identifier in the master table, and consequently the respondent code must be generated at the data migration stage. If variant 2 is bundled with option 1, the headers of some of the master table columns become considerably extended, which makes it necessary to also extend one of the formulas of the data migration mechanism. Where this was the case, a table formula had to be applied instead of the standard formula.

There was also a certain discrepancy identified in how the relevance of individual dimensions was assessed. The SERVQUAL method is based on the assumption that the respondent should distribute 100 points between them. Unfortunately, none of the solutions analysed offers an item which would make it possible to verify if the sum of the points assigned indeed meets that assumption. Therefore, it was necessary to move the verification and the potential adjustment of the assessments to the mechanism providing data migration from the master table to the tool's tables.

All the solutions enabling data migration from the master table to the tables created in the tool were successfully built in line with the MiRel concept, i.e. using a rather small range of built-in spreadsheet features. At no point, none of the solutions thus created made it necessary to use a code developed in any programming language. The foregoing supports an argument that a solution such as the one proposed can be successfully deployed and extended by persons who are familiar with spreadsheets but who have no command of programming.

Acknowledgements

The research presented in the article was supported by statutory work 13/010/BK_22/0065.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

DIGITAL TRANSFORMATION AS A CHALLENGE FOR SMES IN POLAND IN THE CONTEXT OF CRISIS RELATING TO COVID-19 PANDEMIC

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Purpose: This article is devoted to identifying major problems and obstacles to the digital transformation of SMEs in Poland in the context of the Covid crisis and to indicating directions and methods to improve the digitisation level in the SME sector.
Design/methodology/approach: This article seeks to answer the question of what the SME digitisation level in Poland is, what the main obstacles hampering the digital transformation process are and how they can be removed. The following research methods were used: reference works review, analysis of secondary sources (reports from OECD, the World Bank, the European Commission, the Polish Agency for Enterprise Development (PARP), Statistics Poland) and deductive reasoning.
Findings: The digitisation level of SMEs in Poland is relatively low and the main obstacles to accelerating the digital transformation include the financial and competence limitations which can be removed only with institutional support.
Practical implications: This article mentions methods and directions of measures initiated by the government and other institutions to reduce obstacles to SME digital transformation in Poland.
Originality/value: The article has informative values as it contributes to the development of knowledge on the impact of the Covid-related crisis on the speed of the digital transformation in the SME sector in Poland and in other countries worldwide.

Keywords: digital transformation, SME, COVID-19 crisis.

Category of the paper: Conceptual paper.

1. Introduction

For several decades, the sector of Small and Medium-sized Enterprises (SME) has been the key component of the Polish economy. In the company structure by size, small and medium-sized enterprises make 99.8% of all enterprises (with 97.0% of microenterprises, 2.2% of small enterprises and 0.7% are medium-sized ones). The predominant areas of SME activity include services (52.5%), commerce (22.4%), construction (14.9%) and industrial production (10.1%). This sector employs 6.75 million people (67.4% of all enterprise workers) and generates close to 50% of GDP (Raport o stanie małych i średnich przedsiębiorstw w Polsce, 2021).

The technical development and the development of Industry 4.0 make the enterprises implement cutting-edge technology and digital tools more and more often, thus reducing the cost of their operations, improving economic and financial results and achieving many other benefits (Kuusisto, 2017; Dalenogare et al., 2018; Bai et al., 2020). This refers mostly to large enterprises which possess suitable investment, organisational and HR capacities. For SMEs, the digital transformation is a serious challenge, though it is necessary to maintain their position on the contemporary market as it offers opportunities for improving efficiency and competitive advantage (Ulas, 2019; Chan et al., 2018; Li et al., 2017). It is of particular importance in the face of the crisis caused by Covid-19 pandemic which struck the SME sector most (Kala'lembang, 2021; Khai et al., 2021). On the other hand, however, the circumstances and restrictions caused by the pandemic forced the companies to change their operating mode, rebuild business models (teleworking, online transactions) and improve the digital transformation pace (Priyono et al., 2020; Klein & Todesco, 2021).

Considering the SME sector significance for the Polish economy and the need of its digital transformation, this article is aimed at identifying the major problems of and barriers to the digital transformation of enterprises in that sector in Poland in the context of crisis caused by the Covid-19 pandemic and indicating directions and methods to improve the related situation. To meet that objective, the article poses the following research questions:

1. What was the SME digitisation level in Poland before the pandemic?
2. What was the pandemic impact on the SME sector digitisation level?
3. What are the obstacles to the digital transformation of SMEs in Poland and abroad?
4. What should be done to support SMEs in the implementation of cutting-edge technology and digital solutions?

The following research methods were used: reference works review, analysis of secondary sources (reports from OECD, the World Bank, the European Commission, the Polish Agency for Enterprise Development (PARP), Statistics Poland) and deductive reasoning.

The structure of this article, subordinated to fulfilling the major objective, comprises the following sections. Section 2 describes the level of Polish SMEs' digitisation before the Covid-19 pandemic. In section 3, the pandemic impact on the digital transformation pace in small and medium-sized enterprises was discussed. Section 4 presents the major obstacles to the digital transformation of SMEs in Poland and abroad. In section 5, the directions and methods used to support small and medium-sized enterprises when implementing the digital technology and solutions are named. Section 6 contains the conclusions.

2. Level of the Polish SMEs' digitisation before the pandemic

The digitisation level of Polish companies, in particular the ones in the SME sector, as assessed using DESI, was relatively low when compared to other EU states and has remained low. DESI Poland for 2019 was 41.6, while in the EU it was 52.5, giving Poland 25th position in the ranking of 28 EU states. The largest difference was recorded in the following subindices: Integration of digital technology and Human capital, while the lowest in the Connectivity and Use of internet services (Fig. 1).

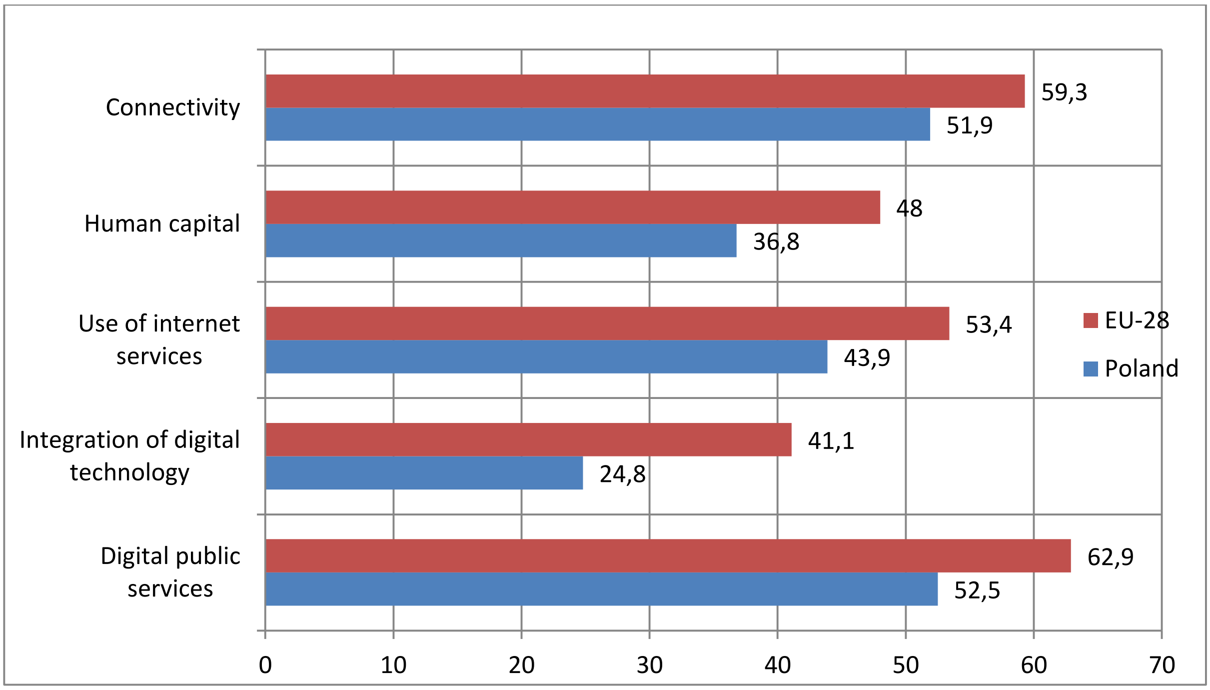

Figure 1. DESI subindices in 2019 (Poland and EU average). Source: Poland in the Digital Economy and Society Index. European Commission. https://digital-strategy.ec.europa.eu/en/policies/desi-poland.

The enterprise digitisation level is indicated mostly by the Integration of digital technology subindex which was 16.3 percentage points lower than the EU average in 2019. Only 12% of SMEs sold online (the EU average was 17%), only 4% of SMES sold online abroad (the EU average was 8%) and the online sale was 7% of the enterprises' turnover (the EU average is 10%).

A similar assessment of the Polish SME digitisation level is provided by the data collected by Statistics Poland (Fig. 2 and 3). As shown in Fig. 2, small and medium-sized enterprises in Poland have access to broadband Internet and their employees are mostly equipped with mobile devices with access to the Internet. The situation is much worse in terms of ICT specialists' employment (40.2% of medium-sized enterprises and 18% of small ones employs them) and in terms of organising training for employees in that respect (the training was organised in 28.7% of medium-sized enterprises and 11.5% of small ones).

When it comes to using cutting-edge technology of Industry 4.0 by Polish SMEs, for large companies the highest difference referred to the cloud computing, using robots and big data analysis (Fig. 3).

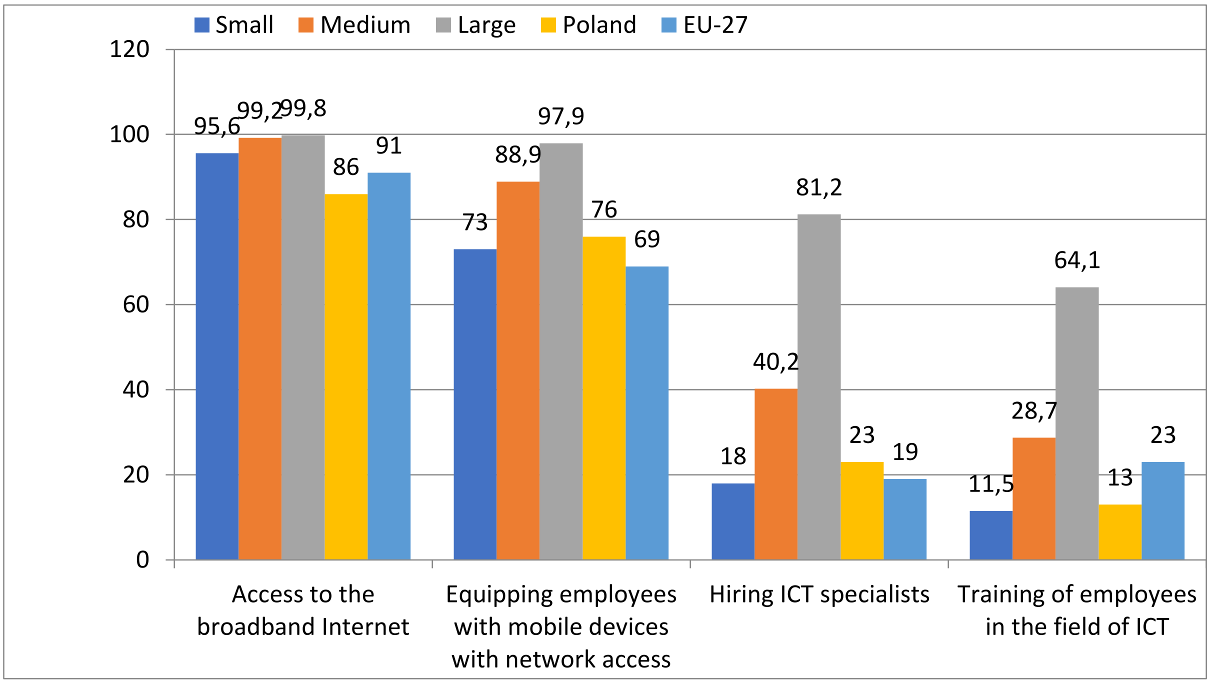

Figure 2. Access to the Internet and mobile devices of SMEs in Poland in 2019. Source: Own work based on: Information society in Poland in 2020 Statistics Poland and the Statistical Office in Szczecin. Warsaw, Szczecin 2020; Report on the Condition of Small and Medium-Sized Enterprises in Poland, 2021. PARP; DESI, 2021. European Commission. https://digital-strategy.ec.europa.eu/en/policies/desi.

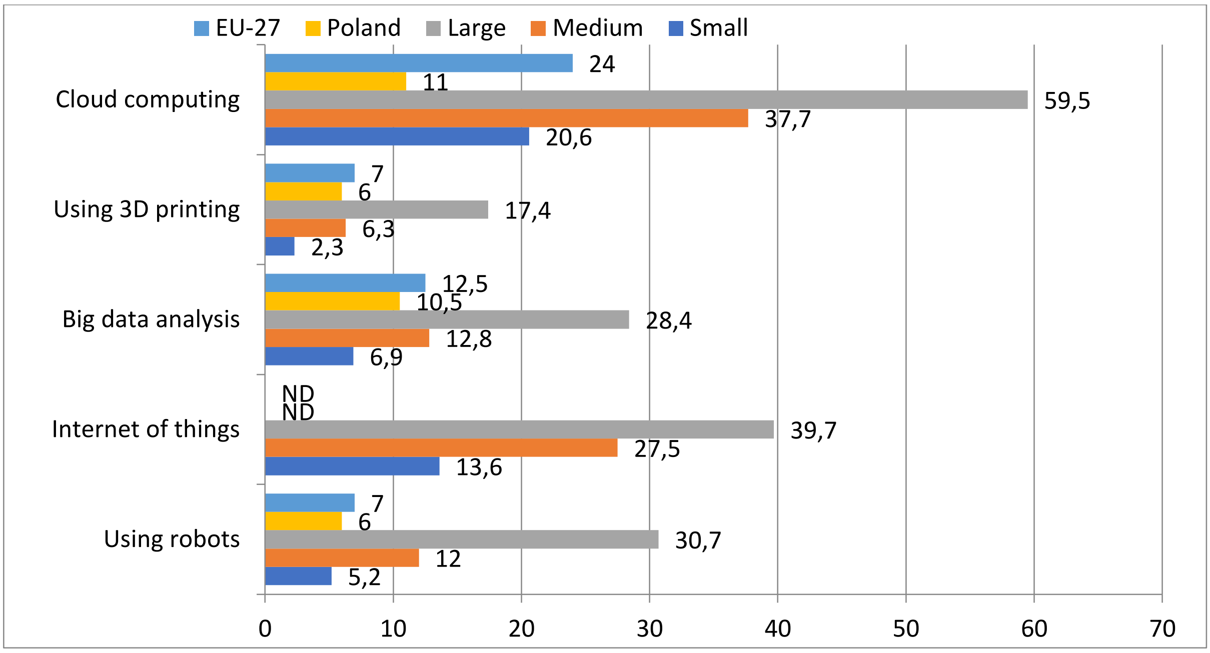

Figure 3. The use of 4.0 technology by Polish enterprises in 2019. Source: Own work based on: Information society in Poland in 2020 Statistics Poland and the Statistical Office in Szczecin. Warsaw, Szczecin 2020; Report on the Condition of Small and Medium-Sized Enterprises in Poland, 2021. PARP; DESI, 2021. European Commission. https://digital-strategy.ec.europa.eu/en/policies/desi.

Small and medium-sized enterprises carry out online sale only to a limited degree. In 2019, fewer than 1/4th of medium-sized enterprises and ca. 15% of small ones processed orders using the Internet (websites, mobile applications or e-commerce platforms) and even fewer SMEs (below 10%) offered chat, chatbot or voicebot services to their customers (Information Society in Poland in 2020, 2020, pp. 94-95).

3. Covid-19 crisis and the pace of digital SME transformation

Lockdowns, obligatory social distancing and other restrictions caused by the Covid-19 pandemic forced companies in many sectors to change their business models and to run their activity remotely to stay on the market and overcome delivery chain disturbances (Sonobe et al., 2021; Klein & Todesco, 2021; Bai et al.,2021). Consequently, it was necessary to accelerate the digital transformation both in large enterprises and in the small and medium-sized ones. According to the global studies, most (ca. 70%) of SMEs intensified using cutting-edge digital technology due to the pandemic (OECD, 2020a). In the United Kingdom, 75% SMEs changed to teleworking and ca. 30% invested in cutting-edge digital tools (Riom & Valero, 2020). More than 72% of small online companies in Canada decided that e-commerce was necessary to succeed in today's conditions (Paypal, 2020). What is more, more than a half of SMEs in Brazil appreciate the digitisation advantages in the form of increased customer acquisition efficiency and improved customer relations (Zdnet, 2020).

Similar changes were recorded in the Polish SME sector as well. According to the data collected by Statistics Poland, more than 1/3rd of Polish enterprises (35.5%) increased the use of ICT in 2020 in connection with the pandemic, including 90.7% of large enterprises, 62.4% medium-sized ones and 28.4% of small ones (The Use of Information and Communication Technology in Public Administration Bodies, Enterprises and Households in 2021).

According to the report by the Polish Agency for Enterprise Development (PARP) called "COVID-19 Business Pulse Survey – Polska" concerning the studies in 2020[1], starting from the pandemic beginning, close to 32% of SMEs increased the use of digital platforms, 18% of enterprises invested in cutting-edge digital solutions (purchase of new hardware or software) and, thanks to digitisation, 20% of enterprises updated and modernised their product and service offering (Fig. 4).

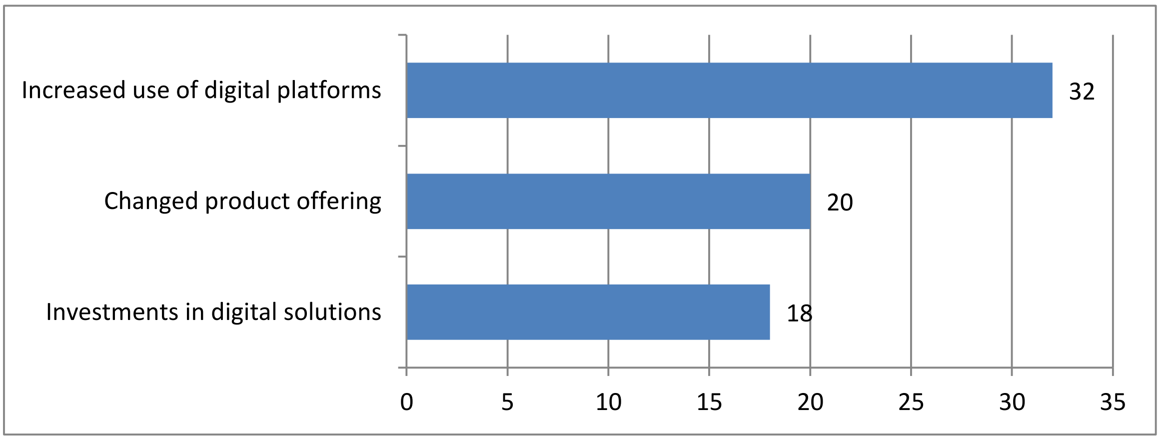

Figure 4. Digital tool use as a result of Covid-19 by SMEs in Poland in 2020 (enterprise number in %). Source: Covid-19 Impact on SME Digitisation in Poland, 2020. https://ictmarketexperts.com/aktualnosci/wplyw-covid-19-na-cyfryzacje-msp-w-polsce/.

The digital tool use by SMEs was diversified by sectors (Fig. 5). The higher use of digital platforms was recorded mostly for commercial (36%) and service companies (36%). Also, most commercial (22%) and service companies (18%) decided to invest in digital solutions. The offering was adjusted by the highest number of service companies (28%). All the changes took place in the manufacturing enterprises to the smallest degree.

[1] The study was carried out by the World Bank and the Polish Agency for Enterprise Development between May and July 2020 based on the sample of 1.4 thousand enterprises.

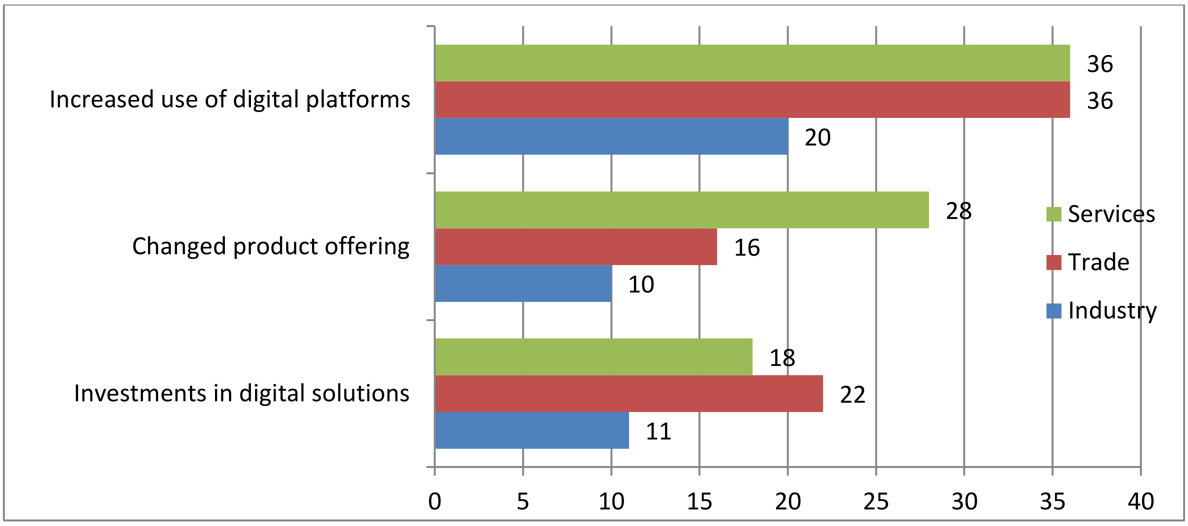

Figure 5. Digital tool use as a result of Covid-19 by SMEs in Poland in 2020 (by sectors, in %). Source: Covid-19 Impact on SME Digitisation in Poland, 2020. https://ictmarketexperts.com/aktualnosci/wplyw-covid-19-na-cyfryzacje-msp-w-polsce/.

When it comes to DESI for 2021, it was 41.0, while in the EU it was 50.7, giving Poland 24th place among 27 EU states. Although Poland improved numerous indices in 2020 (Fig. 6), it did not translate into changing its place in the ranking (DESI, 2021), considering the progress of other EU states.

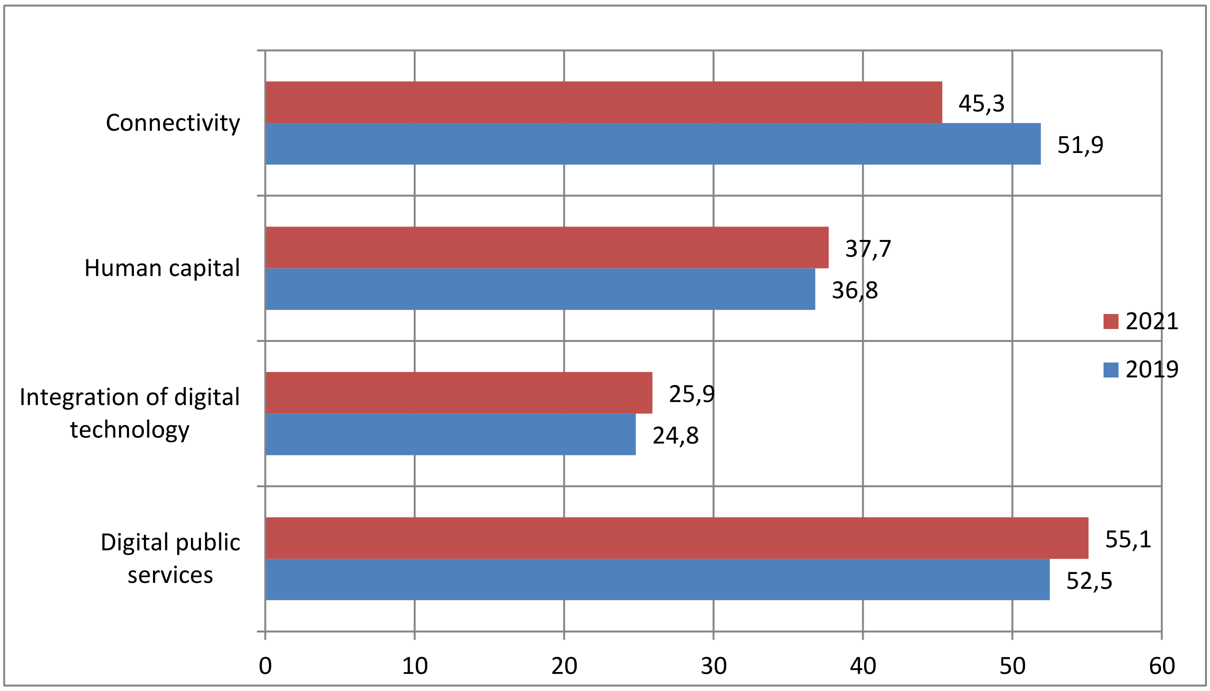

Figure 6. DESI subindices for Poland in 2019 and 2021. Source: Poland in the Digital Economy and Society Index. European Commission. https://digital-strategy.ec.europa.eu/en/policies/desi-poland.

