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IS THE CONCEPT OF INDUSTRY 4.0 STILL INTERESTING FOR SCIENTISTS DUE TO THE EMERGENCE OF INDUSTRY 5.0? BIBLIOMETRIC ANALYSIS

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Abstract

Research purpose. Through Industry 4.0, also referred to as the fourth industrial revolution, new technologies or traditional production resources have been transformed into intelligent objects enhanced by the possibility of identification, scanning, and networking. In recent years, the concept of Industry 5.0 has already started to be discussed. However, is Industry 4.0 an uninteresting or sufficiently researched topic for scientists? The main aim of the scientific article is to perform a bibliometric analysis of the Industry 4.0 issue. The aim was supported by six research questions that reflect the publication trend in the years 2012–2022, the most publishing countries, the most used keywords, the Web of Science category, and authors and publishers.

Design / Methodology / Approach. The data was obtained from the renowned Web of Science database. The monitored period was 2012–2022 for Industry 4.0 and 2016-2022 for Industry 5.0. The year 2023 was excluded from the analysis, as the year 2023 is not finished. The total number of publications that were used in the bibliometric analysis was 20,151 (I4.0) and 293 (I5.0). VOSviewer and MS Excel were used for graphical data processing.

Findings. The oldest publication dedicated to Industry 4.0 in the Web of Science database dates back to 2012. The most scientific articles were seen in 2021, namely 4,326 (I4.0) and 201 in 2022 about I5.0. In 2022, 3848 publications were published. In addition, authors from Germany (2,450), Italy (2,318), China (1,515), and the USA (1,220) address the issue of Industry 4.0. All the countries of the Visegrad Group, Poland (859), the Czech Republic (859), Slovakia (539), and Hungary (282) are most concerned with this problem. If the publications are divided into categories according to the Web of Science database, most of them are included in the categories Engineering Industrial, Engineering Manufacturing, Engineering Electrical Electronic, Computer Science Theory Methods, or Computer Science Information Systems. Publications on Industry 4.0 are published mainly by publishers such as IEEE, Elsevier, Springer, and MDPI. The authors who are most devoted to the mentioned issue are Popkova, Martinek, Rauch, Bogoviz, Silva, and Xu.

Originality / Value / Practical implications. The added value of the scientific article is the summarisation of theoretical starting points from the field of Industry 4.0 and Industry 5.0. Likewise, the article is original from the point of view of conducting a bibliometric analysis, focused on the development of the number of publications, the authors who are most devoted to the given topic, the most commonly used keywords, or countries that focus on Industry 4.0 and Industry 5.0 issues the most. The originality of the article also lies in the mapping of the publications of the monitored issue for the entire previous year, 2022.

Keywords: Industry 4.0; Industry 5.0; Internet of Things; Artificial Intelligence; Bibliometric analysis.

JEL codes: O14; O33

Introduction

The digital, social, and economic needs of businesses are largely framed by the fourth industrial revolution. This idea enhances the cost-efficiency, quality, and effectiveness of enterprises, which has a significant impact on their results (Milosevic et al., 2022). Global manufacturing trends have evolved as a result of Industry 4.0 technologies. In order to meet mass customisation demands and compete with

international industries, industries are implementing Industry 4.0 business models. Industry 4.0 is the name given to the current trend of automation and data interchange in manufacturing (Jamwal et al., 2021). The development in the past decade of Industry 4.0 technologies has brought many new opportunities to manufacturers (Francalanza et al., 2021). The phenomenon known as "Industry 4.0" is the coming together of the physical and digital worlds as "Cyber-Physical Systems" (CPS) (Soomro et al., 2021). Popkova and Giyazov's study from 2021 supports the importance of Industry 4.0's development in modern economic systems with varying degrees of knowledge of economic development. In 2011, during an economic discussion at Hannover Messe in Germany, the concept of Industry 4.0 was first conceived (Liebrecht et al., 2021). In order to fill a gap in the existing literature on the function of venture capital in Industry 4.0, Popkova et al. (2021) established a framework for how venture capital could contribute comprehensively to achieving sustainable development goals using Industry 4.0's digital entrepreneurship.