The ICT integration index grew from 24.8 in 2019 to 25.9 in 2021, but it remained lower than the EU average of 37.6. Slightly more than one half (52%) of Polish small and medium-sized enterprises reached at least the basic level of the ICT use index, while the EU average was 60%. Only 13% of Polish SMEs offered online sale and just 5% trans-boundary sale to other EU states (DESI, 2021).

Introducing cutting-edge technology and accelerating digital transformation in SME sector has remained a significant challenge due to numerous obstacles which are difficult to overcome alone with no external support.

4. Obstacles to digital transformation in SME sector

Reference works have indicated for years that small and medium-sized enterprises should implement cutting-edge information and communication technology more broadly and use e-marketing tools to meet the challenge of Industry 4.0 era and the growing competition (Stockdale & Standing, 2004; Gilmore et al., 2007; Harrigan et al., 2011). Using new digital tools generates numerous measurable benefits, including increased sale (Kumar et al., 2017; Bill et al., 2020), cost reduction (Odoom et al., 2017), improved financial results (Cenamor et al., 2019) and improved innovation and competitive advantage level (Nobre & Silva, 2014; Itani et al., 2017). However, SMEs do not use the full potential of the cutting-edge solutions due to numerous obstacles and limitations. The following obstacles are mentioned most often irrespective of the country and sector (Styvén and Wallström, 2019; Cenamor et al., 2019; Yaseen et al., 2019; Peter & Vecchia, 2020; Coman et al., 2020; Civelek et al., 2020; Chen et al., 2021):

- shortage of funds,
- excessive investment risk and difficulties measuring the ROI,
- insufficient expertise,
- insufficient competences of employees,
- no access to the infrastructure and technical obstacles,
- cybersecurity concerns.

In the OECD report concerning SME digitisation, the following long-term structural obstacles are mentioned (OECD, 2021):

- competence gap preventing managers and employees from identifying digital solution needs and adapting business processes and models,
- financial gap reducing availability of funds for implementing cutting-edge digital technology,
- infrastructure gap concerning insufficient access to fast broadband connections.

It is popularly believed that overcoming larger obstacles, in particular in the context of the pandemic-related crisis, will not be possible without the institutional support of the government, local governments, international institutions and inter-organisation cooperation (Amuda, 2020; Khai et al., 2021; Ssenyonga, 2021; Adam & Alarifi, 2021; Masouras et al., 2021). European SMEs expect broad state aid, starting from employee training, through counselling and mentoring, and ending with tax reliefs and direct financial support from the government or EU (Rupeika-Apoka et al., 2022).

5. Possible activities accelerating digital transformation in SME and their directions

Accelerating the digital transformation in the SME sector becomes a prerequisite for SME survival and development, especially following the crisis caused by the pandemic (Guo et al., 2020). Many authors stress that the cutting-edge digital technology and solutions are the only opportunity for the sector to improve its efficiency, innovation and competitive advantage on the modern markets (Fitriasari, 2020; Kala'lembang, 2021). This is also confirmed by the results of studies conducted in this area. The studies carried out by Scuotto et al. (2021) using the sample of 2 million of European SMEs revealed that the development of that sector in the digital transformation era requires the employees to hold relevant digital competences in the area of information, communication and software.

Given the barriers and obstacles discussed above, it will not be possible to meet the objective and challenge if there is no support offered by the government and local government bodies/authorities and there is no cooperation of other institutions or organisations. Chen et al. (2021) pointed to four directions of government support for the digital transformation in small service enterprises, including building a digital platform dedicated to small service enterprises, promoting mobile/digital payments, co-organising digital training and building an ecosystem of digital cooperation.

According to OECD, governments can support the digital transformation of SMEs in different ways presented in table 1.

Table 1.
Directions of government support for the digital transformation of SMEs

Support direction	Activity types
Increasing the internal potential of the enterprise	• Providing financial support (consultation vouchers, grants) and technology support (diagnosis, self-assessment tools, e-business tools, guidelines, educational materials); • Encouraging to undergo training and improve qualifications (e.g. fiscal incentives, donations, promoting training in the workplace, coaching programmes etc.); • Building data culture by increasing the awareness and skills relating to data management and protection (e.g. by information distribution, financial or technical support); • Improving the digital security level (awareness campaigns, providing tools, audit, assurance framework, protocols and systems of certification as well as training opportunities);
Facilitating access to strategic resources	• Promoting the use of new technology (including e.g. blockchain and artificial intelligence) to reduce transaction costs on financial markets and also to use mobile banking or alternative data to assess credit risk; • Encouraging business innovation in the area of cybersecurity, blockchain, AI etc. (e.g. grants for research and studies, public procurements, tax incentives, demand regulations, competence centres, public-private partnerships etc.); • Connecting SMEs with the knowledge networks by means of the schemes of cooperation with large enterprises, public procurements or network interfaces (e.g. digital innovation hubs, excellence centres, clusters and co-working spaces); • Providing access to data and technology via test stations and experimental laboratories, data centres, digital innovation hubs, university transfer offices, co-creation platforms etc.

Cont. table 1.

Creating a suitable business environment	• Creating supportive regulatory framework (standardisation and improvement of regulations on business secrets, intellectual property, data protection, cybersecurity etc.); • Promoting e-administration and e-services using one-stop shops and digital portals; • Introducing high-quality digital infrastructure using the infrastructure development plans and roadmaps (e.g. fast broadband connections and connection of remote areas).
Promoting general institutional approach	• Development of long-term strategic frameworks, national strategies and action plans and coordination of investments and activities in all areas; • Creating bodies and structures to coordinate the support policy in such areas as AI or blockchain; • Creating multi-enterprise consulting and counselling groups to promote ethical and responsible digitisation policies.

Source: Own work based on: OECD, 2021. The Digital Transformation of SMEs. OECD Studies on SMEs and Entrepreneurship. OECD Publishing, Paris. https://doi.org/10.1787/bdb9256a-en.

In Poland, the entity responsible for the digital transformation process is the Ministry of Digital Affairs with the Council for Digital Affairs. Its tasks comprise e.g. the development and recommendation of solutions concerning the systemic support for the digital transformation. In the framework of the Polish government's activities, the active role of the state is ascribed to five areas, including science, finance, cybersecurity, economy and administration. Generally speaking, the recommended activities refer to all enterprises, but some of them are particularly applicable to SMEs.

The areas of state activity relating to the digital transformation, including the recommended activities for the small business, are presented in Table 2.

Table 2.
Recommendations concerning digital solutions to support the digital transformation of SMEs in Poland

Area – characteristics	Recommended activities for the SME sector
SCIENCE – science, education and research are required for effective digital transformation and are an innovation driver	1) Minimising the deficits in the so-called digital gap and the digital competence development by a general access and incentives for SME entrepreneurs to participate in education; 2) Using the research potential of universities when cooperating with SME entrepreneurs – increasing the practical activity criterion in the parameter-based assessment of universities, e.g. cooperation with SME.
FINANCE – broader access to funds for innovative small and medium-sized enterprises (SME) in particular funding schemes	1) Promoting commercial loans, loan and guarantee funds as a prospective external source of funds for the digital transformation in the SME sector; 2) Creating digital innovation hubs supporting the development of start-ups and SMEs in IT and cybersecurity areas (it would be also a *one-stop-shop* offer for external stakeholders for building trust in young, innovative enterprises without any consolidated market position).
CYBERSECURITY – creating the suitable regulatory environment and infrastructure to guarantee highest cybersecurity standards	1) Creating an organisation to certify companies, products and services relating to cybersecurity on the public administration level which would enable to reduce the time required to approve new technology and bring it to the market; 2) Establishing a central path for buying certified cybersecurity solutions for the public sector, resembling the UK *Cyber Security Services 2,* would facilitate access of the Polish SMEs to public procurements.

Cont. table 2.

ECONOMY – ensuring social cohesion and development balanced in terms of territory	1) Building and developing the dialogue of the administrative structures with start-ups to facilitate their debut and rapid market entry. 2) Developing the tax relief system for SMEs investing in training, professional development of employees and cooperation with universities to accelerate and implement innovation which should result in feedback, thanks to which SMEs will invest in professional improvement and, all the same, feed the adult education system.
ADMINISTRATION – providing high-quality services for citizens (including SMEs) by using cutting-edge ICT solutions and a logical and consistent IT system of the state	1) Creating a number of institutions to promote development, including the ones supporting SME digitisation (when establishing the regulatory framework, particular stress should be placed on the digital agenda and also work on data standardisation and interoperability).

Source: Own work based on: Systemic support for the digital economic transformation. https://www.gov.pl/web/cyfryzacja/systemowe-wsparcie-dla-cyfrowej-transformacji-gospodarki-z-komponentem-security-by-design.

Based on the presented activities recommended by the Polish authorities to support the digital transformation of the SME sector, it can be inferred that they are convergent with the support directions advocated by OECD. However, they are general. The pandemic period changed the conditions of the economic entities' activity and society's life, accelerating the transformations relating to digitising business activity, including the small business one. This was followed by the support for SMEs. The presented areas and activities within them are of a systemic nature and hence not all of them could be adapted to the new conditions. The areas where the steps were taken have been science and finance.

In the SCIENCE area, the government activities were related to training and counselling to minimise the pandemic effects. The government aid entailed co-funding the educational and counselling offering. The proposals addressed to small and medium-sized enterprises covered e.g. counselling relating to changing the company operation model, including changing the sector, using remote solutions, safe teleworking rule, innovative crisis solutions, network administration (for LAN and WAN), creation and development of cloud solutions, server virtualisation, using online marketing tools and more (https://www.parp.gov.pl/component/grants/grants/kompetencje-dla-sektorow-covid).

In the FINANCE sector, the government proposals are related to the financial support to mitigate the effects of COVID-19 and minimise economic and social risks caused by the pandemic by means of the digital transformation of the economy. An example of this scheme is digitisation vouchers for buying programming services and/or out-of-the box software, or for buying fixed assets and/or counselling services to implement a digitisation solution. The activities are aimed at SMEs' implementation of digital technology in connection with the need to change processes, the operations during epidemic, including but not limited to COVID-19 pandemic, or to improve immunity in case of subsequent, similar crises caused by epidemics (https://www.parp.gov.pl/component/grants/grants/wsparcie-msp-w-obszarze-cyfryzacji-bony-na-cyfryzacje).

The above government proposals relating to processes supporting the digital transformation of SME sector as a result of COVID-19 pandemic are embedded in the systemic solutions concerning the transformation of the whole economy. At present, it is difficult to speak of their effects as they have been underway. The financial perspective of EU for 2021-2027 contains numerous instruments designed to fund investments in the automation, robotisation and digitisation of Polish enterprises. An example can be the "Digital Europe" programme aimed at accelerating the digital transformation of Polish business entities.

6. Conclusions

The SME sector is a key component and the driving force of the Polish economy, constituting more than 99% of all enterprises, generating close to one half of GDP and employing more than 67% of people working in business. In the times of digital transformation and Industry 4.0, the effectiveness, innovation and development of the sector are determined by the scope and pace of implementing cutting-edge technology and tools. However, the level of digitisation and advancement relating to implementing new solutions by small and medium-sized enterprises is low when compared to the large enterprises and the EU average. This refers both to the situation before the COVID-19 pandemic and at present.

Although the changes caused by the pandemic (moving to teleworking, online sale) accelerated the digital transformation in most SMEs in Poland and worldwide, the level and scope of using cutting-edge digital tools in the sector enterprises have remained insufficient. This stems from numerous obstacles and limitations of a universal nature, meaning they are identical regardless of the analysed country or sector. The major obstacles are the funds, insufficient expertise and low employee competences.

It is popularly believed that the obstacles cannot be overcome without any institutional support. OECD recommends initiating activities in the following four directions: (1) increasing the internal potential of the enterprise, (2) facilitating access to strategic resources, (3) creating a suitable business environment, (4) promoting general institutional approach.

In many countries, there are numerous projects and programmes launched to support the digital transformation of SMEs in cooperation with other institutions and large enterprises. In Poland, systemic proposals were developed, grouped in five areas: (1) science, (2) finance, (3) cybersecurity, (4) economy and (5) administration. They are convergent with international recommendations. However, it should be stressed that the changed operating conditions as a result of the COVID-19 pandemic brought about the need for activities supporting small and medium-sized enterprises relating to digital transformation. Such programmes were developed in Poland. They covered two types of activities. The first ones were connected with training and counselling to minimise the pandemic effects. The other ones refer to the financial support which is aimed at mitigating the effects of COVID-19 and limiting economic and social risks caused by the pandemic.

The ponderations and conclusions presented in the article:

— contribute to the development of the theory of SME sector operations in the context of its development relating to the digital transformation, stimulated by the COVID-19 pandemic;

- in the managerial aspect, demonstrate how to facilitate the digital transformation process of small and medium-sized companies by indicating the degree of using individual digital tools in Poland and in the European Union, obstacles hampering transformation processes and the presentation of governmental support forms for the SME sector in the specified area;
- from the social perspective, suggest the need for further support of the digital transformation of small and medium-sized enterprises due to their social significance.

The analyses carried out in this article are limited by the absence of empirical studies on the use of digital tools by small and medium-sized enterprises in Poland as a result of the COVID-19 pandemic and obstacles to their digital transformation. The article may provide theoretical grounds for analyses from different perspectives, e.g. by sectors, territory and by enterprise size (micro-, small and medium-sized enterprises).

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

DIFFERENT FACES OF CSR: GREENWASHING IN THE CONTEXT OF ITS IMPACT ON CORPORATE REPUTATION

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Purpose: The aim of the article is to show the negative impact of greenwashing on the company's reputation and to propose ways of using CSR and green marketing tools to reduce green reputation risk.
Design/methodology/approach: The article attempts to answer the question: How to use CSR and green marketing tools so that they are not perceived as greenwashing and do not generate green reputation risk? The following methods were used: literature review, deductive inference based on the analysis of the following concepts: CSR and sustainable development, stakeholder theory, corporate reputation management, stakeholder engagement and social innovation.
Findings: The most frequently postulated method of limiting greenwashing is the legal regulation of CSR, but due to its weaknesses, it is proposed to develop cooperation with stakeholders in order to jointly create green strategies and social innovations.
Practical implications: The methods and directions of activities limiting the negative effects of greenwashing in the context of reducing green reputation risk and improving the reputation management process were indicated.
Originality/value: The article contributes to the development of reputation management theory by drawing attention to another source of reputational risk, the so-called green risk, such as greenwashing, with an indication of how to reduce or avoid it.

Keywords: CSR, greenwashing, corporate reputation, green marketing, reputational risk.

Category of the paper: Conceptual paper.

1. Introduction

The last few decades have been characterized by a dynamic development of the concept and practical CSR activities in the context of implementation of the principles of sustainable development. The so-called green marketing or sustainable marketing have been used as a CSR tool to build a green image and green reputation of a company (Bashir et al., 2016; Ko et al., 2013; Yousaf et al., 2021). The popularization of these concepts and ideas is related to the growing environmental awareness of societies and the growing pressure of many stakeholder

http://dx.doi.org/10.29119/1641-3466.2022.161.21 http://managementpapers.polsl.pl/

groups expecting greater social responsibility from enterprises (Groza et al., 2011; Fontainha et al. 2017). This is especially true for consumers, who are becoming more and more sensitive to environmental and other social issues. Pro-ecological consumers are willing to pay higher prices for environmentally friendly products and products manufactured by companies with high social commitment (Grimmer and Bingham, 2014; Guo et al., 2014; Kumar & Ghode, 2015). In many studies, the authors show a positive impact of the use of CSR and green marketing elements on the image of a product or brand, image and reputation of a company, the level of trust and loyalty of customers (Ko et al., 2013; Wu & Lin, 2016; Bati, 2016; Widyastuti et al., 2019). Many authors also suggest that corporate social involvement and the use of green marketing lead to competitive advantage and better financial results (Kiran, 2012; Flammer, 2015; Leonidou et al., 2017; Moravcikova et al., 2017). Therefore, enterprises more and more often implement CSR programs and use green marketing instruments in their business strategies.

The activities of companies in this area, mainly aimed at building a green image and reputation of the company as a socially responsible organization, sometimes lead to certain abuses, manipulations and unethical practices referred to as greenwashing (Delmas & Burbano, 2011). Generally speaking, greenwashing activities consist in providing the public with manipulated, partially or completely false information about the company's use of various environmentally and socially friendly activities (e.g. production of non-toxic products, use of green technologies, waste disposal, etc.). Consequently, greenwashing is often referred to as the dark side of CSR (Aggarwal & Kadyan, 2014). Disclosing these fairly common practices over many years has a negative effect on companies, especially when it comes to their reputation.

The aim of the article is to identify the negative effects of greenwashing in the context of building and protecting the company's reputation. The implementation of this goal requires answers to the following research questions:

1) What is the origin and forms of greenwashing?
2) What are the reasons for using greenwashing by companies?
3) What are the effects of greenwashing in terms of its impact on the company's reputation?
4) How to use CSR and green marketing tools so that they do not have the appearance of greenwashing and do not generate green reputation risk?

The following research methods were used: literature review and deductive inference based on the analysis of the following concepts: CSR and sustainable development, stakeholder theory, corporate reputation management, stakeholder engagement and social innovation.

The structure of the article was subordinated to the main goal, which is composed of the following sections. Section 2 describes the genesis and types of greenwashing. Section 3 discusses the impact of greenwashing on a company's reputation. Section 4 identifies options and ways to reduce greenwashing to protect company’s reputation from green risk. Section 5 presents a summary and conclusions.

2. Genesis and types of greenwashing

The term "greenwashing" was coined by popular environmentalist and New York Times journalist Jay Westerveld, who in his 1986 publication described a practice in the hotel industry that was advertised as part of an environmental strategy. Namely, the re-use of towels by hotel guests was promoted, which would reduce the excessive consumption of water, while in fact the aim was to reduce the cost of washing (Orange & Cohen, 2010).

There is no single definition of greenwashing, as it is a very complex phenomenon (Lyon & Montgomery, 2015). De Freitas Netto et al. (2020), based on a review of various approaches and definitions, indicated two approaches to greenwashing: (1) greenwashing as selective disclosure and (2) greenwashing as decoupling. Table 1 shows examples of definitions of the approaches highlighted.

Table 1.
Examples of grenwashing definitions according to two different approaches

Highlighted approaches	Examples of definitions
(1) Greenwashing as selective disclosure	• "the act of misleading consumers regarding the environmental practices of a company or the environmental performance and positive communication about environmental performance" (TerraChoice) • "the act of disseminating disinformation to consumers regarding the environmental practices of a company or the environmental benefits of a product or service" (Baum) • "poor environmental performance and positive communication about environmental performance" (Delmas and Burbano) • "communication that misleads people regarding environmental performance/benefits by disclosing negative information and disseminating positive information about an organization, service, or product" (Tateishi)
(2) Greenwashing as decoupling	• symbolic actions, "which tend to deflect attention to minor issues or lead to create 'green talk' through statements aimed at satisfying stakeholder requirements in terms of sustainability but without any concrete action" (Siano et al.) • the gap between "symbolic" and "substantive" corporate social actions (CSA); companies that have a negative CSR performance and at the same time apply a positive communication about their CSR performance (Walker and Wan) • essentially decoupling behaviours that are symbolic environmental protection behaviours with no environmental protection behaviour or failure to fulfil environmental protection commitments, to alleviate the external public pressures and uncertainties and to avoid the conflict with external constituents (Guo et al.)

Source: Own work based on: de Freitas et al., 2020.

Greenwashing can take many forms and types of activities. It can be used by companies that do not conduct any CSR activities at all, as well as by companies implementing specific social projects. Therefore, Dewatripont and Tirole (2005) distinguished two forms of greenwashing:

- hard greenwashing, when the company only uses environmental communication or green advertising, in fact not using any CSR activities,
- light greenwashing, when the company focuses more on advertising its green activities, reducing actual CSR efforts.

Torelli et al. (2020), based on the analysis of the legitimacy theory and signalling theory, distinguished the following four levels of greenwashing:

- Corporate-level greenwashing – misleading communication regarding the company's image and reputation (i.e., the company name and logo, vision, standard adherence, and corporate certification).
- Strategic level greenwashing – manipulated information on the goals of the future strategy, pro-ecological production technology, etc.
- Dark level greenwashing – communication aimed at concealing illegal activities (corruption, money laundering, etc.).
- Product level greenwashing – providing false information about the characteristics of the product (labels, packaging, certificates, etc.).

The distinguished levels of greenwashing are characterized by different goals and methods of communication regarding the environment. They also face different perceptions and reactions of individual groups of stakeholders.

Based on corporate practices and activities, Terrachoice, North American environmental marketing consultancy, identified seven greenwashing sins in a 2009 report (TerraChoice Environmental Marketing, 2009; Baum, 2012):

1) Sin of hidden trade-off – presenting only a few selected features of a product in order to distract consumers from other features that have a negative impact on the environment (e.g., a paper producer may indicate the use of waste paper in its production, while greenhouse gas emissions or chlorine bleaching in the process may be more important issues that are harmful to the environment).
2) Sin of no proof – providing information that cannot be verified with readily available evidence (most often it concerns giving percentage data without referring to a specific source).
3) Sin of vagueness – using misleading words such as "green", "natural", "organic", "environmentally friendly", etc.
4) Sin of irrelevance – pointing to the ecological aspects of the offer that are either of little importance to the environment or are indicated under regulatory pressure.
5) Sin of lesser of two evils – emphasizing a true positive feature of a product, disregarding the overall negative impact of the product on the environment (e.g. ecological cigarettes, fuel-efficient cars).

6) Sin of fibbing – providing false information about the ecological nature of a product (most often it concerns giving false information that the products are certified or registered as organic).
7) Sin of worshipping false labels – using labels that suggest that a product has ecological certificates which the product has not actually obtained.

Greenwashing practices have become so common that greenwashing incidents are noted even among companies with significant, genuine commitment to pro-social activities. Aggarwal and Kadyan (2014) conducted an analysis of green marketing activities (i.e. advertising, websites, sustainable development reports) of selected companies from four sectors: automotive, electronics, food and beverages, and personal care. The surveyed companies include: GM, Toyota, Phillips, Dell, Coca Cola Company, Mc Donald's Corporation, Johnson & Johnson, Procter & Gamble Company. The obtained results showed that even companies with a high overall CSR index used some form of greenwashing. This is where the question arises: why even well-known and reputable companies commit the "sin" of greenwashing?

The motives of greenwashing by enterprises are explained on the basis of several theories: institutional theory, legitimization theory and signalling theory. Walker and Wan (2012) point to two main motives: (1) to obtain legitimacy, according to institutional and legitimacy theory, and (2) to communicate the company's pro-ecological values as a signal to stakeholders, according to the signalling theory. In the first case, enterprises want to gain acceptance and legitimation from various stakeholder groups for whom social commitment and green technologies are of particular importance (Cormier & Magnan, 2015). In the second case, it is about public relations aimed at creating the desired green image and green reputation.

Testa et al. (2018) draw attention to the possibility of pressure from some stakeholders on the undertaking of greenwashing by the company. They examined the impact of the pressure of various stakeholder groups on the implementation of environmental practices defined in international norms and quality standards (e.g. ISO 14001). The obtained results showed that the pressure of some stakeholders can induce real integration of proactive environmental practices (e.g. suppliers and shareholders), while other stakeholder groups can encourage their symbolic adoption, that is greenwashing (e.g. customers and industry associations).

3. The impact of greenwashing on the company's reputation – another source of reputation risk

Reputation for many years has been considered by both theoreticians and practitioners of management as one of the most valuable resources of the company. A positive reputation is a source of long-term competitive advantage, it generates better economic and financial results and builds the company's market value (Flatt & Kowalczyk, 2008; Brønn & Brønn, 2015; Schwaiger & Rathel, 2014; Vig et al., 2017; Esenyel, 2020). The growing importance and popularization of CSR has a large impact on building a positive reputation (Fombrun, 2005; Melo & Garrido-Morgado, 2012; Famiyeh et al., 2016; Šontaitė-Petkevičienė, 2015; Aksak et al., 2016). Social activity is also important when it comes to protecting reputation and its recovery after a crisis (Minor & Morgan, 2011; Kim & Woo, 2019). Emphasizing the close relationship between the CSR concept and the reputation concept, Hillebrand and Money (2007) conclude that these are two concepts, but also two sides of the same coin. Recently, a new category of corporate environmental reputation has even appeared in the literature (Martin-de Castro et al., 2019).

Reputation is based on such fundamental values as honesty and credibility, which build stakeholder trust (Fombrun & van Riel, 1997). Therefore, any fraud, manipulation or unethical behaviour undertaken as part of greenwashing affects the deterioration or even loss of reputation. A spectacular example is the recent Volkswagen Dieselgate scandal (Siano et al., 2017).

Authors of many studies show the negative impact of greenwashing on the company's reputation (Nyilasy et al., 2014; Lim et al., 2013; de Jong et al., 2018). De Jong et al. (2019) additionally prove that negative effects occur not only in the case of full behavioural-claim greenwashing (telling lies), but also in the less severe and less obvious case of partial behavioural-claim greenwashing (telling half-lies).

Greenwashing has many negative consequences for a company in terms of its image and reputation. First of all, it has a negative impact on the opinions, attitudes and behaviour of one of the key stakeholder groups - consumers, namely:

- deteriorates opinions and attitudes towards the brand (Parguel et al., 2011; Nyilasy et al., 2014),
- generates unfavourable "word of mouth" (Chen et al., 2014; Zhang et al., 2018),
- reduces the level of loyalty to the company and the brand (More, 2019),
- weakens purchasing intentions (Akturan, 2018; Aji & Sutikno, 2015; Nguyen et al., 2019; Zhang et al., 2018),
- reduces trust in the company (Chen & Chang, 2013).

Seele and Gatti (2017) note that scepticism and distrust of stakeholders also occur when the company's message about pro-social activities is true, and the suspicions or even accusations of greenwashing are false. The negative effects of greenwashing are also negatively reflected in the financial results of enterprises (Walker & Wan, 2012; Du, 2015). As a result, companies are losing incentive to take green action and report it for fear of being accused of "green" manipulation and exposure to green reputational risk. In this way, greenwashing ultimately harms not only consumers and businesses but also the environment itself (Furlow, 2010).

As you can see, the use of greenwashing practices has negative consequences when it comes to the attitudes, behaviours and decisions of many stakeholder groups, including one of the key reputation groups – consumers. Greenwashing leads to feelings of suspicion and growing scepticism about all information about the company's environmental activities (Rahman et al., 2015; Aji & Sutikno, 2015). The research of the SW Research and Opinion Research Agency – EKOBAROMETER carried out in 2020 shows that every third Polish consumer does not believe in the sincerity of ecological advertising (EKOBAROMETER – Critical towards ecomarketing, but not necessarily towards ecology, 2020). This means that consumers are critical of eco-marketing, but not necessarily of ecology itself. All this leads to a decline in trust in the company and the dissemination of unfavourable opinions to other stakeholder groups (Szabo & Webster, 202; Chen et al., 2014). In this way, greenwashing, and so in a sense also CSR, becomes another source of reputational risk, the so-called reputational green risk (Chen & Chang, 2013; Coombs & Holladay, 2015; Tarabieh, 2021).

It is worth noting that recently the literature has drawn attention not only to greenwashing as a deliberate abuse of CSR for the purpose of building an ad hoc green image, but to an overly superficial and short-sighted approach and use of CSR. The authors suggest that enterprises practice CSR as a public relations strategy, cover-up, or marketing strategy aimed at maintaining and improving competitiveness in the industry (Katono, 2021; Newman et al., 2020). Companies focus more on promoting and advertising their CSR activities, rather than on the activities themselves, which in fact are not that many (Jozef et al., 2019).

The possibility of a reputational green risk, i.e. of being suspected of greenwashing, presents companies with the dilemma of whether to communicate their CSR activities at all and how to do so. The importance of this problem is well illustrated by the results of the experiments carried out by Vries et al. (2015). The experiments concerned the reaction of stakeholders to the given motives for environmental investments of the surveyed companies in the energy sector. It was found that respondents were more likely to suspect the company of greenwashing when it quoted greenwashing motives for its investments, while these suspicions were lower when it quoted economic motives.

To sum up, greenwashing may bring short-term, superficial benefits in the form of creating a green image of the company, but in the long run it has negative effects, breeds scepticism of stakeholders and generates green reputation risk.

4. Possibilities and ways of limiting greenwashing in order to protect the company's reputation

Most researchers believe that the main reason for the generation and diffusion of greenwashing is the lack of regulations on CSR and treating it as a voluntary practice (Alves, 2009; Gatti et al., 2019a). Therefore, many authors suggest that an effective method of controlling and limiting greenwashing practices are legal regulations at the general economic level (Feinstein, 2013; Huang & Chen, 2015) or at least at industry level (Smith & Font, 2014). The role of governments in the process of making these regulations is debatable (Dentchev et al., 2015), but in many countries governments take such initiatives, triggering a lively discussion about whether CSR should be exclusively voluntary (Gatti et al., 2019b; Wang et al., 2019). Markham et al. (2014) postulate the need for governments and other stakeholder groups (environmental organizations, consumer associations, public benefit institutions, etc.) to work together to create a regulatory framework that would give a stronger mandate to monitor and control the integrity of sustainable business practices in enterprises. Gatti et al. (2019a) suggest that greenwashing could be prevented more effectively by combining voluntary and mandatory aspects of CSR in such a way as to promote creative and effective CSR initiatives while setting boundaries and rules for their implementation and communication.

The method of limiting greenwashing through legal regulations is being criticized as it does not seem to be effective. Lee et al. (2018), analysing this problem from the economic side, found that even if greenwashing is legally regulated, companies will not necessarily act pro-ecologically if they find that the additional cost of CSR is too high. On the other hand, the lack of regulation may encourage companies to take genuinely green actions to meet the expectations of key stakeholders.

An important role in reducing greenwashing may be played by changing the method of CSR reporting. So far, there are no unified standards in this regard. The information that companies place there is often too general, not very specific and, most importantly, difficult to verify, and therefore not very reliable (Nawrocki & Szwajca, 2016). Uyar et al. (2020), based on research in the logistics sector, found that if the information contained in the reports reflects the actual implementation of pro-social and environmental activities, it is received very positively by shareholders and other stakeholder groups.

It seems, however, that even the best regulations and their strict enforcement will not replace the real good will of enterprises to undertake CSR activity and provide reliable information. De Jong et al. (2019) conclude that only genuinely ecological activities of a company will have the desired positive reputation impact. The problem is how to communicate these activities to convince stakeholders of this integrity and gain their trust.

The direction of solving this problem postulated in the article is the development of cooperation with stakeholders in the development of environmental and pro-social projects. Research on the involvement of stakeholders in various initiatives and activities of the company has been going on for many years, along with the development of the stakeholder theory (Sinclair, 2011; Peterson, 2013). Abuzeinab and Arif (2014), based on research conducted in the British construction sector, have shown that stakeholder engagement can dynamize the processes of creating innovative, green offers and the implementation of green business models. According to Mathur et al. (2008) stakeholder engagement is an opportunity for social learning when stakeholders learn about each other's values, seek common values, and together they can create and implement joint initiatives. It is an important factor determining sustainable development. Vollero et al. (2016) propose a change in the strategic approach to CSR and its communication towards stakeholder involvement in these processes.

The concept of stakeholder engagement refers to the concept of the so-called social innovation, developed on the basis of such theories and concepts as: K. Davis' theory of social consent, Creating Shared Value (CSV), Hybrid Value Chain (HVC), Corporate Social Innovation (CSI) or CSR 2.0 (Szwajca, 2017). Social innovations concern the development and implementation of innovative products, services, and business models that are to serve the needs of society and environment. Various actors and stakeholder groups can participate in the creation of social innovations: citizens, enterprises, non-profit organizations, local communities, public institutions, etc. (Herrera, 2015; Osburg & Schmidpeter, 2013). Engaging stakeholders in the implementation of pro-social or pro-ecological (green) projects makes them feel not only their co-creators and beneficiaries, but also entities co-responsible for the entire creative process. It seems that participation in these activities is one of the most convincing evidence of the company's implementation of CSR activities.

5. Conclusions

Popularization of the idea of CSR in the context of striving for sustainable development has led to the widespread implementation of various pro-social and pro-ecological activities by enterprises. One of the tools used as part of CSR is green marketing, primarily advertising. Enterprises determined by striving to be perceived as a socially responsible, environmentally friendly organization begin to abuse green themes in their messages and communication. This leads to not very "clean", ethically questionable practices known as greenwashing. Greenwashing, known as the dark side of CSR, is the dissemination of incomplete, manipulated or completely untrue information to the public about the company's social and environmental activities in order to gain stakeholder favour and build a positive, green image and reputation.

Greenwashing practices have been used since the 1980s. They can take various forms and nature and can be applied at the level of strategy of the whole company as well as at the operational level as specific marketing activities. Disclosure of greenwashing has a very negative impact on the company's reputation, generating the so-called green reputation risk. In order to limit greenwashing, it is suggested to legally regulate CSR, to enable its control and to improve transparency. However, according to many authors, this solution is debatable and not necessarily effective. The article proposes to develop cooperation with stakeholders and involve them in joint pro-ecological or pro-social initiatives. Research shows that stakeholder engagement can lead to the development of innovative green technologies or products, and even the creation of green business models. The proposed solution refers to the concept of social innovations that arise as a result of cooperation between various groups of stakeholders. Participation in the creation and implementation of CSR activities is the best evidence for convincing stakeholders that these activities are real, not fake.

Considerations and conclusions presented in the article:

- contribute to the development of the theory of reputation management in the context of the company's pursuit of the principles of sustainable development,
- in the management aspect, they indicate how to improve the effectiveness of reputation management in the context of CSR by avoiding greenwashing practices,
- on social grounds, they suggest the need to limit greenwashing practices due to their negative impact on the motivation of enterprises to undertake social initiatives.

The limitation of the analyses carried out in the article is the lack of empirical research on stakeholder reactions to various forms of greenwashing in the context of reputation protection. The article may constitute the theoretical basis for conducting such research in various cross-sections, e.g. by industry, territory or by stakeholder groups.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

RESPONSIBILITIES OF PROJECT MANAGERS. A TEXT MINING ANALYSIS OF JOB ADVERTISEMENTS

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Purpose: To identify the duties and responsibilities of project managers by analysing the content of online job advertisements.
Design/methodology/approach: Job advertisements were automatically downloaded for 63 countries/areas available on Indeed. A text mining analysis of fragments of the advertisements describing the scope of duties was carried out. The text mining analysis included initial text processing, creating corpora of the documents, creating a document-term matrix, and using classic methods derived from data mining.
Findings: The research established the most frequently used words and n-grams in job advertisements. They have been presented in the form of figures. The 2-grams are also presented in the form of a net, a directed graph. The LDA algorithm identified abstract topics describing the duties and responsibilities of project managers. The most frequent words, n-grams, and topics identified by the LDA algorithm were used to identify the duties and responsibilities of project managers.
Research limitations/implications: Only job advertisements written in English were analysed. The postings were downloaded only for six days. An attempt to automatically identify the responsibilities section did not yield the expected results. Therefore, it was carried out manually for random advertisements, which reduced the number of analysed documents. The content of the job advertisements was not analysed by country/area.
Practical implications: The method applied can be used by organisations training future project managers, to modify and better adapt curricula to the needs of the labour market.
Originality/value: Studies have shown that text mining of job advertisements can help determine the duties and responsibilities of project managers.

Keywords: text mining, duties and responsibilities, project manager.

Category of the paper: research paper, case study.

1. Introduction

Contemporary organisations operate in increasingly difficult conditions, characterised by the high complexity and dynamics of internal and external processes. Aggressive competition, unstable business environment, and changing customers' expectations force companies to take unconventional actions and constantly modify their offers. Traditional, rigid organisational structures do not allow companies to quickly adapt to the environment. The solution may be project management. Projects can help organisations to implement new solutions, products, and services. They make companies more flexible, enabling them to effectively and efficiently achieve their goals.

Projects are one of the more frequently used ways of structuring work in organisations (Bakker, DeFillippi, Schwab, & Sydow, 2016). They have become ubiquitous not only in the economy but also in our society and our lives (Jensen, Thuesen, & Geraldi, 2016). The growing use of project management as a way for organisations to develop their intentions has been a trend in recent decades. Project management has already proved to be more effective than traditional management methods, particularly in the case of innovative undertakings unrelated to companies' core business (Munns & Bjeirmi, 1996).

Central to the discipline of project management is the position of the project manager (Meng & Boyd, 2017; Sommerville, Craig, & Hendry, 2010). Research in the area of project management points out the critical role of the project manager in achieving project success (Malach-Pines, Dvir, & Sadeh, 2009; Müller & Turner, 2007). The competencies of this person are one of the most important factors for the success of a project (Spalek, 2005). According to Ling et al., both the competencies and responsibilities of the project manager are closely related to the factors affecting project success (Ling, Ning, Chang, & Zhang, 2018). There is a consensus in the literature that project managers have sole responsibility for the planning and effective management of projects (Ahsan, Ho, & Khan, 2013; Andersen, 2016; Konstantinou, 2015; Korhonen, Laine, Lyly-Yrjänäinen, & Suomala, 2016; Ramazani & Jergeas, 2014; Schmid & Adams, 2008).

As the knowledge, skills, and attitude of project managers significantly affect the project's success, the pressure on those in this position increases (Alvarenga, Branco, Guedes, Soares, & Silva, 2019). Project management, next to experience, is one of the most frequently sought competencies (Anantatmula & Shrivastav, 2012; Pant & Baroudi, 2008). Recruiting the ‘right’ project manager is a significant challenge for organisations and continues to be an important organisational imperative (Ahsan et al., 2013).

The fundamental objective of the paper was to determine the scope of the project manager's responsibilities with a text mining analysis of job advertisements. The analysis was aimed at identifying the most popular duties. The structure of the work has been subordinated to the goal. The first part of the study involved a literature review to identify and categorise project manager competencies. The second stage was a text mining analysis of job advertisements posted to an online board. Sections with duties and responsibilities were analysed. The analysis involved text preprocessing, building of corpora of documents, construction of document-term matrices, application of classic data mining methods and a popular topic modelling algorithm. The results are shown in the figures. The most popular words, n-grams, and topics identified with LDA were presented. Two-grams were presented as a net as well. The most common duties of project managers were determined using the most frequent words, n-grams, and abstract topics identified with LDA.

2. Project manager's roles, responsibilities, and duties

The project manager's job is one of the most challenging positions in any organisation because it requires a broad understanding of the different areas that need to be coordinated and strong interpersonal skills (Ahsan et al., 2013). The project manager acts as a problem solver, finding the best options to achieve project objectives and ensure smooth execution of project team's responsibilities (Ahmed, Azmi, & Masood, 2013). Project managers who mastered the art and skills of project management (praised as being the heroes of projects management) are often those who grasped various, and seemingly unrelated, bits and pieces of project life, can manage the unforeseen, can apply principles and tools creatively, and are around to promote and offer support when needed (Blomquist, Hällgren, Nilsson, & Söderholm, 2010).

PRINCE2 defines the role of a project manager as a person who is given authority and responsibility for the day-to-day management of a project to deliver the required products within constraints (Office of Government Commerce (OGC), 2009). The role of the project manager is more challenging than the role of a typical functional manager (Anantatmula, 2010). It is extremely complex and unique as it is based on temporary assignments and the absence of formal positions (Bredin & Söderlund, 2013). This role can be described by a list of tasks and a wide range of responsibilities (Lutas, Nistor, Radu, & Beleiu, 2020).

The primary responsibility of the project manager is to ensure that the project is properly planned, executed, and completed (Mantel, Meredith, Shafer, Sutton, & Wiley, 2011), that all work is completed on time, within budget and scope and at the right level of performance (Heagney, 2016). The project manager's primary responsibilities are to deliver the final product (1) by quality requirements, (2) within budget constraints, and (3) within the schedule specified by the company or the customer (Gaddis, 1959). Primary duties of the project manager include planning activities, organising work, leading the team, and monitoring and controlling progress (Pawlak, 2006; Wachowiak, Gregorczyk, Grucza, & Ogonek, 2004). The project manager is responsible for (Pawlak, 2006):

- defining the organisational structure of the project,
- setting project goals and submitting them for approval,
- overseeing the pursuit of the goals,
- shaping the project's structure,
- planning and overseeing timetables and budget,
- assembling the project team,
- leading the project team,
- fostering information circulation within the project,
- making relevant decisions.

According to Nicholas and Steyn. The most common duties of the project manager include (Steyn & Nicholas, 2012):

- planning tasks, actions, and results under the project by drawing up work structure, timetables, and budget, assigning resources to tasks, and controlling their realisation,
- selecting and organising the project team,
- forging and maintaining relationships with project stakeholders,
- negotiating and integrating function leaders, subcontractors, and senior management team linked to the project,
- monitoring project progress,
- identifying functional and technical problems,
- resolving problems or searching for appropriate ways to resolve them,
- managing conflicts and handling crises,
- recommending project discontinuation if it is impossible to achieve its goals.

The project manager's responsibility in projects is to deal with the ‘real’ management and staff working on the project (Gaddis, 1959). The project manager is ‘the person assigned by the performing organization to lead the team that is responsible for achieving the project objectives’ (Institute & PMI, 2012; ManagementInstitute, 2017). General activity related to leading the project team is an important and onerous function of the project manager. Assembly of the project team with the right members is important but appropriate task distribution is as well. Another crucial skill is motivating the team, integrating it, resolving conflicts, and improving the efficiency of operations and communication in the team (Pawlak, 2006; Wachowiak et al., 2004).

Team leading is much more than traditional management. The project manager should share their knowledge and experience and instil a sense of confidence and responsibility for the project among the team (Pawlak, 2006; Wachowiak et al., 2004). Project team leading includes such tasks as teambuilding, project resources analysis, division of labour, team member training, work organisation, communication, knowledge sharing, decision making, motivating and evaluating, employing the right project monitoring system, controlling task progress, and conflict solving (Nicholas & Steyn, 2017).

The project manager deals with representatives of other networks of people and other resources. They form a chain of intermediaries that allow the project manager to act remotely, to make changes, and to claim to represent all those affected. There are other stakeholders, other actors outside who want to influence the project (Blackburn, 2002). The project manager is a member of the project team who reports to the project owner team, is accountable to stakeholders, and has the main goals: representing the interests of the project, ensuring that project goals are achieved, leading the project team, representing the project to appropriate environments, and supervising the preparation of project documentation (Gareis, 2005).

The project manager's responsibilities can also be perceived from the perspective of project execution management, which includes such vital issues as (Trocki et al., 2013):

- project planning – defining the objective, assumptions, scope, and effects of the project, planning project structure (jobs and actions to complete them), project timetable (to represent its course in time), project resources (assignment of resources to jobs and actions and their organisation in time), project costs (budgeting), risk plan, quality, communication, and procurements,
- project team assembly – analysing necessary human resources (particularly their competencies) and acquiring them, motivating, conflict resolving, drafting and implementing an appropriate communication strategy,
- monitoring and control – verifying project timeliness and budget compliance, delegating jobs to project team members, job quality control,
- project closure – handing the project over to the owner, settlements, drafting operational documents, project execution report, making the decision to close the project, dissolution of the project team.

Crawford et al. presented the duties and responsibilities of individual roles within the project environment (among others for a programme manager, project portfolio manager, manager of project support, or project manager). They suggested the following duties and responsibilities of the project manager (Crawford, Cabanis-Brewin, Bigelow, James, & Pennypacker, 2008):

- Define project objectives and prioritise them with the programme manager, project sponsors, director of strategic project office (SPO), or chief project officer (CPO).
- Select team members, communicate their performance information to team members' functional managers, director of SPO, and project support manager (PSM).
- Support the requirements of the enterprise program manager to provide the necessary information and support for the successful implementation of the programme.
- May be responsible for one or more projects.
- Negotiate the execution of activities with team members and their managers, if they are operating in a matrix environment.

- Be a coach in explaining assignments and deliverables; mentor others in project management practices; check the quality of work and manage the integration of team members' work.
- Develop a strategy to optimise the professional development of each team member with the PSM.
- Co-create the project charter with the team, including defining completion criteria.
- Manage and communicate a clear vision of project objectives and motivate the project team to achieve them, creating a project environment that enables peak performance by team members.
- Organise the work into manageable groups of activities (phases) and identify an effective approach to completing the work.
- Using estimators, develop a complete and accurate project estimate; make appropriate use of reserves.
- With project planner(s), prepare the project plan and obtain management approval.
- Analyse risks, develop contingency plans, and identify triggering events and responsibility for initiating mitigating actions. Oversee the activities of the risk administrator. Gather information from stakeholders and rank key project risks in terms of the total impact.
- Work with the planner/scheduler/controller to track and report on plan progress, cost and schedule reporting and change control.
- Analyse actual performance against the plan and make adjustments in line with plan objectives.
- Manage relationships with project stakeholders, including internal and external clients and vendors, keeping them informed of progress and issues to manage expectations for all project requirements and deliverables.
- Involve functional expertise and specialist SPO staff in project reviews and key decision making.
- Manage changes to maintain business plan commitments; initiate a review if objectives need to change.
- Set and publish clear priorities among project activities.
- Arbitrate and resolve conflicts and interface issues within the project.
- Manage the financial aspects of the project: budgeting, capital project management, etc.
- Supervise project documentation and update knowledge bases; analyses lessons learned and shares them with other directors and project managers.
- Together with the analyst(s), analyse the original estimates against the actual hours and duration and understand the factors that contributed to the differences.
- Effectively coordinate team activities to meet project milestones.
- Provide input/justification for project costs and budget implications.

- Cooperate with the methodologist to ensure the implementation of SPO standards, processes, and support services.
- Proactively identify changes in the scope of work and ensure appropriate planning measures are taken with internal and external clients for re-evaluation and amend the scope of work requirements, budget and schedule.
- Oversee reporting activities of planners and analysts, determining when to escalate issues to appropriate management levels.
- Represent the project in meetings (with external consultants, departmental, and senior management), make sure that priorities are communicated and understood, and that progress/delays/problems are reported.
- Determine what constitutes successful closure for all parties. Get approval and signature from all parties when closing is achieved.
- Troubleshoot customer relationship, government relationship, project quality, project risk, and project security issues.
- Manage supplier relations and procurement related to the project(s).

The nature of project management requires that the project manager fulfils various functions simultaneously. The project manager should be (Vaupel, Schmolke, & Krüger, 2000):

- the leader of the project to lead the team, set goals, and direct work,
- a mediator to identify signs of conflicts and crises in the project team and search for solutions to ensure proper work environment, negotiate with project stakeholders,
- a mentor to share knowledge and experience, participate in solving technical problems regarding project execution,
- an economist to take care of the financial results of the project, search for the most effective ways to reach project goals, know the market, know client's needs, and the role of the project in the organisation's strategy,
- an organiser to plan and organise project teamwork, search for ways to resolve complex issues, predict events and implement preventive measures,
- a bureaucrat to lay down principles and procedures for project execution, ensure project management process conformity with internal and external requirements, determine mechanisms for reporting and controlling work progress, evaluate the performance of the project team,
- manage human resources: set requirements and recruit employees, ensure their development, set rules for performance rewarding and punishing,
- a psychologist to establish relationships with people, motivate, support in difficult times, help resolve crises, consider social and emotional needs of their co-workers,
- a salesperson to work with the client, foster project image and positive involvement of stakeholders, and promote team achievements and project success.

3. Research methodology

The job advertisements for the study with ‘project manager’ in the title were downloaded from 17.04.2021 to 22.04.2021 from Infeed. Postings for all 63 countries/areas were searched. The process was conducted using the RStudio environment with packages *rvest* (Wickham, 2019), *downloader* (Chang, 2016), and *xml2* (Wickham, Hester, & Ooms, 2020).

The next step was to remove advertisements in languages other than English. The language was determined using packages *cld2* (Ooms, 2020) and *cld3* (Ooms, 2021). Advertisements that the author believed were duplicates of other postings were removed as well. An advertisement was treated as a duplicate if its content was identical to the content of another advertisement published by the same organisation. The advertisement content was considered a string of characters. The comparison was made in RStudio with the comparison operator ‘==’. The analysis involved 25,884 postings from 44 countries/areas. The advertisements were posted to data frames of 25,884 rows and four columns. A single row stored data on a single advertisement in the following columns:

- ‘Adverts_ID’ – generated unique advertisement number.
- ‘Adverts_title’ – title of the advertisement.
- ‘Adverts content’ – the entire content of the advertisement.
- ‘Country_area’ – the name of the country/area for which the advertisement was posted, for example, ‘Poland’ for advertisements downloaded from https://pl.indeed.com.

The preliminary analysis revealed that:

- 20,208 (78.1%) of the advertisement had other words in addition to ‘project manager’ in the title (for example ‘IT Project Manager – Telecommunications (Permanent)’, ‘Senior Project Manager’, ‘Graduate Electronics Project Manager’) – these advertisements were classified to set A;
- 5,676 (21.9%) of the advertisements had only ‘project manager’ in the title. They were allocated to set B;
- the advertisements did not use semantic HTML tags following JobPosting or used them incorrectly. The tags label various sections of the HTML document, such as required educational background (‘educationRequirements’), job description (‘responsibilities’), or financial terms (‘baseSalary’);
- the order of the sections and their headings varied among the advertisements (such as company overview, job description, requirements);
- some advertisements lacked certain sections, such as requirements, job description, or company overview.

The next step was to identify (1) the part describing responsibilities and (2) its heading. The identified data were put into two additional columns:

- Responsibilities – the part of the advertisement with responsibilities.
- Responsibilities_title – the heading of the part describing responsibilities.

The process was conducted manually for randomly selected advertisements because the structures of the advertisements differed, and JobPosting HTML tags were missing. Twenty A-set and five B-set advertisements were randomly selected for each country/area. If the number of advertisements for a country was lower than twenty for set A and five for set B, all advertisements were selected. Only the selected advertisements were left in the data frame and then exported into an .xlsx file. Then the content of columns Responsibilities and Responsibilities_title was created in the spreadsheet with 'select, copy, paste'. The data were then imported into RStudio. At this point, the data frame consisted of 988 rows and 6 columns.

Table 1 presents the numbers of downloaded and randomly selected advertisements by country/area and sets A and B. According to the table, 1,650 advertisements were fetched for Australia; 75.5% (1,246) were classified to set A and 24.5% to set B. Twenty five advertisements were analysed for this country (20 in set A and 5 in set B). Out of the 25,884 downloaded advertisements, 988 were analysed: 791 from set A and 197 from set B.

Table 1.
The number of job advertisements downloaded and selected for analysis

Country/area	Downloaded job advertisements				Selected job advertisements		
	A	B	Total		A	B	Total
Argentina	32 (80%)	8 (20%)	40		20 (80%)	5 (20%)	25
Australia	1.246 (75.5%)	404 (24.5%)	1.650		20 (80%)	5 (20%)	25
Austria	94 (91.3%)	9 (8.7%)	103		20 (80%)	5 (20%)	25
Belgium	391 (85%)	69 (15%)	460		20 (80%)	5 (20%)	25
Brazil	30 (73.2%)	11 (26.8%)	41		20 (80%)	5 (20%)	25
Canada	1.087 (76%)	343 (24%)	1.430		20 (80%)	5 (20%)	25
Chile	13 (68.4%)	6 (31.6%)	19		13 (72.2%)	5 (27.8%)	18
China	462 (83.5%)	91 (16.5%)	553		20 (80%)	5 (20%)	25
Colombia	24 (85.7%)	4 (14.3%)	28		20 (83.3%)	4 (16.7%)	24
Costa Rica	35 (66%)	18 (34%)	53		20 (80%)	5 (20%)	25
Czech Republic	62 (92.5%)	5 (7.5%)	67		20 (80%)	5 (20%)	25
Ecuador	4 (100%)	0 (0%)	4		4 (100%)	0 (0%)	4
Germany	323 (92.6%)	26 (7.4%)	349		20 (80%)	5 (20%)	25
Hong Kong	187 (84.6%)	34 (15.4%)	221		20 (80%)	5 (20%)	25
Hungary	136 (82.9%)	28 (17.1%)	164		20 (80%)	5 (20%)	25
India	835 (66.5%)	420 (33.5%)	1.255		20 (80%)	5 (20%)	25
Italy	40 (90.9%)	4 (9.1%)	44		20 (83.3%)	4 (16.7%)	24
Kuwait	13 (65%)	7 (35%)	20		13 (72.2%)	5 (27.8%)	18
Luxembourg	47 (90.4%)	5 (9.6%)	52		20 (80%)	5 (20%)	25
Malaysia	199 (72.4%)	76 (27.6%)	275		20 (80%)	5 (20%)	25
Mexico	103 (73%)	38 (27%)	141		20 (80%)	5 (20%)	25
Morocco	12 (85.7%)	2 (14.3%)	14		12 (85.7%)	2 (14.3%)	14
Netherlands	76 (79.2%)	20 (20.8%)	96		20 (80%)	5 (20%)	25
New Zealand	228 (69.9%)	98 (30.1%)	326		20 (80%)	5 (20%)	25
Nigeria	48 (73.8%)	17 (26.2%)	65		20 (80%)	5 (20%)	25

Cont. table 1.

Norway	30 (81.1%)	7 (18.9%)	37		20 (80%)	5 (20%)	25
Oman	14 (77.8%)	4 (22.2%)	18		14 (77.8%)	4 (22.2%)	18
Pakistan	29 (61.7%)	18 (38.3%)	47		20 (80%)	5 (20%)	25
Panama	4 (80%)	1 (20%)	5		4 (80%)	1 (20%)	5
Peru	5 (83.3%)	1 (16.7%)	6		5 (83.3%)	1 (16.7%)	6
Philippines	257 (68.7%)	117 (31.3%)	374		20 (80%)	5 (20%)	25
Poland	147 (84%)	28 (16%)	175		20 (80%)	5 (20%)	25
Singapore	907 (69.5%)	398 (30.5%)	1.305		20 (80%)	5 (20%)	25
South Africa	58 (81.7%)	13 (18.3%)	71		20 (80%)	5 (20%)	25
South Korea	31 (83.8%)	6 (16.2%)	37		20 (80%)	5 (20%)	25
Spain	127 (92%)	11 (8%)	138		20 (80%)	5 (20%)	25
Taiwan	82 (88.2%)	11 (11.8%)	93		20 (80%)	5 (20%)	25
Thailand	111 (69.4%)	49 (30.6%)	160		20 (80%)	5 (20%)	25
Turkey	30 (71.4%)	12 (28.6%)	42		20 (80%)	5 (20%)	25
Ukraine	91 (69.5%)	40 (30.5%)	131		20 (80%)	5 (20%)	25
United Kingdom	2921 (77%)	871 (23%)	3.792		20 (80%)	5 (20%)	25
United States	9.539 (80.5%)	2.307 (19.5%)	11.846		20 (80%)	5 (20%)	25
Uruguay	6 (85.7%)	1 (14.3%)	7		6 (85.7%)	1 (14.3%)	7
Vietnam	92 (70.8%)	38 (29.2%)	130		20 (80%)	5 (20%)	25
	20.208 (78.1%)	5.676 (21.9%)	5.884		791 (80.1%)	197 (19.9%)	988

The next stage was a text mining analysis of responsibilities sections stored in the Responsibilities column. The RStudio was used for this purpose. The analysis involved text preprocessing, building n-grams, creating corpora, searching for the most common words and n-grams, and generating abstract topics using the Latent Dirichlet Allocation method (LDA). Some actions were repeated until the results were satisfactory.

Some of the preprocessing operations included:

- removal of all characters except letters,
- lowercasing,
- removal of words considered useless (such as conjunctions, prepositions, etc.) with an original list of stopwords,
- stemming.

The cleaned text was used to generate n-grams of two to four words. N-grams are sequences of characters or words extracted from a text (Majumder, Mitra, & Chaudhuri, 2002). The n-grams were created separately for each piece of text with the End Of Line character (EOL) at the end. The resulting n-grams were put into additional columns: 2-gram, 3-gram etc.

Table 2.

Text cleaning and n-gram creating – example

Original	After cleaning	Two-grams
Creating and manage project plans	create manage project plan	‘create manage’; ‘manage project’; ‘project plan’
Conduct daily stand-ups and retrospectives at the end of each sprint and ensure that the team is continuously learning from previous experience.	conduct daily stand retrospective sprint ensure team continuously learn previous experience	‘conduct daily’; ‘daily stand’; ‘stand retrospective’; ‘retrospective sprint’; ‘sprint ensure’; ‘ensure team’; ‘team continuously’; ‘continuously learn’; ‘learn previous’; ‘previous experience’

Table 2 shows the results of precleaning and generation of 2-grams for two random pieces of text. Column ***Original*** contains text before cleaning. The first excerpt initially consisted of a dash and five words. Column ***After cleaning*** shows the same text after it has been cleaned. The number of words was reduced to four. The dash and 'and' have been removed. 'Creating' and 'plans' were stemmed to 'create' and 'plan'. The words from the ***After cleaning*** column were used in 2-grams.

The data from column Responsibilities comprised the first document corpus. The content of each cell was treated as a separate document. The remaining corpora were generated from columns with the n-grams. A document-term matrix with the term frequency (TF) was created for each corpus. The next action was to find the most common words and n-grams and visualise them. The most common n-grams were presented as figures. Two-grams were also presented as a net with a directed graph. Words in the 2-grams were the nodes. The more popular a word in the 2-grams, the larger the node. The 2-grams were presented as edges of the directed graph. The more popular a 2-gram, the darker the edge. For example, edges of 2-grams 'project management' and 'project team' (Fig. 4) are black because these were the most popular 2-grams in the analysed documents. Less common 2-grams, such as 'quality assurance' are grey or light grey.

The last stage was the application of LDA, which is a popular topic modelling algorithm. The supposition for the algorithm is that each document is represented by a set of topics, and each topic is represented by words. The LDA method was described by D. Blei, A. Ng, and M. Jordan (Blei, Ng, & Jordan, 2003). The study employed the implementation of the algorithm available in an R package, *topicmodels*. The topics were generated for documents in column *Responsibilities*.

The topics identified by LDA with the most common words and n-grams were then used to pinpoint the duties and responsibilities of the project manager.

4. Results

Figures 1 and 2 show the most common words in the investigated fragments of job advertisements. The word 'project' was used 3,939 times. It was the most widespread one. It was followed by 'team' (1,438 times), 'ensure' (1,208 times), 'manage' (1,184), and 'management' (1,167). One can analyse the words in figures 1 and 2 containing the 80 most popular words to try to determine the most popular responsibilities of project managers. Words 'project' 'manage', and 'management' suggest that the project manager simply manages project(s). They draw up plans, schedules, budget, and project files (words 'plan'; 'schedule', 'budget', 'require', and 'documentation'). They set the project scope and resources necessary (words 'resources', 'scope', require 'require').

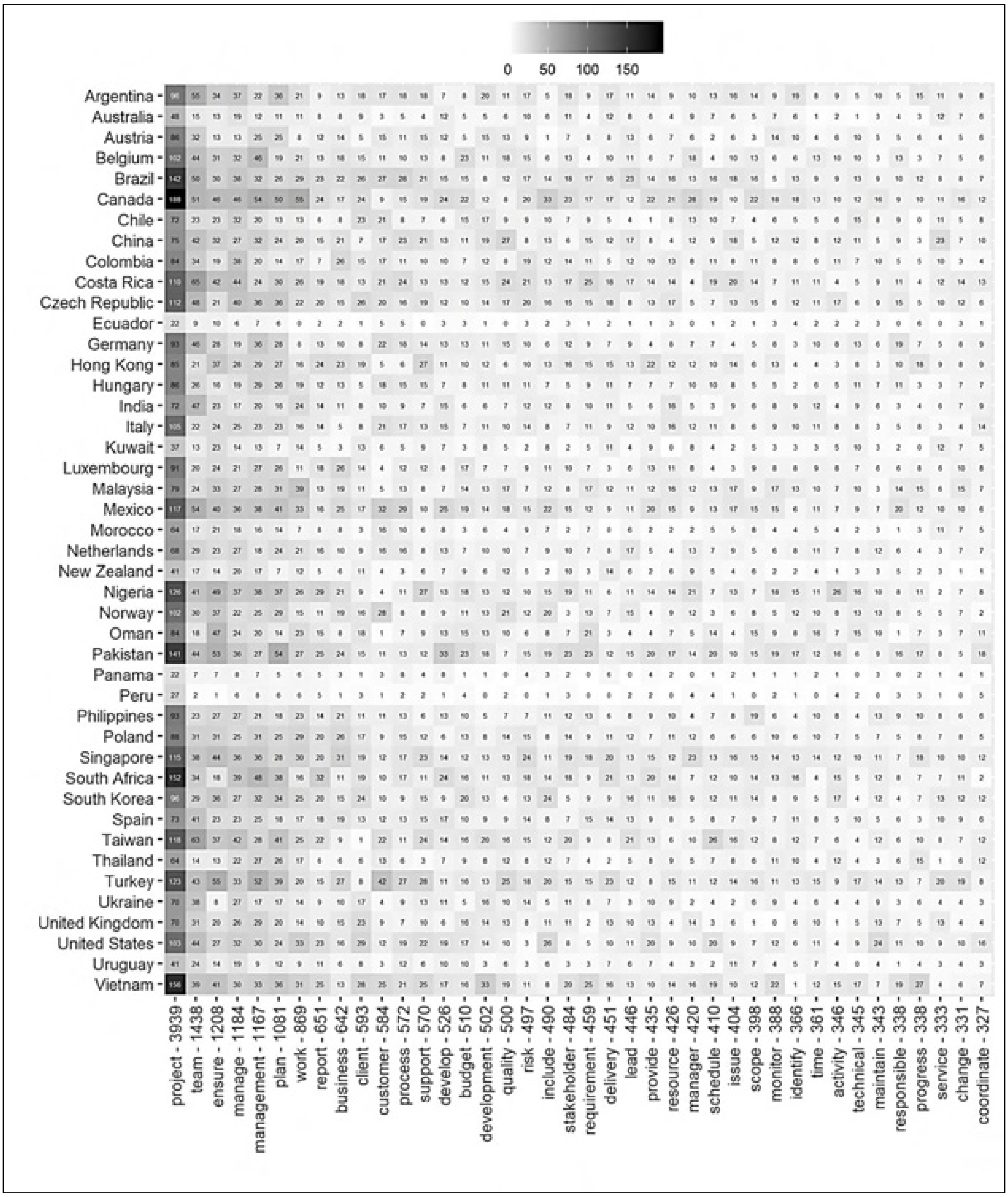

Figure 1. The most used words – part 1.

They manage project risks by identifying their sources and potential implications (words ‘risk’, ‘project’, ‘manage’, and ‘identify’). They also manage costs (word ‘cost’) and communication within the project (‘communication‘). They monitor and ensure project quality (words ‘monitor’, ‘quality’, and ‘ensure’). The project manager often deals with people. They lead the project team, manage, and coordinate their operations (‘lead’; ‘manage’; ‘project’; ‘team’; ‘coordinate’; ‘work’). They communicate with and meet clients (internal and external) and project stakeholders (words ‘communicate’; ‘internal’; ‘external’, ‘client’;

'project'; 'stakeholders'; and 'meet'). They manage relationships with customers (words 'customer' and 'relationship'). They address day-to-day business, search for solution and implement them to ensure project progress (words 'issue', 'solution', 'implementation', 'implement', and 'progress').

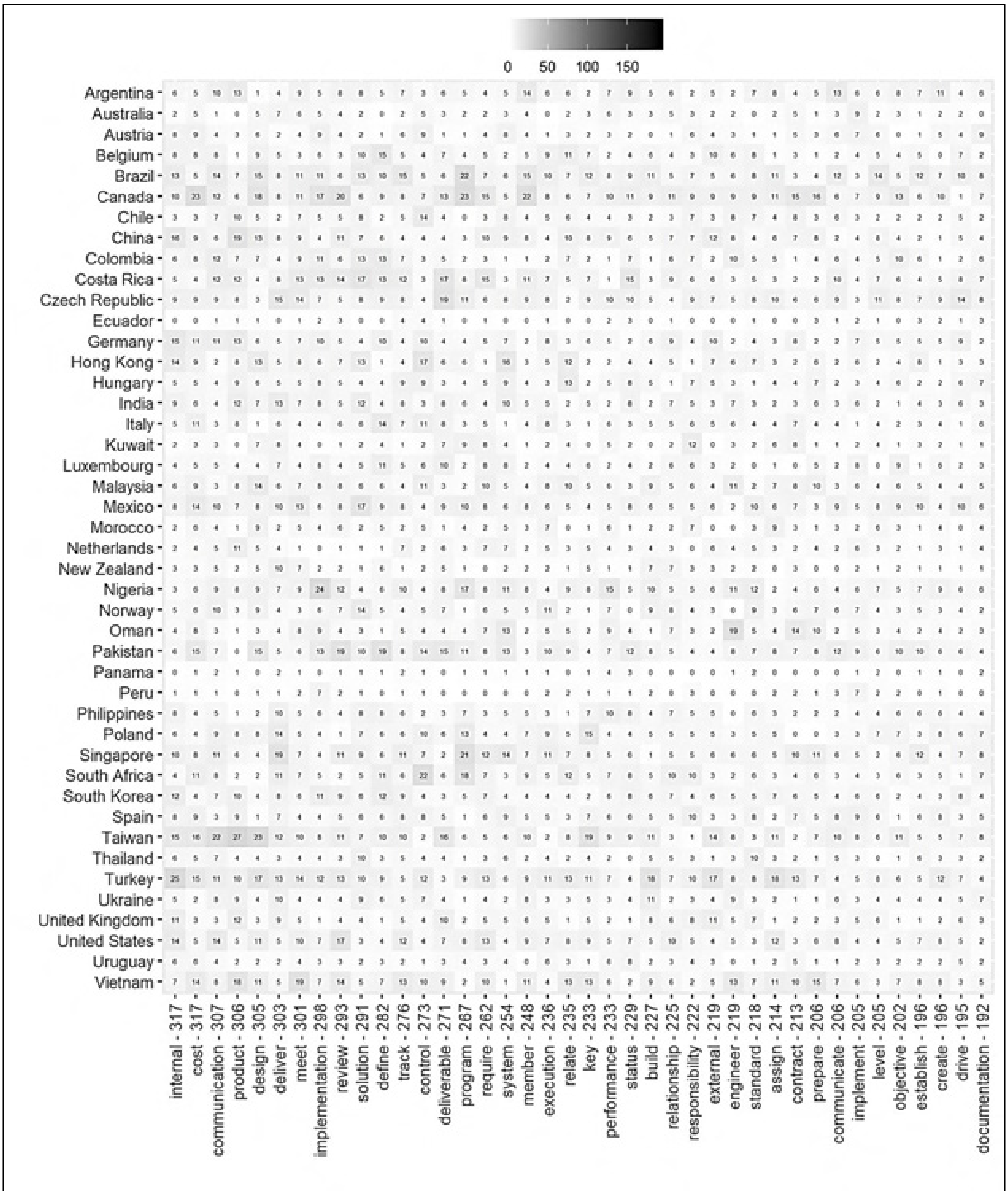

Figure 2. The most used words – part 2.

The 2-grams in Figure 3 confirm the conclusions regarding the most common words in Figures 1 and 2. The primary focus of project managers is to manage projects (2-grams ‘project management’, ‘manage project’, and ‘management project’). The manager defines the plan, scope, budget, timetable, and resources (‘project plan’, ‘project scope’, ‘project budget’, ‘project schedule’, ‘scope budget’, ‘scope schedule’, ‘plan schedule’, and ‘project resource’). They draw up project documentation (2-gram ‘project documentation’), manage project risks (2-grams ‘risk issue’, ‘risk management’, ‘project risk’, and ‘issue risk’), manage product quality (2-grams ‘ensure quality’, ‘quality assurance’, and ‘quality standard’), monitor project execution (‘monitor project’ and ‘control project’), and resolve problems (‘resolve issue’). It is again apparent that the project manager should manage project stakeholders relationships (2-gram ‘project stakeholder’) particularly with the key ones (‘key stakeholder’ and ‘relevant stakeholder’). The 2-gram ‘external stakeholder’ may suggest that project stakeholders are internal for some projects. Two-grams ‘report progress’, ‘progress report’, ‘status report’, ‘report project’ indicate that the project manager reports on the progress. Two-gram ‘cross functional’ may suggest that a cross-functional team could be necessary for some projects, and the project manager either leads them or is a member of that team.

project_management (275); project_team (252); manage_project (217); project_manager (196); project_plan (184); team_member (174); ensure_project (152); internal_external (122); cross_functional (100); project_scope (95); work_closely (82); project_status (77); risk_issue (70); project_delivery (62); project_budget (60); risk_management (60); project_risk (59); report_project (59); project_schedule (59); team_ensure (58); time_budget (57); project_progress (56); status_report (55); lead_project (54); project_documentation (53); functional_team (51); project_execution (50); assign_project (50); schedule_budget (48); develop_project (46); scope_schedule (46); define_project (46); policy_procedure (46); lesson_learn (42); management_project (42); responsible_project (42); change_management (42); ensure_quality (41); monitor_project (41); project_deliverable (40); include_limit (39); key_stakeholder (39); project_resource (38); relationship_client (38); manage_relationship (38); quality_standard (38); manage_change (38); external_stakeholder (37); project_include (37); support_project (37); management_team (37); management_process (37); aspect_project (37); life_cycle (37); track_project (37); communicate_project (37); create_maintain (36); ensure_compliance (36); resolve_issue (36); customer_satisfaction (36); monitor_control (36); track_progress (35); stakeholder_ensure (35); report_progress (35); control_project (35); business_development (35); scope_budget (34); relevant_stakeholder (34); senior_management (34); management_plan (34); software_development (34); maintain_project (34); change_project (34); process_improvement (34); deliver_time (33); ensure_effective (33); detail_project (33); progress_report (33); plan_schedule (33); deliver_project (33); issue_risk (33); project_program (33); project_performance (32); project_stakeholder (32); party_vendor (31); schedule_cost (31); business_process (31); quality_assurance (31); develop_maintain (31); development_team (31); ensure_timely (31); delivery_project (31); ensure_team (31)

Figure 3. The most used 2-grams.

Figures 4, 5 and 6 shows 2-grams in a net. The net in Figure 4 has 77 nodes for 93 2-grams. They are 2-grams from Figure 3 found at least 31 times in the documents. The top left corner of Figure 4 represents 2-grams ‘quality standard’ and ‘ensure quality’. The arrow on the edge indicates the order of words in the 2-gram. There are nodes ‘issue’ and ‘risk’ below 2-grams ‘quality standard’ and ‘ensure quality’. The edge between them has two arrows. These are two overlapping edges with opposing arrows. This piece of the net shows two 2-grams: ‘risk issue’ and ‘issue risk’. The net in Figure 4 has some nodes linked to only one other node, such as 2-grams ‘lesson learn’, ‘life cycle’, ‘work closely’, or ‘satisfaction customer’ while others are connected to multiple nodes.

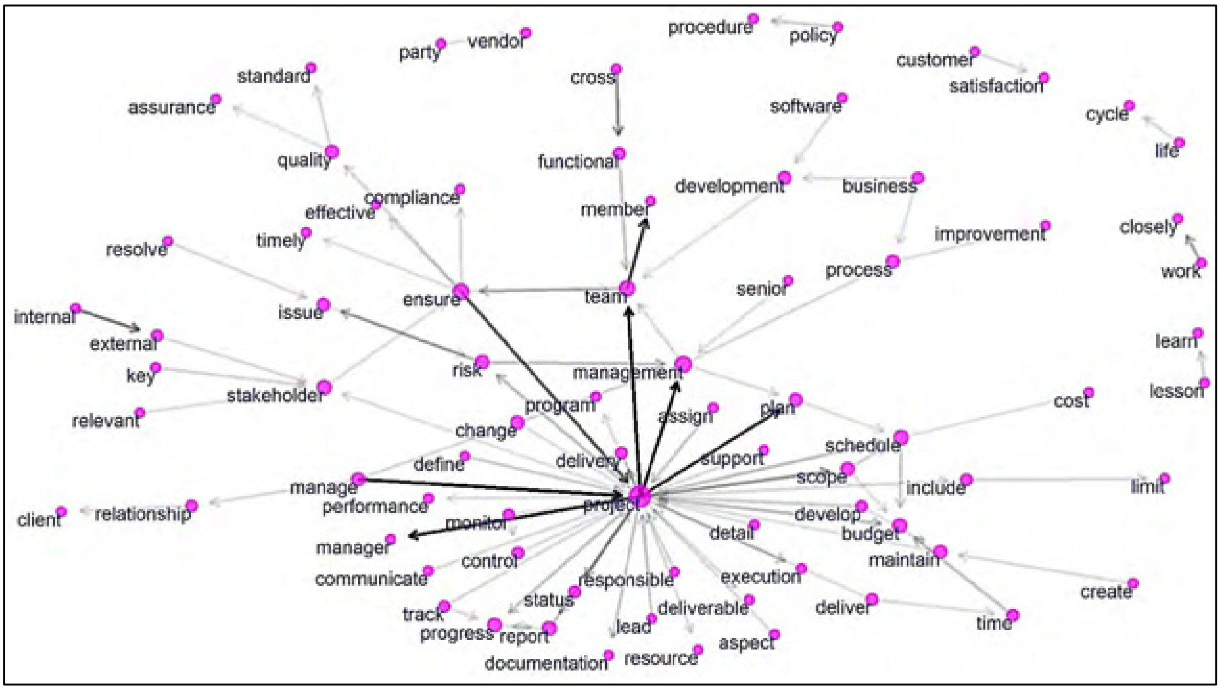

Figure 4. Two-grams as a net.

Figures 5 and 6 show 2-grams, where one of the words was the most common one in the corpora, ‘project’. The net in Figure 5 shows 2-grams with ‘project’ as the first word, such as ‘project schedule’ or ‘project success’. The net consists of 2-grams that occurred at least 13 times. It has 50 nodes and 49 edges, representing 49 2-grams and 50 words. The net in Figure 6 represents 2-grams with ‘project’ as the second word, such as ‘execute project’ or ‘control project’. The net presents 2-grams that occurred at least 16 times. It consists of 49 nodes and 48 edges.

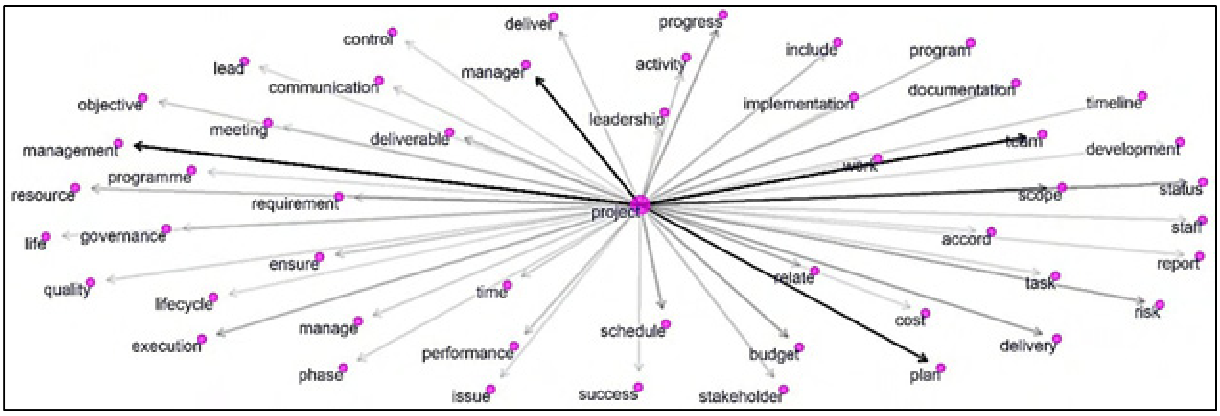

Figure 5. 2-grams with ‘project’ as the first word.

The nets in Figures 5 and 6 contain also 2-grams that were not shown in Figures 3 and 4 due to their frequencies. Results for 2-grams in Figures 5 and 6 that were not included in Figures 3 and 4 are consistent with previous analysis of the most common words and 2-grams in Figures 1, 2, 3, and 4. The project manager is a person who implements, manages, acts, works, and leads in a project or projects (2-grams ‘project implementation’, ‘implement project’, ‘project deliver’, ‘project manage’, ‘project governance’, ‘project activity’, ‘project work', 'project lead', and 'project leadership'). Executes and coordinates the project (2-grams 'coordinate project' and 'execute project'). They manage the costs and communication (2-grams 'project communication', 'project cost', and 'communication project'). They monitor and ensure project quality (2-gram 'project quality'). The project manager monitors, reports, and controls project execution (2-grams 'project ensure', 'project control', 'project report', and 'progress project'). They resolve problems (2-gram 'project issue') and ensure that objectives are achieved and the project is a success (2-grams 'project objective' and 'project success'). They manage project lead time, stages, and lifecycle (2-grams 'project time', 'project timeline', 'project phase', 'project life', 'project lifecycle', and 'phase project'). The project manager can be involved in multiple projects or complex projects (2-grams 'multiple project' and 'complex project').

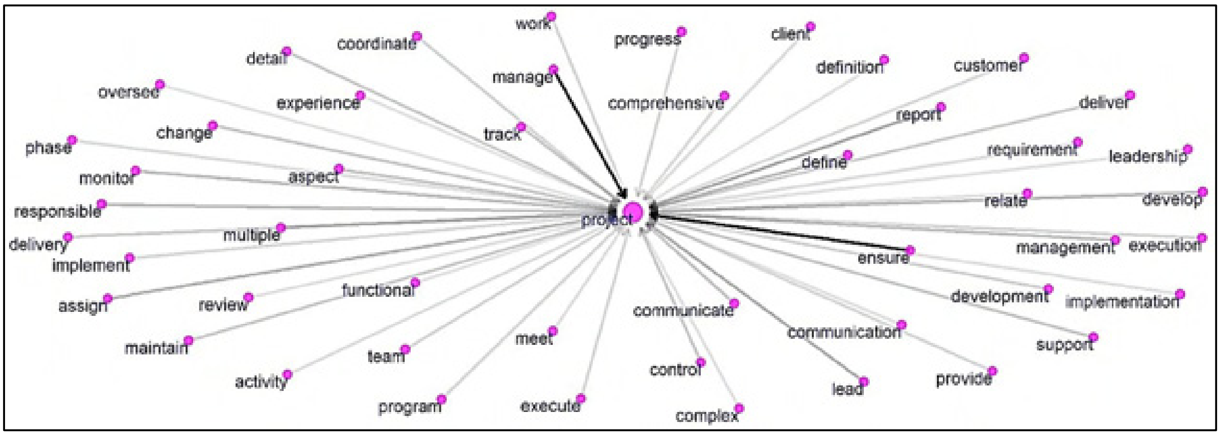

Figure 6. 2-grams with 'project' as the second word.

project_team_member (49); cross_functional_team (45); internal_external_stakeholder (33); project_manager_responsible (28); ensure_project_deliver (26); manage_change_project (24); project_scope_schedule (22); lead_project_team (22); project_deliver_time (22); detail_project_plan (22); change_project_scope (22); project_scope_objective (21); develop_detail_project (19); scope_schedule_cost (18); manage_project_team (17); manage_relationship_client (17); project_management_process (17); project_management_methodology (17); project_life_cycle (16); scope_schedule_budget (16); stakeholder_ensure_technical (16); scope_objective_involve (16); relevant_stakeholder_ensure (16); perform_risk_management (16); objective_involve_relevant (16); involve_relevant_stakeholder (16); ensure_technical_feasibility (16); create_maintain_comprehensive (16); maintain_comprehensive_project (16); time_scope_budget (16); report_project_status (16); senior_project_manager (15); cross_functional_project (15); comprehensive_project_documentation (15); project_team_ensure (14); risk_management_minimize (14); relationship_client_stakeholder (14); project_plan_monitor (14); management_minimize_project (14); coordinate_internal_resource (14); manage_project_budget (14); deliver_time_scope (14); project_management_team (13); manage_project_scope (13); definition_project_scope (13); internal_external_team (13); manage_project_resource (13); define_project_scope (13); key_performance_indicator (13); develop_project_plan (12); plan_monitor_track (12); measure_project_performance (12); flawless_execution_project (12); identify_manage_risk (12); communicate_project_status (12); manage_project_risk (12); project_management_plan (12); maintain_project_plan (11); functional_project_team (11); report_project_progress (11); vendor_flawless_execution (11); performance_tool_technique (11); party_vendor_flawless (11); monitor_track_progress (11); assist_definition_project (11); project_status_update (11); monitor_control_project (11); project_management_tool (11); manage_client_expectation (11)

Figure 7. The most used 3-grams.

ensure_project_deliver_time (22); manage_change_project_scope (21); develop_detail_project_plan (18);
stakeholder_ensure_technical_feasibility (16); scope_objective_involve_relevant (16);
project_scope_objective_involve (16); involve_relevant_stakeholder_ensure (16);
change_project_scope_schedule (16); relevant_stakeholder_ensure_technical (15);
project_scope_schedule_cost (15); objective_involve_relevant_stakeholder (15);
maintain_comprehensive_project_documentation (15); risk_management_minimize_project (14);
perform_risk_management_minimize (14); manage_relationship_client_stakeholder (14);
create_maintain_comprehensive_project (14); project_deliver_time_scope (13); deliver_time_scope_budget (12);
cross_functional_project_team (11); party_vendor_flawless_execution (11); detail_project_plan_monitor (11);
definition_project_scope_objective (11); assist_definition_project_scope (11);
vendor_flawless_execution_project (10); project_plan_monitor_track (10); plan_monitor_track_progress (10);
scope_schedule_cost_verification (9); schedule_cost_verification_technique (9);
project_performance_tool_technique (9); measure_project_performance_tool (9);
ensure_resource_availability_allocation (9); clarify_specific_requirement_project (6);
work_cross_functional_team (6); order_clarify_specific_requirement (5); detail_order_clarify_specific (5);
develop_maintain_project_plan (5); relationship_internal_external_stakeholder (5);
strength_skill_experience_level (5); member_individual_strength_skill (5); individual_strength_skill_experience (5);
scope_cost_schedule_contractual (5); develop_project_management_plan (5); define_project_scope_objective (5);
ensure_project_complete_time (5); member_cross_functional_team (5); project_scope_goal_deliverable (5)

Figure 8. The most used 4-grams.

Figure 7 shows 69 most common 3-grams that occurred at least 11 times. Figure 8 shows 46 4-grams that occurred at least five times. Analysis of the most popular 3-grams and 4-grams confirms previous conclusions. The project manager manages client and project stakeholder relationships (for example, n-grams ‘relationship internal external stakeholder’, ‘manage relationship client stakeholder’, ‘relationship client stakeholder’, or ‘manage client expectation’). They manage the project team (for example, 3-grams ‘manage project team’, ‘lead project team’), but can also be part of (internal and external) project teams (for example, n-grams ‘internal external team’ or ‘member cross functional team’). They also control the budget, scope, objective, risk, resources, and time of project execution (for example, n-grams ‘time scope budget’, ‘deliver time scope budget’, ‘definition project scope objective’, ‘project scope schedule cost’, ‘manage project risk’, ‘perform risk management minimize’, ‘manage project resource’, and ‘ensure resource availability allocation’). They set the project plan and monitor and report the progress (for example, n-grams ‘develop project plan’, ‘project plan monitor track’, ‘report project progress’, and ‘report project status’).

Figure 10 shows topics generated with the LDA algorithm. Their objective was also to identify the scope of responsibilities and most common tasks of the project manager. Each topic contains six words with the highest beta value. It represents the probability of word j occurring in topic i.

The number of topics to be generated by the LDA algorithm was a pivot decision. Four metrics were calculated as described in (Arun, Suresh, Veni Madhavan, & Narasimha Murthy, 2010; Cao, Xia, Li, Zhang, & Tang, 2009; Deveaud, SanJuan, & Bellot, 2014; Griffiths & Steyvers, 2004) with function FindTopicsNumber from R package ldatuning (Nikita & Chaney, 2020). The metrics were computed by training several LDA models with topics ranging from 2 to 50. The results in Figure 9 suggest that the optimum number of topics in light of these metrics was from 17 to 50 topics. The number of topics was also determined via a manual inspection of a variety of topic sets trained using several different numbers of topics. The final number of topics was set to 21.

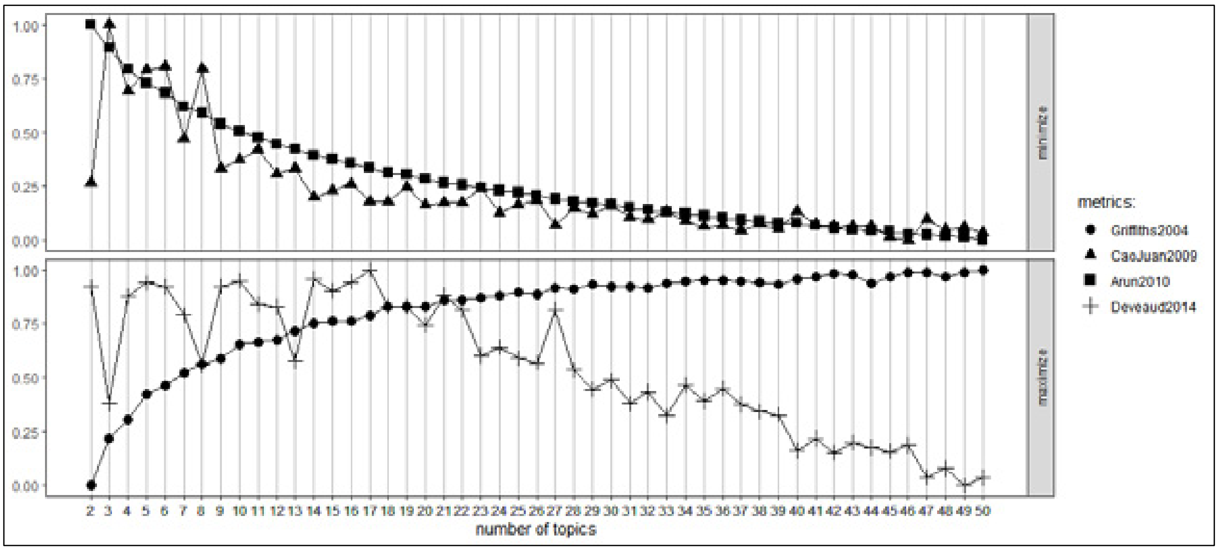

Figure 9. The selection of the number of topics in topic modelling using four metrics.

The topics generated by LDA (Fig. 10) also suggest the most common duties and responsibilities of the project manager. Those previously identified have been confirmed. The project manager performs actions related to project management (topic 12), determines the plan, scope, and resources needed for the project (topic 17), manages project risk by identifying its sources and potential impact (topic 20), manages costs and communication within the project (topic 11), monitors and ensures project quality (topic 2), leads the project team, manages and coordinates its operations (topics 5 and 18), manages project clients and stakeholders (topics 1, 6, and 9), monitors and reports project progress (topics 4 and 19), and supports partners involved in the project (topic 7). The project manager identifies new opportunities and helps with the development of the organisation's business strategy (topic 14). They are the guardian of current standards and procedures (topic 10). Topics 8, 13, and 16 may suggest activities related to the execution of specific types of projects, for example, software development, specific technical solutions or structures.

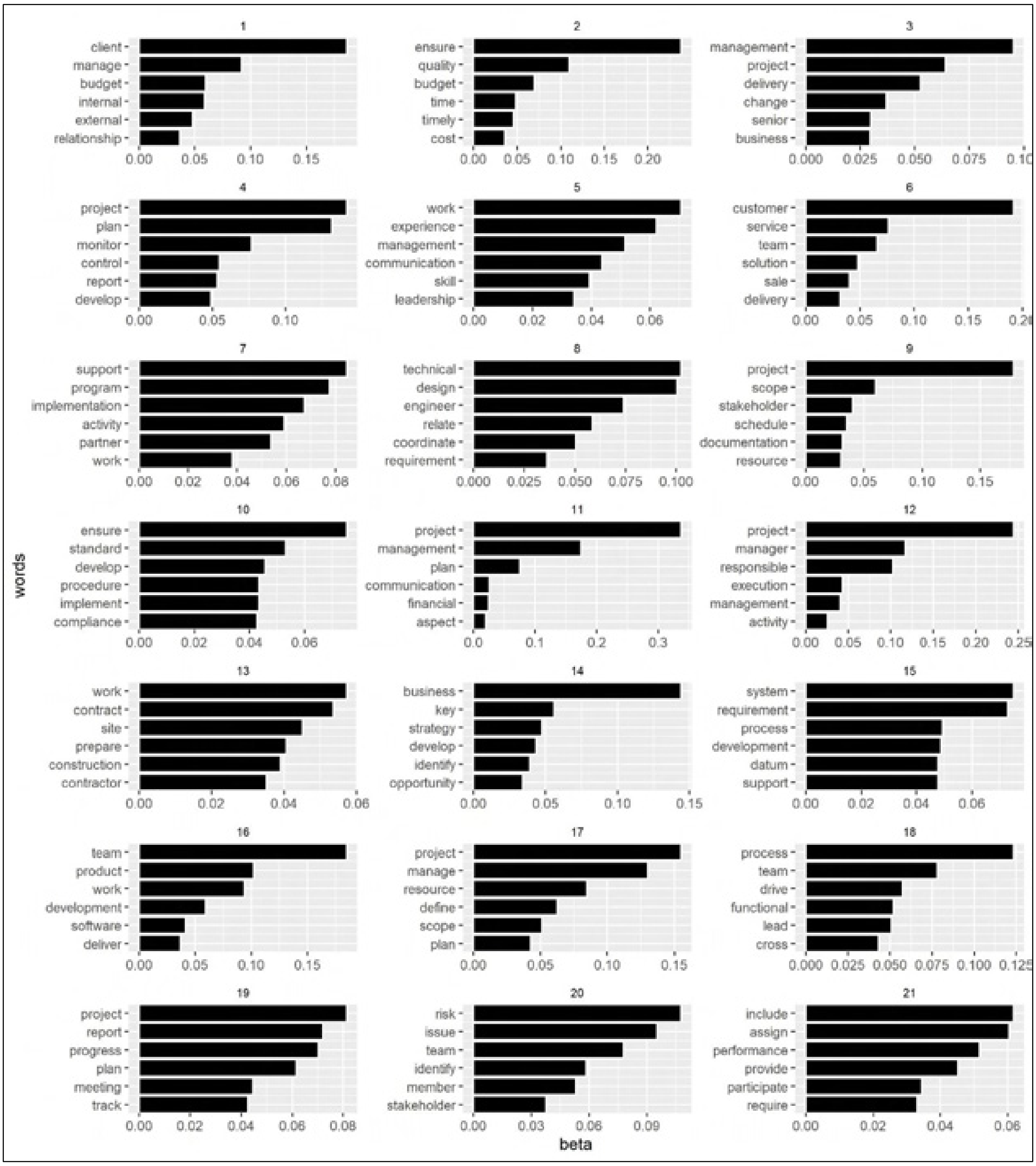

Figure 10. The topics generated with LDA.

5. Discussion and conclusions

The analysis of the most frequent words, n-grams, and topics identified with LDA exhibited the following responsibilities of project managers:

- various general tasks relevant to project management,
- resolving day-to-day problems to ensure project progress,

- drawing up a plan, schedule, budget, and documentation for the project,
- project scope and resources necessary,
- managing project risk, identifying its sources and potential effects,
- managing costs and communication for the project,
- monitoring and ensuring project quality,
- leading the project team, managing and coordinating its work,
- managing project client and stakeholder relations,
- monitoring project progress,
- reporting project progress,
- identifying new opportunities and aiding the development of the organisation's business strategy.

The scope of responsibilities and duties identified in the paper is consistent with other authors' previous research. Primary duties of the project manager include planning activities, organising work, leading the team, and monitoring and controlling progress (Pawlak, 2006; Wachowiak et al., 2004). The project manager acts as a problem solver, finding the best options to achieve project objectives (Ahmed et al., 2013). Their primary responsibility is to ensure that the project is properly planned, executed, and completed (Mantel et al., 2011), that all work is completed on time, within budget and scope and at the right level of performance (Heagney, 2016). They often report on the project progress, are accountable to stakeholders and guard such main goals as representing the interests of the project, ensuring that project goals are achieved, leading the project team, representing the project to appropriate environments, and supervising the preparation of project documentation (Gareis, 2005). The duties and responsibilities of the project manager identified by the author also partly correspond to those listed by Crawford et al. (Crawford et al., 2008)

The present study has certain limitations. Only job advertisements in English were analysed. Therefore the number of advertisements from countries where English is not an official language was reduced. The advertisements were downloaded for a period of six days only. The attempt to automatically identify the section with duties and responsibilities did not succeed. Therefore, the identification was done manually for random advertisements. It reduced the number of documents analysed. The content of the job advertisements was not analysed by country/area, although results in Figures 1 and 2 suggest certain differences among them.

Future research could focus on the following matters:

- to develop a tool/solution to automatically identify a specific section in a job advertisement, such as requirements, job description, company overview, which would facilitate analysing all downloaded job advertisements,

- to compare responsibilities of project managers:
  - by project type,
  - be economy sector,
  - by country, continent, official language, country size, or population size,
- job advertisement categorisation using text clustering (for example K-means text clustering),
- analysis of job advertisements in languages other than English following machine translation into English.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

EDUCATION AT TECHNICAL SECONDARY SCHOOLS FOR THE NEEDS OF INDUSTRY 4.0 IN POLAND WITH PARTICULAR CONSIDERATION OF THE ŚLĄSKIE VOIVODSHIP

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Purpose: The research presented here was intended to describe to what extent secondary technical education is prepared to educate staff for the needs of Industry 4.0.
Design/methodology/approach: The research was conducted by analysing the education offer of Polish and Silesian technical secondary schools while identifying professions that are important for the development of Industry 4.0 concept in production enterprises. The results obtained on a national scale were compared with those of the Śląskie voivodship.
Findings: During the research it was found that the education offer in terms of preparation of future technical staff for the needs of Industry 4.0 is not sufficient and definitely not diversified enough. Among the "professions of the future" the profession of IT technician definitely prevails and its share in the offer is several times higher than that of other professions.
Research limitations/implications: The research concerned only the offer of Polish secondary schools and not the actual number of students attending them. It is also difficult to accurately compare the values under study in the rest of the European Union due to the diversity of secondary education systems across countries.
Practical implications: The research conducted shows that there is a need for greater promotion among young people of those faculties that are relevant from the perspective of requirements of the Industry 4.0. The promotion should take place both at the level of government and local authorities with active participation of industry representatives.
Originality/value: The paper presents an analysis of Polish, and in particular Silesian technical secondary schools from the point of view of the opportunities they offer to graduates of primary schools wishing to gain a profession of a technician useful in their future careers in modern enterprises following the concept of Industry 4.0. The research results can serve as a starting point for analysis of the condition of Polish education in the context of requirements of employers wishing to employ qualified staff useful in modern production facilities in the future.

Keywords: Industry 4.0, smart factory, education, technical schools, Silesia.

Category of the paper: research paper.

1. Introduction

The global economy, the pursuit of competitive advantage, diversification and expansion of the supply chain, products customisation, increasingly widespread digitalisation of all aspects of a company's operations, and expansion of the Internet. The combination of these and other phenomena led to emergence of the concept of the fourth industrial revolution called Industry 4.0. The fourth industrial revolution does not anticipate revolutionary changes in existing manufacturing technologies and techniques, it only assumes their use in the integral world of ICT technologies, consequently creating intelligent manufacturing systems (Bendkowski, 2017; Mącik, 2016).

Meeting the demands of new, constantly evolving manufacturing concepts requires not only new technical solutions: machines, equipment, systems, but above all an army of highly qualified engineers and machine and equipment operators. In order to be successful on this battlefield, it is essential that future employees are properly prepared. The education process constantly faces new and bigger challenges. The industry needs well-educated specialists with new skills and capable of self-development (Moid, 2020; Siemieniecka, 2021). New fields of education are emerging: ICT, mechatronics, robotics or broadband radio communication. The existing ones gain new meaning: optics, electronics, computer science, automation (Zawłocki, 2017).

A qualified specialist whose qualifications will meet the requirements of the Industry 4.0 idea is not only a specialist in his or her narrow field. It is a versatile technician or engineer who is familiar with computer science, telecommunications and automation (Iwański, 2017). Thus, it seems reasonable to start such education as early as possible. The challenges of the new era are faced not only by technical universities but also by secondary schools that prepare qualified operators and technicians and above all candidates for future engineers and managers who are familiar with basic technical issues (Benešová & Tupa, 2017).

2. Literature review

The idea of the fourth industrial revolution, commonly known as Industry 4.0, came to light in 2014. Some authors saw its première at Hanover trade fairs (Olszewski, 2016; Lasi et al., 2014), but it is also believed that the concept was first announced publicly at the World Economic Forum in Davos (Iwański, 2017). The platform was created by an Advisory Committee of technical organisations and industry representatives working under the auspices of the German Academy of Technical Sciences (Olszewski, 2016).

The main, basic idea of the Industry 4.0 concept is the notion of smart factory, which is a modern and intelligent factory based on socio-technical systems (Bendkowski, 2017). In order to better understand the idea and scope of the concept we need to take a closer look at the structure of a modern company within a value chain (Fig. 1).

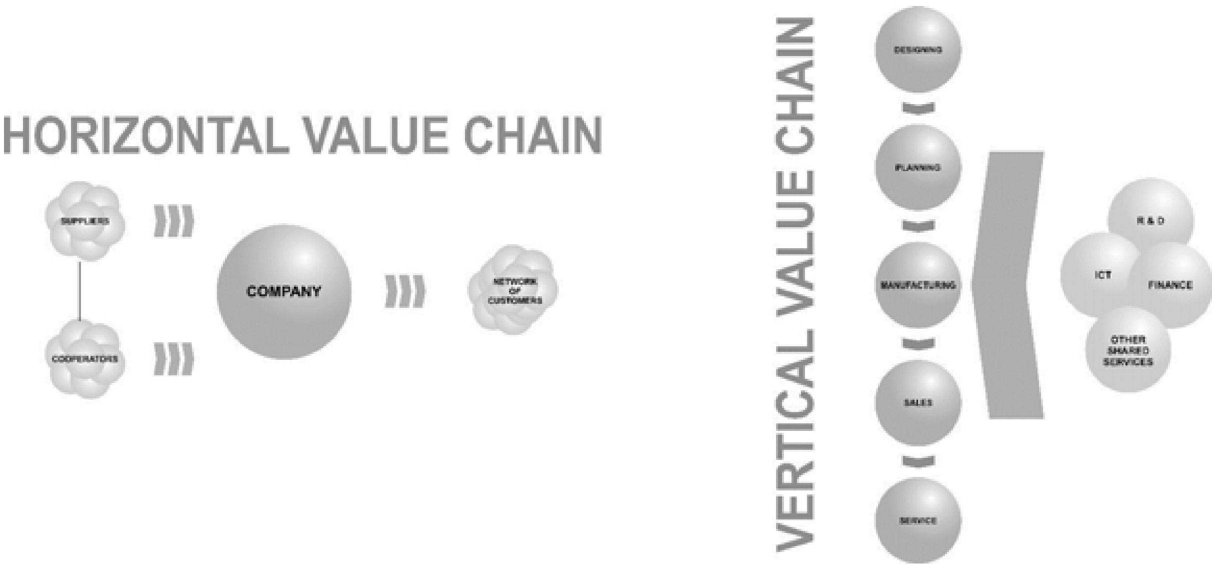

Figure 1. Value chains in Industry 4.0. Source: based on (Oesterreich, 2016; Koch et al., 2014).

Smooth functioning of the idea of Industry 4.0 assumes integration based on digital technologies (both information and communication technologies) for each participant in the horizontal value chain, i.e. cooperators, suppliers and customers, and of course the company itself. This will ensure the smooth flow of information and thus the smooth functioning of the process of the supply of raw materials, components and products (Sirine & Andadari, 2020). However, integration of the vertical value chain is also important, which will allow for smooth cooperation not only between particular departments of a company but also between individual participants of the manufacturing process and even individual machines and devices. The application of modern, coherent and proven ICT solutions will increase the level of autonomy of individual elements of the chain, minimising the probability of errors caused by employees. It is not sufficient to only "equip" the connection system between horizontal and vertical chain links with new technologies. The most essential element is to enable, through technical solutions, each link in the chain to communicate with each other autonomously (Tjahjono, 2017). Such integration is to support not only the manufacturing process but also product development and seamless customisation (Kamiński, 2018; Wang et al., 2017). In order to implement such an ambitious concept it is necessary to equip all links of the value chain with modern technological solutions, such as (Atzori et al., 2010; Baena at al., 2017; Lu et al., 2017):

- Industrial Internet of Things,
- broadband wireless communication,
- automation, robotics, cyber-physical systems, universal mechatronics,
- autonomous transport and storage systems,

- additive manufacturing,
- virtual and augmented reality,
- predictive analytics,
- optoelectronics,
- computing clouds, Big Data and more.

Smooth implementation of comprehensive, modern and even pioneer solutions poses enormous challenges for today's engineers. The proposed new technological solutions are interdisciplinary and combine several science and technology domains. This requires employees to constantly expand their knowledge or learn new things, for example mechatronics, optoelectronics or predictive analytics to name just a few. However, IT and telecommunication come to the fore due to the need to integrate all system components into a single IT network. The new working environment so formulated requires employees to have interdisciplinary knowledge and requires continuing education in innovation in their own and related domains (Gracel & Makowiec, 2017).

The new requirements for technical staff demand excellent preparation of specialised staff on different levels who are useful in the Industry 4.0 era. Jobs that involve independent product manufacturing are becoming less and less crucial while skills required to operate complex, modern machines and devices are becoming more and more important. It is becoming increasingly difficult for unskilled people, who can quickly be trained to perform simple manual work, to find their place in the labour market. In order to prepare young people for the requirements of contemporary labour market, it is necessary to start specialised education already at the stage of secondary schools – in industry and technical schools. As indicated in reports by Manpower Group (a staff recruitment company), both global and Polish industry has been facing shortage of qualified blue-collar workers (e.g. electricians, mechanics, welders, etc.), technicians, IT specialists and engineers for many years. These groups of professionals lead the ranking of sought-after employees year after year (Manpowergroup, 2020).

In 2017, as a result of Polish education system reform, an 8-year primary school was introduced. Those who graduate can continue education in a 4-year general secondary school, 5-year technical secondary school or 3-year grade I vocational school (Fig. 2) (Panasiuk & Kaczmarek, 2018).

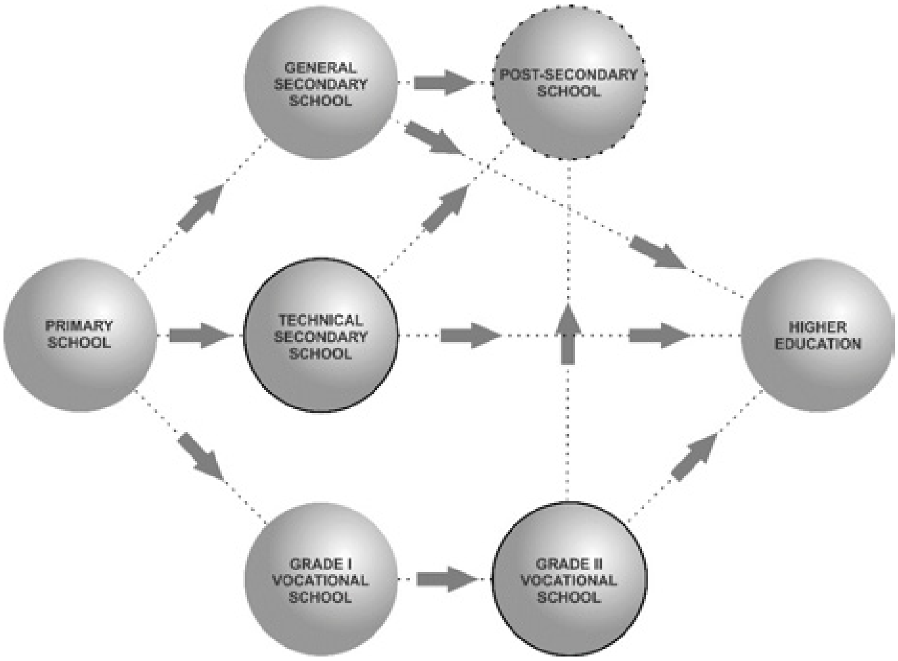

Figure 2. A fragment of Polish education system for young people. Source: on base (Zawłocki & Niewiadomski, 2017).

In order to obtain the professional title of a technician, one must either complete a technical secondary school or, after completing grade I vocational school, continue education in grade II vocational school. Graduates of general secondary schools, technical secondary schools and grade II vocational schools can continue education in post-secondary schools. This type of school offers a technician's diploma only in certain branches, such as the health care branch, the social work branch or the security and safety of persons and property branch. All graduates of secondary schools can also learn new skills in qualifying vocational courses (Zawłocki & Niewiadomski, 2017).

The best possible preparation of future employees to perform their jobs in new working environments requires not only the expansion of the educational offer to include new professions and skills, but also the development of existing curricula to include innovative elements implemented in industry on an ongoing basis. The sources of innovation in industry are mainly scientific research centres and research and development departments in companies. This is why contemporary teaching in vocational schools should have a dual nature. As many researchers point out, the measure of good employee education is, in addition to theoretical knowledge in schools, practical learning in industrial plants.

Multi-stage technical education can be a good answer to the growing demand for interdisciplinary knowledge of technical staff (Gracel, 2016). A young person who graduates from a secondary school with a professional title of technician can continue education at a university. Further studies can involve the same domain or completely new direction, thus combining the knowledge acquired in the technical secondary school with knowledge acquired during engineering studies (Zawłocki, Nieroba, Niewiadomski, 2015).

3. Methods

For the purposes of the research, faculties offered to primary school graduates were analysed in 202 technical secondary schools in Śląskie voivodship. Only state schools for young people were considered. According to current data from Statistics Poland there are 207 such schools in Śląskie voivodship (GUS, 2021). Thus, it should be assumed that more than 97% of the population was analysed.

Data obtained on a voivodship scale were compared with data on a national scale. For this purpose the "Information guide to vocational education professions" published in 2020 was used. This is currently the latest comprehensive study on vocational schools in Poland (Magnowski, 2020). Data concerning European Union were aggregated based on information from Eurostat, in particular from "Education and training" and "Regional statistics" sections.

The names of professions analysed and their assignment to specific branches are in accordance with the classification of professions of vocational education of the Ministry of Education and Science. The study includes those professions which are trained in 5-year technical secondary schools for youth or in grade II vocational schools. Professions that require post-secondary education and professional training were not included. This is why the study does not cover such professions as professions in the health care industry and the security and safety of persons and property industry.

A total of 101 professions were analysed, which fall within the following 30 industry branches:

- audiovisual industry,
- construction industry,
- ceramics and glass industry,
- chemical industry,
- wood and furniture industry,
- economic and administrative industry,
- electric energy industry,
- electronics and mechatronics industry,
- hairdressing and cosmetics industry,
- mining and drilling industry,
- commercial industry,
- tourist, hotel and catering industry,
- forestry industry,
- mechanical industry,
- precision mechanics industry,
- metallurgical industry,

- automotive industry,
- horticultural industry,
- healthcare industry,
- printing industry,
- fashion industry,
- agricultural and breeding industry,
- fisheries industry,
- forwarding and logistics industry,
- food industry,
- ICT industry,
- road transport industry,
- rail transport industry,
- air transport industry,
- water transport industry.

The classification of professions is updated on an ongoing basis by the Ministry of Education and Science. New entries are added and names (and qualifications) of existing professions change. Among the analysed professions a "robotics technician" is an example (MEN, 2020). It is not included in the 2020 list, but in 2022 there are already 6 units planned in Śląskie voivodship in which it will be possible to acquire this profession.

Based on a review of literature on the subject, those industries that may be relevant from the point of view of their usefulness for the development of the Industry 4.0 concept have been identified. They were divided into two groups. The first group includes particularly important professions: in electronics and mechatronics industry and in ICT industry. They are represented by the following professions:

- IT technician,
- mechatronics technician,
- electronics technician,
- software development technician,
- ICT technician,
- automation technician,
- telecommunications technician,
- technician in the field of IT for visually impaired people,
- broadband electronic communication technician,
- robotics technician.

The other group consists of industries that are useful for the development and functioning of the assumptions of Industry 4.0. These are: electric energy industry, mechanical industry and precision mechanics industry. The following professions are included:

- mechanic technician,
- electrical technician,
- technician of renewable energy equipment and systems,
- optician technician,
- energy technician,
- welding technician,
- lifting equipment technician.

In the research part, only industries and professions belonging to these two groups were considered.

4. Results

According to data published by Eurostat between 2013 and 2019, around 48% of all secondary school students in EU countries studied in vocational secondary schools. As there are different systems of secondary education in different Member States, it is not possible to state unequivocally what percentage of young people chooses the schools that best correspond to the Polish technical secondary school ("technikum") (Eurydice, 2022).

In order to compare how popular technical (vocational) schools are in particular countries, an average number of students of such schools per 1,000 residents was calculated. The results are presented in Figure 3.

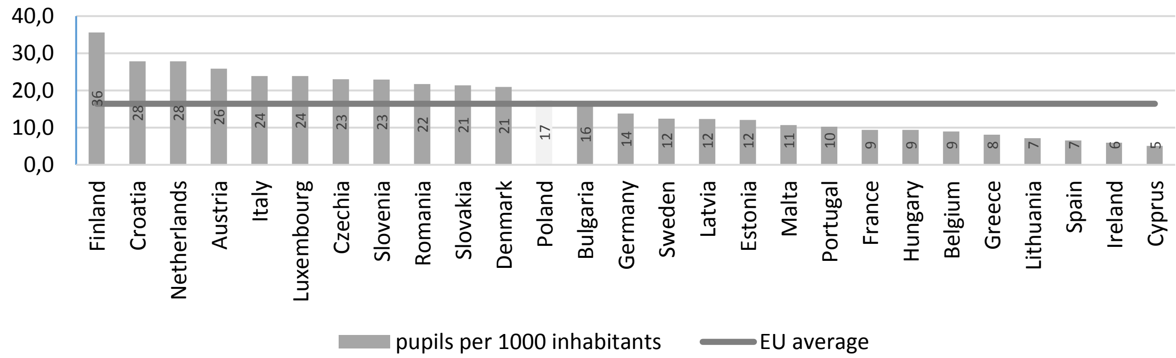

Figure 3. Number of students of vocational secondary schools in European Union.

The average in the entire EU is 16.4 students per 1,000 residents. Vocational secondary schools are most popular among young people in Finland, Croatia, the Netherlands and Austria. The fewest students choose this type of school in Lithuania, Spain, Ireland and Cyprus. In this summary, Poland is slightly above the average (17 students/1,000 residents), at the beginning of the second half of the rate (median = 13.8).

In Poland, the offer of education in technical secondary schools in 2020 consisted of 12,793 units in 96 professions, in 30 industries. Percentage share of units in particular industries is presented in Figure 4.

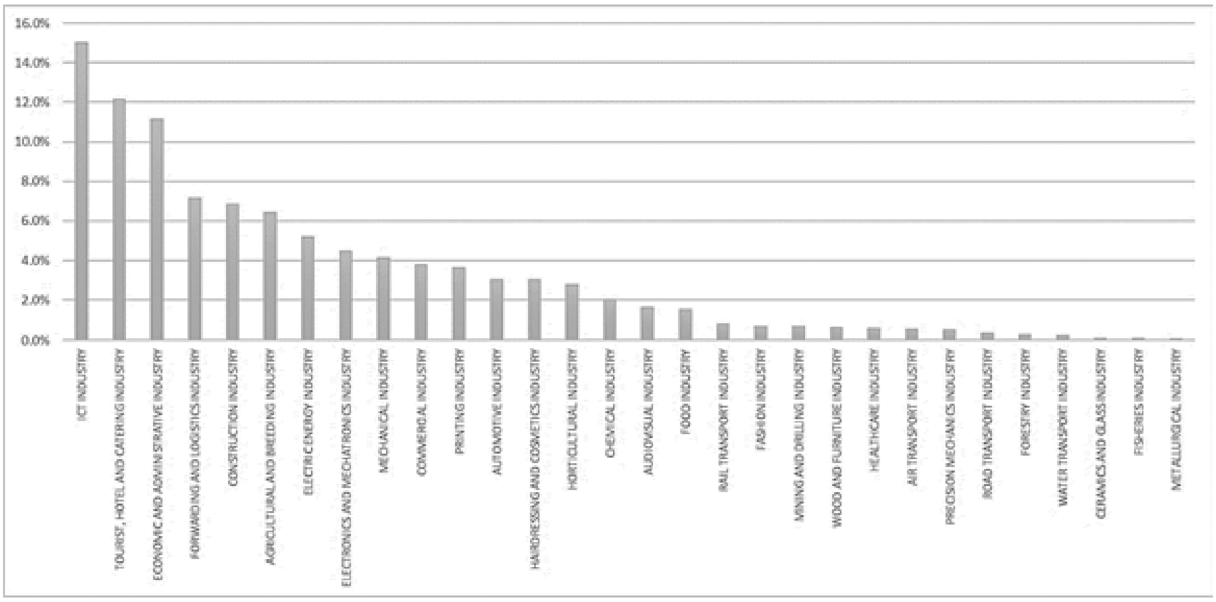

Figure 4. Percentage share of particular industries in total number of units in Poland.

Based on the collected data it can be said that industries from the first group, which are relevant for the development of Industry 4.0, constitute 19.5% of all units. Industries from the other group constitute 9.5%. Industries from the first and the other group together constitute 29% of all units in Poland in which primary school graduates could start their education.

The ICT industry is the most represented in Poland. In 2020, it included 1,924 units, which constitutes 15% of the entire education offer.

In the Śląskie voivodship in total there were 933 units from which graduates of eight grade can choose. The percentage share of particular industries of professions is presented in Figure 5.

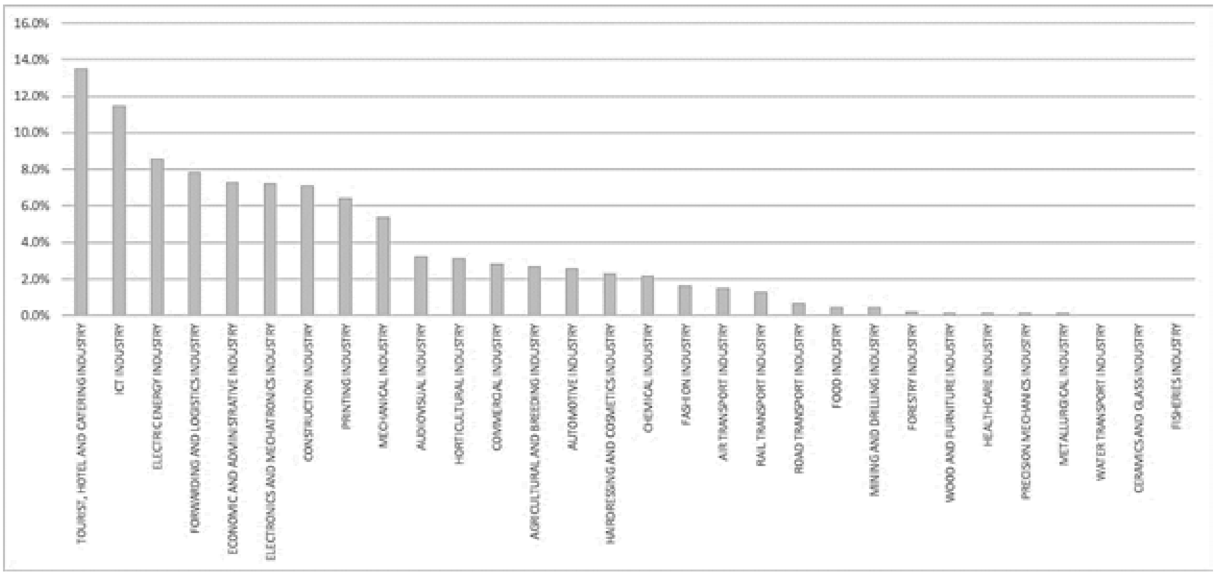

Figure 5. Percentage share of particular industries in total number of units in Śląskie voivodships.

In Śląskie voivodship, the education offer for 2022/2023 school year is represented by 27 industries. Industries in the first group constitute 18.6% of all units. Industries from the other group constitute 12.9%. The first and the other group of professions together constitute over 31.5% of all units in Śląskie voivodship.

The most numerous educational offer (in terms of potential usefulness in Industry 4.0) in Śląskie voivodship is represented by units in which young people can study professions included in the ICT industry. There are 126 such units, which is 11.5% of all units in Śląskie voivodship. Only the offer in hotel and catering industry is more numerous (13.5%).

In order to examine the professional structure of both analysed groups, Table 1 was created, which contains the number of units and their percentage share in group I and II together. Based on this, the pie charts included in Figures 6 and 7 were developed.

Table 1.
Share of professions by group in Poland

Group I – industries that are relevant for Industry 4.0			**Group II – industries that are useful for Industry 4.0**		
Profession	**Number of units**	**Percentage**	**Profession**	**Number of units**	**Percentage**
IT technician	1509	60.4%	Mechanic technician	496	40.7%
Mechatronics technician	263	10.5%	Electrical technician	329	27.0%
Electronics technician	232	9.3%	Technician of renewable energy equipment and systems	228	18.7%
Software development technician	174	7.0%	Optician technician	68	5.6%
ICT technician	167	6.7%	Energy technician	50	4.1%
Automation technician	79	3.2%	Welding technician	35	2.9%
Telecommunications technician	51	2.0%	Lifting equipment technician	12	1.0%
Technician in the field of IT for visually impaired people	12	0.5%			
Broadband electronic communication technician	11	0.4%			
Robotics technician	0	0.0%			
TOTAL	2498		TOTAL	1218	

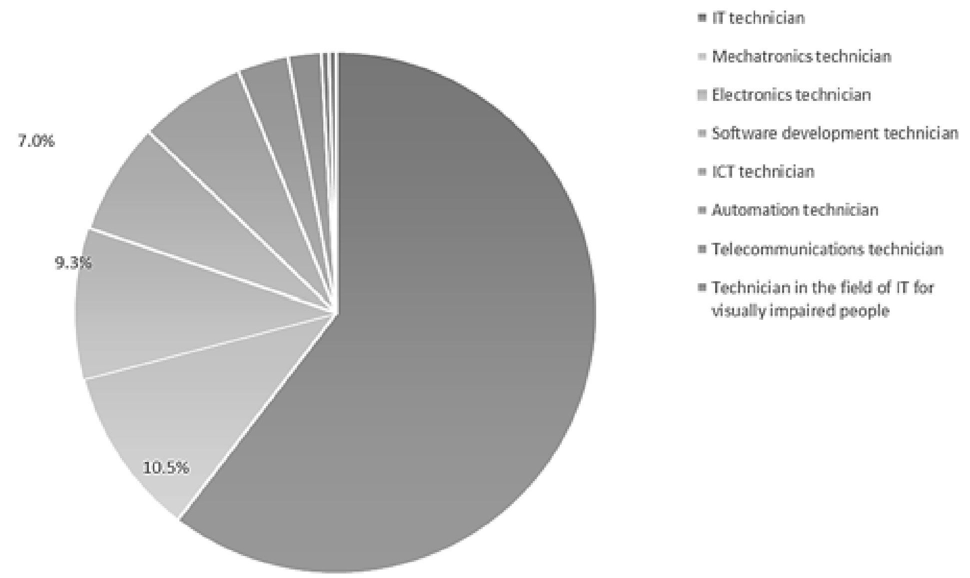

Figure 6. Percentage share of particular professions in group I in Poland.

Based on the above data (Fig. 6, Table 1) it can be noticed that the profession of IT technician constitutes over 60% of all offered professions in Poland. Disparities in the structure of the number of offered units become apparent when quartiles are analysed. In the first quarter, there are only 3% of all units that represent the following professions: telecommunications technician, technician in the field of IT for visually impaired people and broadband electronic communication technician. The second quarter constitutes 9.8% of all units in the following professions: ICT technician and automation technician. The third quarter constitutes 16.3% of units and it includes units that teach the professions of electronics technician and software development technician. The last quarter constitutes 70.9% of the entire offer and it includes professions of IT technician and mechatronics technician.

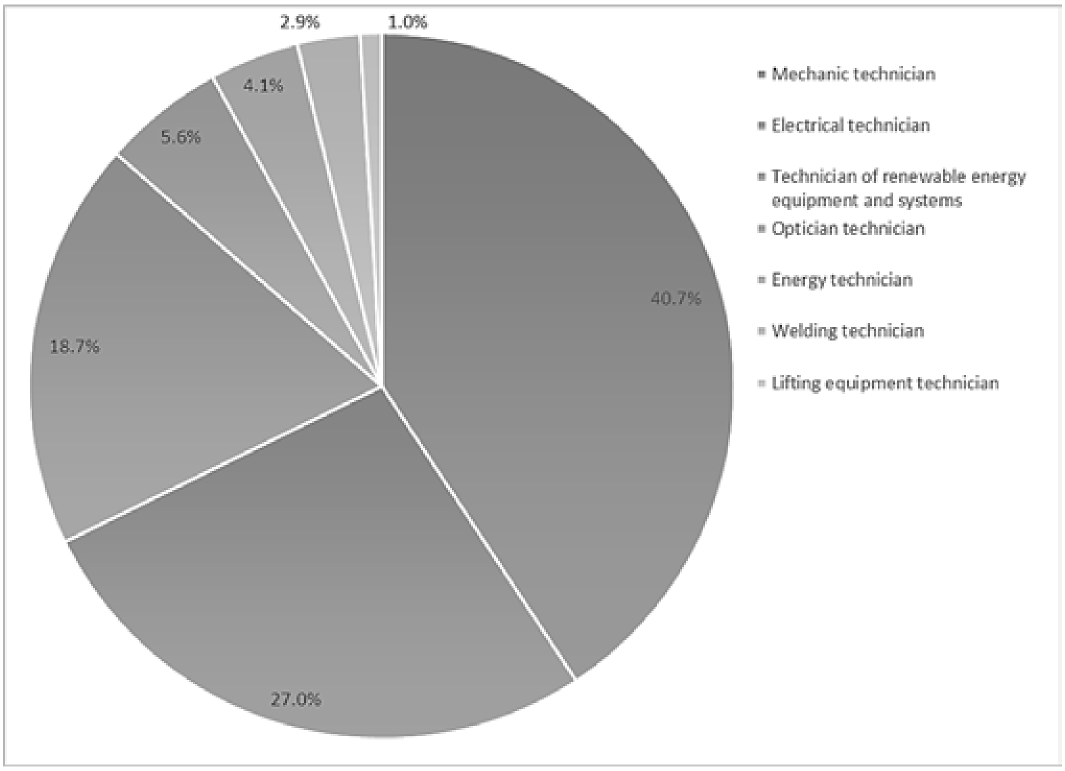

Figure 7. Percentage share of particular professions in group II in Poland.

In group II of industries useful for Industry 4.0 (Fig. 7, Table 1) it can be noticed that in the first quarter there is only 3.9% of all units representing the professions of welding technician and lifting equipment technician. The second quarter constitutes 9.7% of all units in the following professions: optician technician and energy technician. The third quarter constitutes 18.7% and it includes units that teach the profession of technician of renewable energy equipment and systems. The last quarter constitutes 67.7% of the entire offer and it includes professions of mechanic technician and electrical technician.

Next, the structure of the offer in technical secondary schools in Śląskie voivodship was analysed in a similar manner. The results are presented in Table 2 and Figures 8 and 9.

Table 2
Share of professions by group in Śląskie voivodship

Group I – industries that are relevant for Industry 4.0			Group II – industries that are useful for Industry 4.0		
Profession	**Number of units**	**Percentage**	**Profession**	**Number of units**	**Percentage**
IT technician	68	39.1%	Electrical technician	42	35.0%
Mechatronics technician	28	16.1%	Mechanic technician	38	31.7%
Software development technician	26	14.9%	Technician of renewable energy equipment and systems	20	16.7%
Electronics technician	19	10.9%	Welding technician	12	10.0%
Automation technician	14	8.0%	Energy technician	6	5.0%
ICT technician	9	5.2%	Optician technician	1	0.8%
Robotics technician	6	3.4%	Lifting equipment technician	1	0.8%
Technician in the field of IT for visually impaired people	2	1.1%			
Telecommunications technician	1	0.6%			
Broadband electronic communication technician	1	0.6%			
TOTAL	174		TOTAL	120	

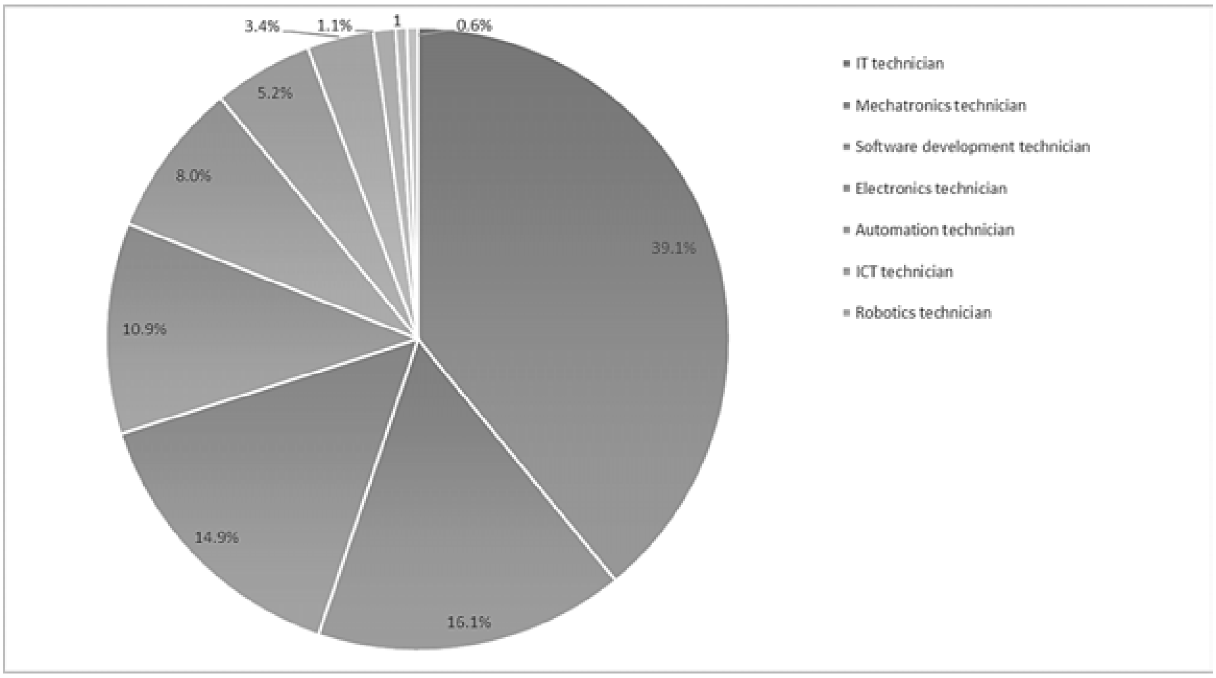

Figure 8. Percentage share of particular professions in group I in Śląskie voivodships.

The data obtained for schools in Śląskie voivodship (Fig. 8, Table 2) show that the most dominant offer among group I is the profession of IT technician (39%). After analysing the quarters it can be seen that in the first quarter there are only 2.3% of all units that represent the following professions: telecommunications technician, technician in the field of IT for visually impaired people and broadband electronic communication technician. The second quarter constitutes 8.6% of all units in the following professions: ICT technician and robotics technician. The third quarter constitutes 19% and it includes units that teach the professions of electronics technician and automation technician. The last quarter constitutes 70.1% of the entire offer and it includes professions of IT technician, automation technician and mechatronics technician.

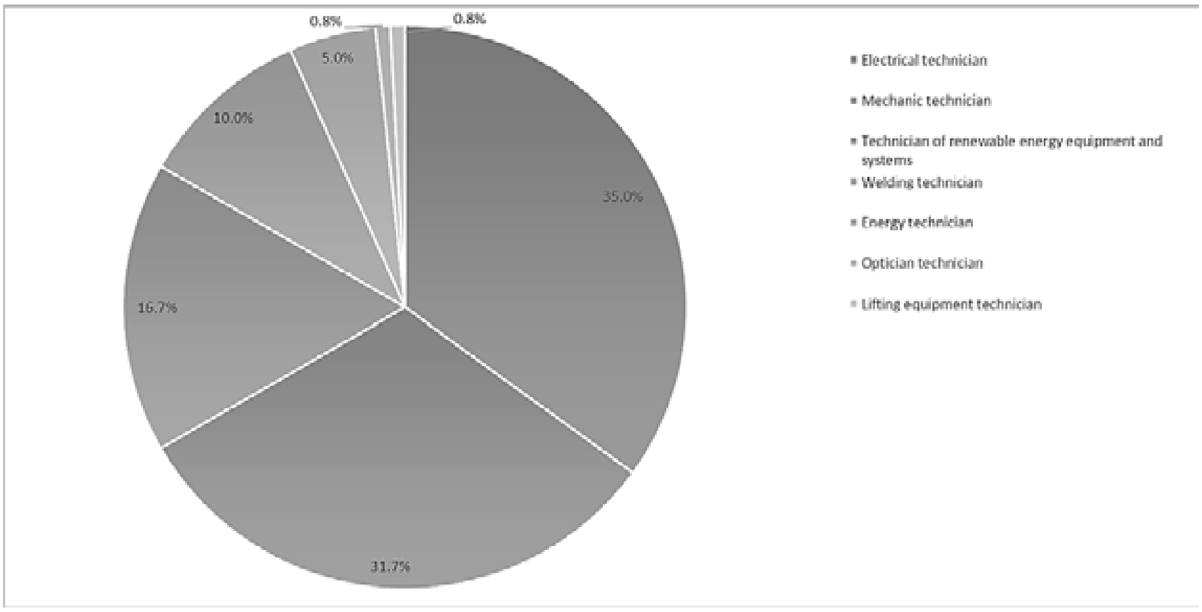

Figure 9. Percentage share of particular professions in group II in Śląskie voivodships.

In group II of industries useful for Industry 4.0 (Fig. 9, Table 2) it can be noticed that in the first quarter there is only 1.7% of all units representing the professions of welding technician and optician technician. The second quarter constitutes 15% of all units in the following professions: welding technician and energy technician. The third quarter constitutes 16.7% and it includes units that teach the profession of technician of renewable energy equipment and systems. The last quarter constitutes 66.7% of the entire offer and it includes professions of mechanic technician and electrical technician.

5. Conclusions and discussions

The research aimed at determining if Polish, and in particular Silesian, technical secondary schools are prepared to educate staff capable of meeting the challenges faced by modern enterprises in the context of the fourth industrial revolution.

The research did not take into account the qualitative aspect of Polish education in technical secondary schools, but only the quantitative dimension – thus defining the offer of the institutions addressed to graduates of primary schools.

In the countries of the European Union, approximately 48% of primary school graduates study in secondary vocational education and this figure has not changed significantly over the years. In comparison with other European Union countries, Poland is in the middle when it comes to the popularity of secondary vocational schools. In the period 2013–2019, a result of

17 students per 1,000 residents was recorded, with a European average of 16.4. The highest result was noted in Finland – over 36.5%, and the lowest in Cyprus – 5 students per 1,000 residents.

In the strategy entitled "Industrial Policy of Poland" published in 2021 by the Ministry of Economic Development, Labour and Technology the key axes are digitalisation of the Polish industry and education of staff for Industry 4.0. In light of these considerations, the share of technical secondary schools in the secondary school market in comparison with other European Union countries appears to be insufficient.

Taking into account the offer of places in units teaching professions important from the point of view of the needs of Industry 4.0, the share of units meeting these requirements in Poland is at the level of 29%, of which more than half represents the ICT industry. The situation is slightly better in Śląskie voivodship because these units constitute around 31.5%. Also, here the ICT industry has the biggest share, however its share is only over 1/3 of all professions. These figures include professions classified in the first group of professions most relevant from the perspective of Industry 4.0 requirements (19.5% at the national level and 18.6% at the voivodship level) and in the other group of professions useful from the perspective of Industry 4.0 (9.5% at the national level and 12.9% at the voivodship level).

In the first group, the profession of IT technician dominates (60% at the national level and 39% at the voivodship level). It is followed by the professions of mechatronics technician, software development technician and electronic technician and then by ICT technician, robotics technician, technician in the field of IT for visually impaired people, telecommunications technician and broadband electronic communication technician. In the other group of professions useful for the development of Industry 4.0, the professions of mechanic technician and electrical technician dominate (respectively 40.7% and 27.0% at the national level and 31.7% and 35% at the Śląskie voivodship level). In terms of number of offers they are followed by the professions of technician of renewable energy equipment and systems, optician technician, energy technician, welding technician and lifting equipment technician.

The results clearly show that IT technician is the dominating offer among all the professions of groups I and II, which also dominates among all the offers on the market. Unfortunately, other professions, such as automation technician, robotics technician or other professions in the ICT industry, are in minority. In the author's opinion, such a small diversification in educational offers is definitely insufficient in terms of educating future staff that will work in modern factories of Industry 4.0. Thus, the offer for other "professions of the future" should be expanded and education in such units should be promoted both nationally and locally, with particular emphasis on participation in these activities by representatives of industry.

Finally, it is important to stress the fact that the results relate to secondary schools offer and do not indicate the actual number of students who have used or will use it.

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SILESIAN UNIVERSITY OF TECHNOLOGY PUBLISHING HOUSE

SCIENTIFIC PAPERS OF SILESIAN UNIVERSITY OF TECHNOLOGY 2022
ORGANIZATION AND MANAGEMENT SERIES NO. 161

WEB DATA SCRAPING FOR DIGITAL PUBLIC RELATIONS ANALYSIS BASED ON THE EXAMPLE OF COMPANIES INSTALLING PHOTOVOLTAIC SYSTEMS

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Purpose: The first objective of this article was an attempt at identifying the major differences between such terms as public relations (PR), digital public relations (DPR) and digital marketing (DM). The second objective was to employ selected web data scraping techniques to analyse DPR of service providers installing photovoltaic systems.
Design/methodology/approach: The first objective of this article was achieved by analysing reference works. To achieve the second objective, the author used MS Excel, web scraping and proprietary computer scripts in R and Python. In this way, selected details were obtained from the companies catalogue at panoramafirm.pl and Google search engine, and then the received results were compared and analysed. What is more, the results from Google search engine were obtained and analysed for 964 towns and cities entered in the engine with the "photovoltaics" phrase.
Findings: 50 thousand URLs were obtained and 1,755 unique website domain addresses were extracted. Analysing the content of websites at the obtained Internet domains, 6 major categories of websites were identified, which appeared in the first 10 search results for the photovoltaic-related queries. These are: Company Websites (CW), Blog Websites (BW), Announcement Services (AS), SEO Landing Pages (SLP), Public Announcement Pages (PAP) and Social Media Page (SMP). Each of these categories is characterised briefly and a few examples are provided for each of them.
Research limitations/implications: The limitations of this article include the focus on one companies catalogue, i.e., panoramafirm.pl, and the results from Google search engine solely for the Polish language. Moreover, only the results of the first 10 links from Google engine for the single "photovoltaics" phrase and town/city name were taken into consideration.
Originality/value: This article has a theoretical and practical value. The analysis allowed to identify six categories of websites, which may be analysed with respect to digital public relations in the area of photovoltaic system installation. The most important of them are the websites belonging to the Company Website (CW) and Social Media Page (SMP) types. This article is addressed to anyone interested in obtaining data from the Internet using web scraping technique and data analysis in the area of digital public relations (DPR).

Keywords: digital public relations, Poland, cities, photovoltaics, web scraping.

Category of the paper: Research paper.

1. Introduction

Technology development, globalisation and continuous development of companies result in growing competition on the product and service market. This may affect, in particular, micro-enterprises, small and medium-sized ones (MSMEs) operating on local markets. For this reason, it is necessary to create a favourable image of the company and its products among current and prospective customers, employees and business partners. This is why the companies are more and more active in the widely understood public relations and marketing activities. This range can be further reduced to the Internet. Then, the studies will comprise the digital public relations and digital marketing.

One of recently developed business activity areas in Poland has been the market of services relating to replacing central heating boilers and installing photovoltaic systems. This service market has been developing dynamically for two years. This is proven by reports and statistical data (Raport_IOE, 2021). This is why, considering the continuous change of the theory and practice of public relations (Huang et al., 2017), (Arief & Saputra, 2019), (VanDyke & Lee, 2020) and the development of services related to photovoltaic systems installation, it is necessary to study current trends of using digital public relations in the operations of small and medium-sized service companies. To do it, analysis data must be obtained from websites and social media profiles of service providers installing photovoltaic systems. However, the problem is that there are a lot of such companies in Poland. It is infeasible to analyse the multitude of companies in terms of DPR alone. This is why it is necessary to look for and apply techniques and tools supporting it. The first step is obtaining current website addresses of installation companies in Poland.

The objectives of this article include (1) explaining major differences between the basic terms, such as public relations, digital public relations and digital marketing, as well as (2) obtaining selected web data for DPR analysis.

The article consists of 4 parts. The first part presents important differences between public relations, digital public relations and digital marketing. The second part shows the technique of using MS Excel and web scraping to obtain selected web data. MS Excel was used to retrieve collective data concerning all Polish cities from polskawliczbach.pl. Web scraping served to obtain address details of service providers installing photovoltaic panels from panoramafirm.pl and Google search engine data. The third part presents the results obtained. The data taken from the websites catalogue at panoramafirm.pl was compared to the one from Google search engine for the key phrase company name + company address. What is more, the results of analysing data obtained from Google search engine for the phrase of the city/town name and photovoltaics are presented. The final part contains discussion and conclusions.

2. Public relations, digital public relations and digital marketing

Advertising, the marketing communication tool used most frequently in commercial companies, has been losing its power of effective communication as its recipients are overloaded with advertisements and become resistant to traditional advertising stimuli. Advertising, as a one-way mass media tool, has not been as effective as it used to. This is why, it becomes necessary to change the structure of traditional marketing communications to more customised and interactive formats. A technique to improve the marketing communication efficiency is to shift the leading role from advertising to public relations. The public relations tools used in practice may ensure superior transparency in internal and external communications of the organisation and, at the same time, offer more effective marketing communication (Naumovska & Blazeska, 2016).

There are numerous definitions explaining what public relations are. In 1976, Rex Harlow analysed 472 definitions of public relations (Theaker, 2020, p. 3). He defined public relations as a specific management function, which enables to establish and maintain two-way lines of communication, understanding, acceptance and cooperation between the organisation and the general public (social environment), covering problem or issue management, helping the managers to notify the general public on an ongoing basis and respond to it, defining and emphasising managers' responsibility to serve public interest, helping managers to follow changes and use them efficiently, also acting as an early alarm system, which helps to foresee trends (Harlow, 1976; Agee et al., 1992, p. 3; Theaker, 2020, p. 3). Public relations are defined as a reputation as well, i.e. the results of what you do, what you say and what others say about you (Theaker, 2020, p. 5). Public relations comprise all types of communication between the organisation and its social environment (Mahendra, 2020). Marketing is popularly associated with any activities in the company, which are to promote product or service sale.

Some researchers base the difference between marketing and public relations on two words, i.e., consumer and profit. The traditional marketing role is to understand the consumer and produce products or services, which will satisfy their needs with a benefit for the supplier (Theaker, 2020, p. 6). For public relations, this is a favourable image of the company and its products, i.e., **reputation**.

Digital public relations and digital marketing are based mostly on websites and digital platforms. Traditional media, i.e., printed press, business cards, hard-copy catalogues etc., are not entirely gone, but are used to a decreasing degree. Noticeably, more and more organisations have been using different digital platforms to carry out public relations activities. They created new dynamic channels to sell products, create consumers' groups, increase website traffic and the awareness of existing concerns (Alexander, 2016). Digital public relations are a foundation of effective competitive strategy now (Gifford, 2010). Using digital public relations enables to create trust between the service provider, the product, the idea and the consumers (Mohamed, 2022).

Digital marketing and digital public relations are two separate notions. They may use different techniques, tools, impact area and results. Examples of differences between the digital marketing and digital public relations described in reference works and scientific works are presented in Table 1.

Table 1.
Examples of differences between the digital marketing and digital public relations

	Digital marketing	**Digital public relations**
General	The act of selling or promoting company products and services. The activities include Internet advertising as well.	Maintaining a favourable public image of the company, organisation or products.
Examples of experts' tasks	Buying advertising space on digital platforms; Planning advertising campaigns of products and services; Developing promotional materials; Developing forms of sale promotion and special offers.	Developing press releases concerning new organisational initiatives, products or services; Updating and managing company releases; Developing topics for discussion to involve Internet community in discussions concerning the company and its products; Participating in charity and social campaigns on the Internet.
Examples of success indicators	Has the sale of products or services increased and how much? Was it possible to achieve a higher ROI (Return on Investment) and how much higher was it? Has the number of visits to product or service pages increased and how much?	Was it possible to arouse the interest in the company, products or services among the Internet users? Was it possible to create favourable publications or responses concerning the company, products and services and how much? Has the number of favourable opinions and comments increased and how much?

Source: own work based on (Website startup, 2021).

However, in practice marketing and public relations in commercial companies have much in common. They comprise activities aimed at building awareness of the company brand and products, as well as protecting its reputation on the market. Thanks to it, the company becomes more recognisable and competitive. Although they may be separate, the combination of marketing and public relations, as well as the other way round, often makes the end objectives even more visible for the company.

Public relations (PR) have evolved from the traditional to the digital era. At present, we can speak of PR 1.0, 2.0., 3.0 or even 4.0 (Arief & Saputra, 2019; Permatasari et al., 2021). Public relations 1.0 is a traditional PR era. In it, printed media were the basic information distribution channel. This meant the prevailing role of one-way communication from a single source to many targets, i.e., one-to-many communication. Public Relations 2.0 was the era when Internet media were born. It was characterised by many-to-many communication. This era witnessed the earliest days of printed media transfer to digital platforms. Public Relations 3.0 is the era when social media were born. It was when social, professional and even employee journalism appeared. Public Relations 4.0 is the era of artificial intelligence and big data.

This is when artificial intelligence solutions are introduced into public relations. Human public relations cooperate with robots, which are not only able to monitor the network and write publications, but also schedule digital content uploading and respond quickly to any discussions and opinions posted online (Arief & Saputra, 2019). This is why skilful, automated web data scraping may soon become a highly important area of organisation operations relating to digital public relations.

3. Materials and methods

When studying web data scraping to analyse digital public relations of service providers installing photovoltaic panels, answers to the following study questions were sought:

1. What are the techniques, advantages and disadvantages of scraping web data concerning companies installing photovoltaic systems?
2. What share of companies installing photovoltaic panels in panoramafirm.pl catalogue has their own websites? Are they up-to-date? Are address details from website catalogues (e.g., from panoramafirm.pl) sufficient and reliable?
3. How many websites relating to photovoltaic panel installation in Poland can be obtained by analysing the first 10 Google search results for the key phrase town/city name and photovoltaics? Are they solely websites of companies installing photovoltaic panels in the given town/city?

The studies were carried out from December 2021 to April 2022. Their major focus was analysing websites relating to photovoltaic system installation in Poland.

The study plan was composed of 4 stages repeated in several iterations. The study diagram is presented in Figure 1.

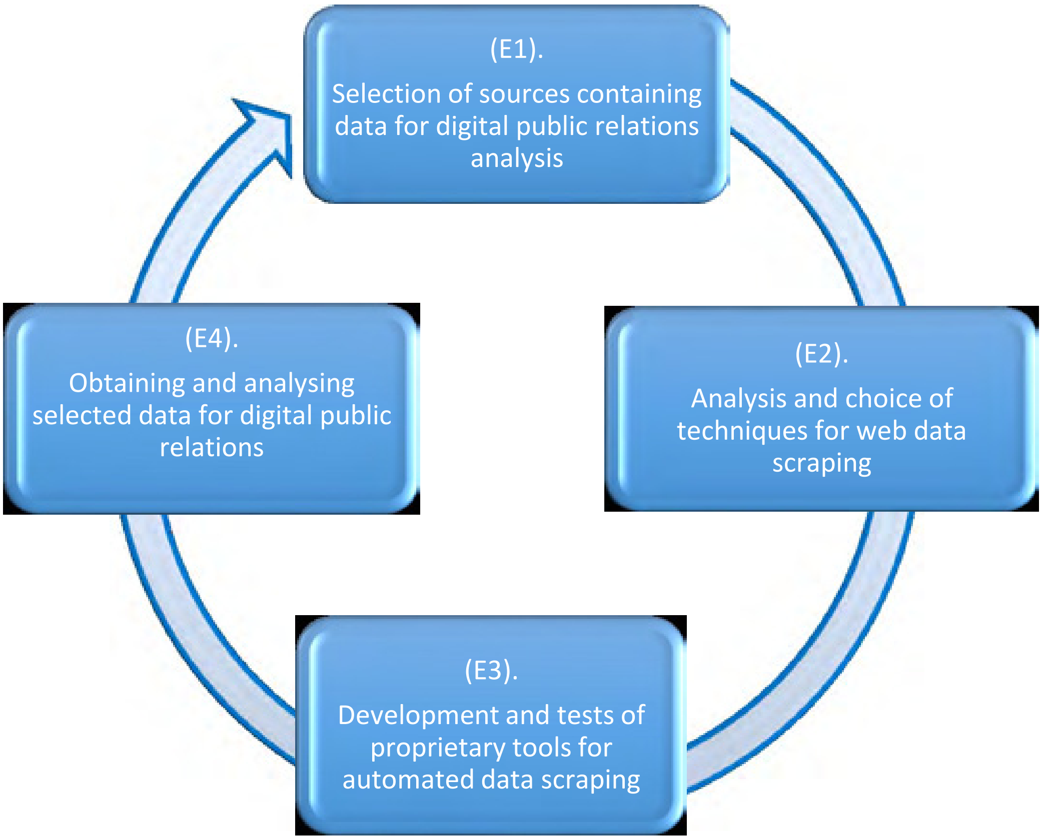

Figure 1. Study stages.

The first stage (E1) consisted in selecting sources containing data for digital public relations analysis. In this case, it was decided to analyse the content of a companies catalogue of the popular Polish portal (panoramafirm.pl). This website is available on the Internet for free. It contains address and website details of companies, e.g., those installing photovoltaic systems. Initially, when scraping the data, the "copy-paste" technique was used. However, this is highly time-consuming. It is not useful when analysing big data, i.e., the website address catalogues. This is why, it was decided to look for techniques to automate that operation, which can be used in practice.

The second stage (E2) consisted in analysing and selecting techniques to automate web data scraping. The techniques included: importing data from the Internet in MS Excel; using R language; using Python language, using libraries, such as Pandas, Beautiful Soup, HTMLSession, os, requests (Dogucu & Çetinkaya-Rundel, 2021; de las Heras-Pedrosa et al., 2020; Beautiful Soup Doc., 2021; GitHub Facebook Scraper, 2021), using API (Application Programming Interface), using get_posts module from the facebook_scraper package (GitHub Facebook Scraper, 2021) etc. It was decided to test various techniques and employ them in practice to retrieve data from panoramafirm.pl. The selected techniques included MS Excel, as well as R and Python languages with additional libraries.

The third stage (E3) consisted in the development and tests of proprietary tools for automated web data scraping. That was the most time-consuming stage of the study. It required getting technical expertise and applying it in practice.

The fourth stage (E4) consisted in obtaining and analysing data from the website catalogue (panoramafirm.pl). The data analysis carried out required another iteration of the presented research diagram. Consequently, several further iterations were carried out according to the diagram presented in Figure 1. The subsequent iterations brought web data for all Polish towns/cities and Internet domain addresses for websites relating to photovoltaics from Google search engines. The phrase used was town/city name + photovoltaics. The results were analysed and assumptions for the next iteration of studies were developed. Each iteration was followed by the analysis of advantages and disadvantages of the techniques and tools employed.

4. Results

During the first iteration, data was scraped from panoramafirm.pl. Once "photovoltaics" was entered, the list of more than 25 pages with company addresses was displayed. Due to the high number of entities, retrieving the data manually and analysing it would be very time-consuming and monotonous. This is why work was automated. Proprietary scripts in Python and R were developed. Thanks to a loop, all pages were read out and data of 568 companies was retrieved. The data was saved in an xlsx file. The saved data included a company name, address, URL of a website, e-mail, phone number and service category. Once duplicates and poor-quality data were removed, 442 companies were obtained. The most frequent categories, in which the companies in this database operated, are listed in Table 2.

Table 2
Service category data obtained using web scraping from panoramafirm website for the photovoltaics phrase

Category	Category (Polish name)	Number
Renewable energy	Energia odnawialna	135
Electric power distribution	Dystrybucja energii elektrycznej	107
Electrical installation works	Elektroinstalatorstwo	98
Electrical heating	Ogrzewanie elektryczne	35
Heating installation and maintenance	Instalacja i serwis ogrzewania	26
Turnkey building and finishing works	Budowa i wykończenia pod klucz	16
No classification	Brak klasyfikacji	13
Air-conditioning maintenance and installation	Serwis i instalacja klimatyzacji	9
Renewable energy generation	Wytwarzanie energii odnawialnej	9
Renewable heat sources	Odnawialne źródła ciepła	8
Heating devices	Urządzenia grzewcze	6

Source: own work.

There were 240 URLs provided for the companies (54%). Next, it was checked how many of those addresses were active and could be opened in a browser. It turned out that 212 out of 240 addresses were active (88%). For 28 (12%) of addresses, the browser reported security issues or website absence.

In the second iteration, it was decided to verify the consistency of URLs in panoramafirm.pl and the ones obtained in Google search engine. For that purpose, a company name and town/city were entered (1). Next, data was retrieved from the Google business profile (2-5) and the search results (6-8). All numbers are plotted on Figure 2.

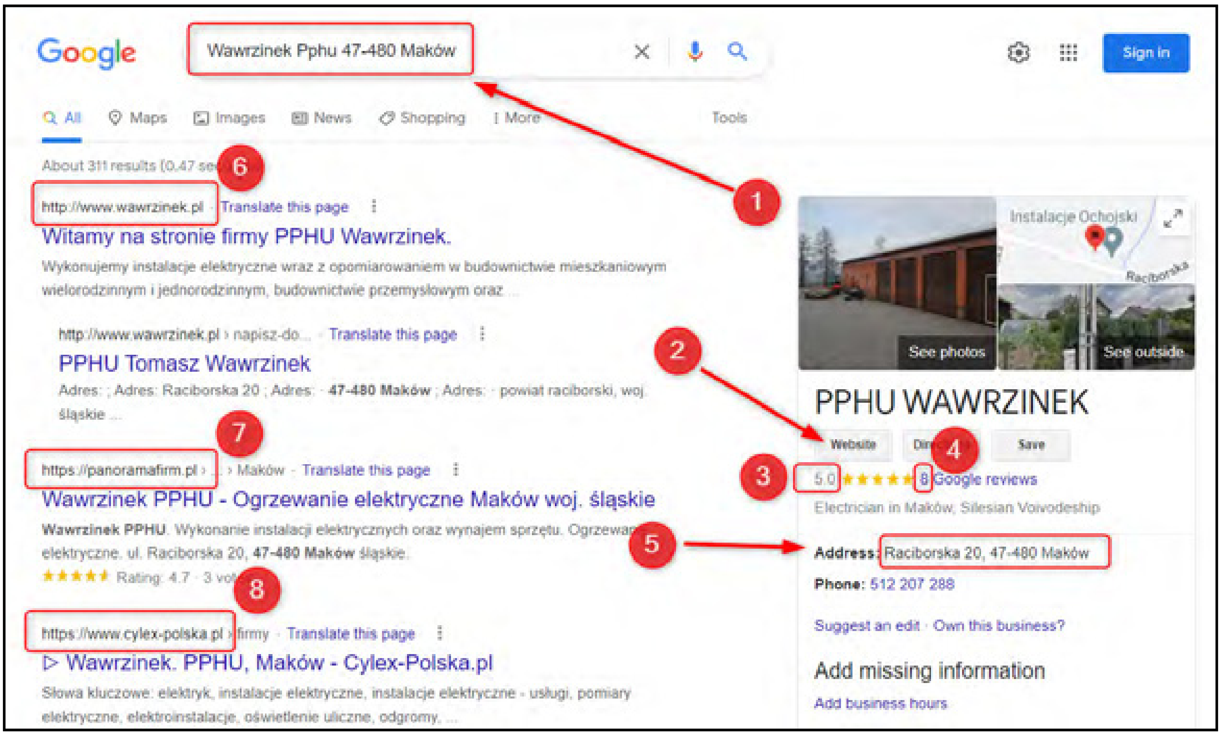

Figure 2. Data obtained from Google search engine for the phrase consisting of company name and town/city.

To automate the process, a script was written in Python using an automated test platform called Selenium. The data was collected in a separate worksheet. Next, it was unified to consist solely of main Internet domains and https:// protocol. The obtained results were compared and the consistency of the results from panoramafirm.pl companies catalogue and Google search engine was verified.

It turned out that websites' URLs were consistent in 151 cases. The results are presented in Table 3.

Table 3.
Comparison of URLs of companies installing photovoltaic panels at panoramafirm.pl and in Google search results (business profile – Google Button Website button)

	Data from panoramafirm.pl (PF)	Data from Google Button Website (GBW) search engine
Number of companies	442	442
Number of URLs	240	265
Number of Internet domain addresses consistent in PF and GBW	151	151

Note: PF – panoramafirm.pl, GBW – Google Button Website.

Source: own work.

What is more, it turned out that many of the first Google search results showed addresses of various popular Polish companies catalogues (Table 4).

Table 4.
10 most popular websites taking initial positions in Google search results after the company name and address was entered from panoramafirm.pl websites catalogue

URL	Number
https://panoramafirm.pl/	174
https://aleo.com/	48
https://biznesfinder.pl/	24
https://krs.infoveriti.pl/	15
https://krs-online.com.pl/	13
https://dnb.com/	12
https://mapa.targeo.pl/	10
https://krs-pobierz.pl/	9
https://pkt.pl/	4
https://aktualnyodpis.pl/	3

Source: own work.

As not all companies had their URLs in the websites catalogue (panoramafirm.pl), and when their names were entered in the browser solely 265 addresses were obtained (Google Button Website), it was decided to expand data scraping by entering the phrase consisting of a town/city name + photovoltaics. This is why another iteration was carried out based on the study diagram (Figure 1).

During the study, data for all 964 towns/cities in Poland was obtained from polskawliczbach.pl/miasta. Data presented there come from Statistics Poland (GUS_cities, 2021) and display the situation as at 31 December 2020 (Figure 3).

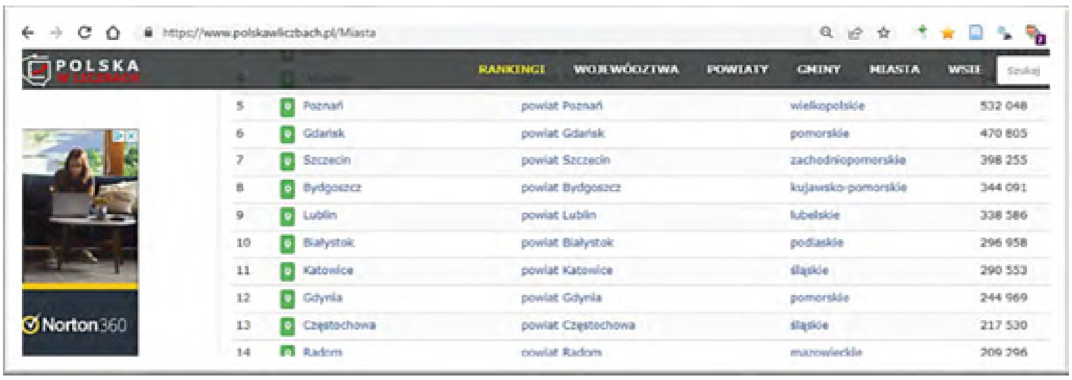

Figure 3. Database of Polish towns and cities.

It was impossible to extract the data using “copy+paste” technique to MS Excel, as the data did not save correctly. It would be too time-consuming to copy individual items. For this reason, the technique of importing data from the Web was used in MS Excel (MS Excel > Data > Get Data from Other Sources > From Web). After the URL https://www.polskawliczbach.pl/Miasta was entered, the entire content of the database was retrieved and saved in a cities.csv file.

For the subsequent iteration, it was decided to enter the phrase consisting of the town/city name + photovoltaics in the search engine and then to retrieve the resultant URLs (Figure 4).

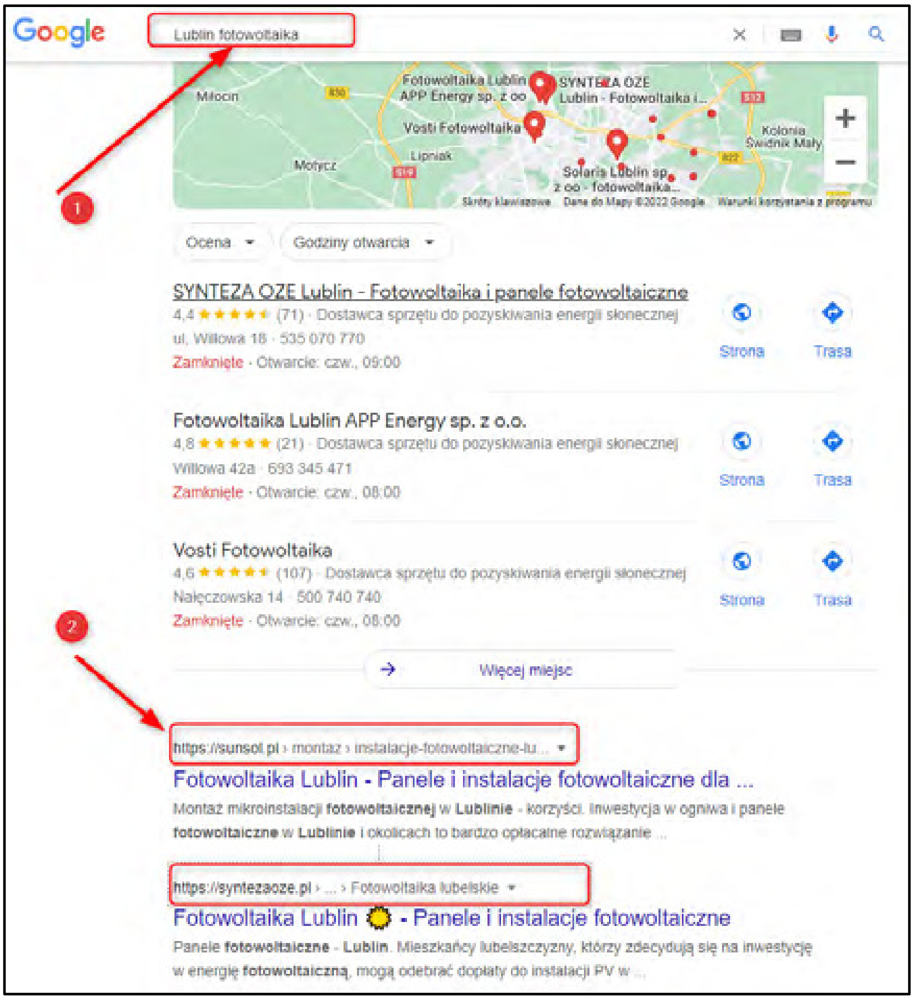

Figure 4. Obtaining data from the Google search engine for the town/city name and photovoltaics.

Data was collected solely from the first results page. No paid advertisements and business profiles on Google maps were considered. Analysing and saving such a high number of pages would not be possible if it were not for using scripts automating the data saving operations. In order not to overload servers with excessive number of queries, high delay was set for queries and the code was set to save to text files to enable its analysis on a later date. The obtained results were analysed. They are presented in Tables 5 and 6.

Table 5.
Aggregate number of data retrieved from the search engine for the query of a town/city name and photovoltaics (for 964 towns/cities in Poland)

Variable	Number
Total URLs retrieved from the search engine.	53020
1 Internet domain instance	1271
< 4 Internet domain instances	287
< 10 Internet domain instances	117
< 100 Internet domain instances	63
>= 100 Internet domain instances	17
Total unique Internet domain addresses	1755

Source: Own study.

Table 6.
List of 15 Internet domain addresses appearing most frequently in search results for the key phrase of a town/city name and photovoltaics (for 964 towns/cities in Poland)

Internet domain address	Results number
https://oze.net.pl	760
https://fotowo.pl	668
https://farmy.pl	531
https://ongeo.pl	514
https://www.oferteo.pl	478
https://www.fotowoltaika.org.pl	351
https://syntezaoze.pl	247
https://miastoslonca.pl	232
https://sunsol.pl	224
https://sitarsky.pl	217
https://hymon.pl	209
https://kalkulatormocy.pl	206
https://mkfotowoltaika.pl	147
https://www.olx.pl	137
https://www.brewa.pl	125

Source: Own study.

Having saved the unique Internet domain addresses and analysed the content of 100 selected websites they redirected to, a division into 6 main website categories was proposed:

- Company Website (CW) – company websites offering products and services relating to photovoltaic systems.
- Blog Website (BW) – blogs, guidebooks and useful tools relating to photovoltaic system installation.
- Announcement Services (AS) – companies catalogues and announcement services (AS).
- SEO Landing Page (SLP) – websites, which are positioned and developed by specialist companies to reach the most prospective customers. Those are usually simple websites with main key phrases and a contact phone number, aimed at achieving high positions in search engines in response to specific key words.
- Public Announcement Page (PAP) – announcement websites of government agencies and local government authorities informing about e.g., programmes, investments and grants relating to photovoltaic system installation.
- Social Media Page (SMP) – public websites and groups connected with photovoltaic system installation in popular social media.

Table 7 presents examples of website addresses included in particular groups.

Table 7.
Categories and examples of websites in the area of photovoltaic panel installation

ID	Category	Examples of websites
1	Company Website (CW)	https://www.brewa.pl; https://www.soltechenergy.pl; https://www.esoleo.pl/; https://www.brewa.pl; https://eeef.pl/; https://sundaypolska.pl/; https://jbenergia.pl; https://zatokaenergii.pl
2	Blog Website (BW)	https://fotowoltaikaonline.pl; https://ongeo.pl; https://enerad.pl/
3	Announcement Services (AS)	https://www.olx.pl; https://www.oferteo.pl; https://fixly.pl; https://panoramafirm.pl/fotowoltaika
4	SEO Landing Page (SLP)	https://oze.net.pl; https://fotowo.pl; https://farmy.pl; https://kalkulatormocy.pl; https://mkfotowoltaika.pl; https://www.solar2biznes.pl; https://instalacje-solarne.pl; https://fotowoltaiczneinstalacje.pl
5	Public Announcement Page (PAP)	https://samorzad.gov.pl/web/gmina-bransk/projekt-oze-2; https://samorzad.gov.pl/web/gmina-kalwaria-zebrzydowska/odnawialne-zrodla-energii-przewodnik; http://bip.wolin.pl/strony/13976.dhtml; https://www.pruszkow.pl/srodowisko/dofinansowanie/moj-prad/
6	Social Media Page (SMP)	https://pl-pl.facebook.com/FotowoltaikaStargard/; https://www.facebook.com/fotowoltaikastarachowicemarcingalka/; https://pl-pl.facebook.com/protonenergia/

Source: Own study.

The subsequent stage would be an automatic classification of every website into specific categories. Depending on the website category, it would require proposing new analysis tools and techniques. For a Company Website, it would be obtaining information concerning, e.g., social media and opinions in a Google business profile. While for a Social Media Page, it would be, e.g., obtaining information on the number of news, comments etc. Every additional information requires new script development, testing and practical application. This means that this is a highly time-consuming process, though required for a comprehensive analysis of DPR data sets.

5. Discussion and conclusions

Analysing a single, specific Internet activity, we can perceive it in the context of digital marketing and digital public relations. The difference may be slight for commercial companies, but an attempt can be made to identify it. The studies carried out in Europe in 2020 among 2,324 managers revealed that PR practitioners faced more moral challenges in their everyday work than 8 years earlier. There are growing concerns relating to bots, big data, influencers in social media and sponsored content (Hagelstein et al., 2021). It is a difficult task to create online content able to push its way through the digital chaos and appeal directly to consumers. There is a problem of competing with a multitude of information, choosing the suitable platform, tools and forms of content distribution (Myers, 2016, pp. 40-55), as well as techniques and tools for web data scraping and analysis.

This article focuses on the market of photovoltaic panel installation services in Poland. It presents techniques of obtaining address details using a spreadsheet and scripts in Python and R. Automated address details scraping to analyse digital public relations is an introduction to a comprehensive analysis. The first step was to obtain complete, up-to-date and reliable data concerning website addresses containing information important for a DPR analysis. It was highly time-consuming to prepare suitable tools to scrap and cleanse data. Attention had to be paid to tool testing and error handling. For those applications, web scraping technique was employed, as well as R and Python scripts were developed. This allowed to obtain 1,755 unique Internet domains for websites relating to photovoltaic panel installation in 964 Polish towns and cities based on ten first Google search results for the phrase consisting of the town/city name and photovoltaics. Web scraping, as a technique of obtaining web data, is used by a growing number of companies and organisations, as well as practitioners and scientists. It is used, e.g., to collect data concerning prices of listed stock on an ongoing basis, with the frequency higher than standard (Lin & Yang, 2022) and to collect and compile prices of products with high variability frequency in different locations (Benedetti et al., 2022). Web scraping is also used to collect and analyse employers' needs concerning competences of future employees from the most popular advertising websites (Wyskwarski, 2021) and to collect and analyse Facebook data concerning criminal activity relating to illegal trading in prohibited products (Xu et al., 2020). This technique is sometimes employed to collect data to detect abusive comments on social media, including Twitter, YouTube and Facebook (Vrysis et al., 2021), and to collect for sentiment analysis during COVID-19 (Bhagat et al., 2021). There are numerous publications devoted to collecting data from social media, i.e. Reddit (Higgins et al., 2021), Twitter (Hernandez-Suarez et al., 2018; Dongo et al., 2021), Facebook (Mancosu & Vegetti, 2020). There are even manuals concerning scraping data from the web and social media and using it in analytics (Russell, 2013). The Internet has become a vast source of information, which may support decision-making processes both in companies and in public entities. Analytical departments may obtain data from the market and social media and then analyse it.

The analysis of websites relating to photovoltaic system installation based on URLs obtained in this study reveals that they may be divided into 6 major categories. They include Company Websites (CW), Blog Websites (BW), Announcement Services (AS), SEO Landing Pages (SLP), Public Announcement Pages (PAP) and Social Media Pages (SMP). Only a small fraction of them can be ascribed to more than one category.

For this reason, when creating a database of entities for DPR analysis, it is necessary to consider different categories of websites and prepare suitable analytical tools and techniques for them. This should be kept in mind when planning any operations and data analysis in this area, with respect to digital public relations and digital marketing. The website categories identified in the article are the best example. Business profiles should be analysed with respect to DPR, different than the government and local government websites or social media. For this reason, it is important to consider the category of websites used by the organisation and serving for its comparison to others. Thanks to analytics, managers are able to understand the environment where their companies operate better and adapt their activities to the rapidly changing market.

The Internet becomes a more and more important environment of promotion and building business relations with others. This is why DPR activity and the ability to obtain suitable data from the Internet in this respect and analysing is may become a more and more important component of the operations of contemporary public organisations and commercial companies.

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