The main aim of the scientific article is to perform a bibliometric analysis of the Industry 4.0 issue. The aim was supported by six research questions:

1. What were the publication trends in the monitored issue of Industry 4.0 in the years 2012–2022 and Industry 5.0 in the years 2016-2022?
2. Which countries are most devoted to the field of Industry 4.0 and Industry 5.0?
3. Which keywords are used most often in scientific publications on Industry 4.0 and Industry 5.0?
4. According to the Web of Science, under which categories do publications on Industry 4.0 belong?
5. Which authors focus on the issue of Industry 4.0 the most?
6. Which publishers publish most often about the field of Industry 4.0?

The paper is divided as follows: The introduction is devoted to the concepts of Industry 4.0 and Industry 5.0. The methodology section portrays the use of bibliometric analysis. The result section is the part where we present our findings. The last part is the conclusion, which contains the summary of the findings.

Literature review

Industry 4.0 is "the digitalisation transition led by connected technologies to establish a cyber-physical entity," according to Soomro et al. (2021). Industry 4.0 is a manufacturing strategy built on integrating cutting-edge technologies like CC, CPS, and IoT into production processes in order to increase output (Freund & Al-Majeed, 2021). As Industry 4.0 relies heavily on radiofrequency technologies, some brief insight into this problem is provided by Martinek et al. (2021), including the Internet of Things (IoT) and 5G deployment.

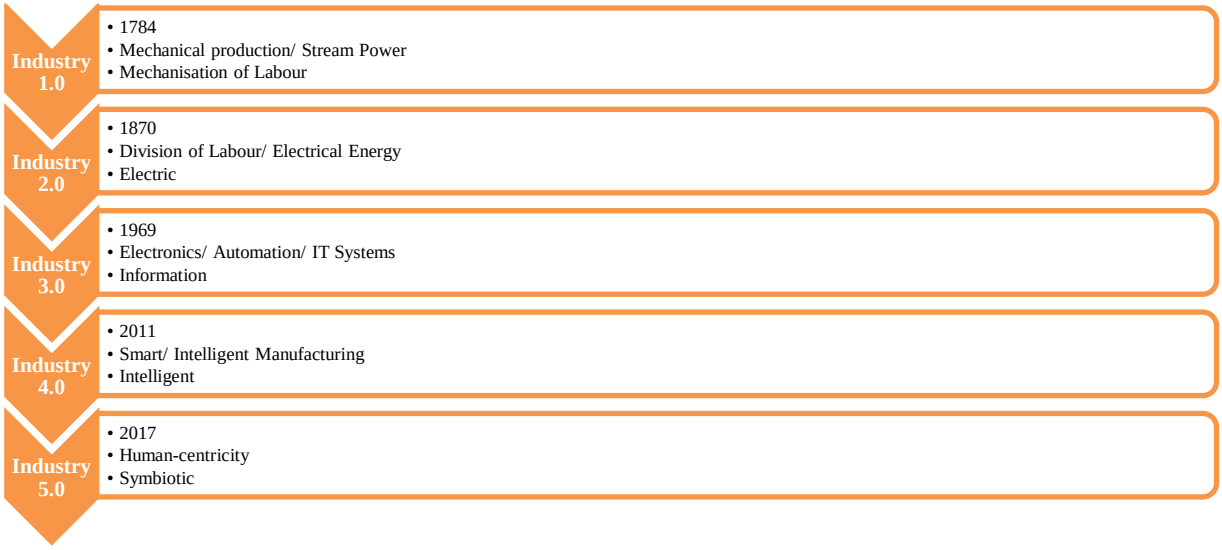

Fig. 1. The evolutionary history of industry X.0 (Source: Own processing according to Leng et al., 2022)

The progress of Industry X.0 is seen in Fig. 1. Water steam is used to power manufacturing machinery in Industry 1.0, ushering humanity into the "Steam Era." When the market (one of the pillars of the Industrial Revolution) explodes, humanity has access to early resources and the economy's primitive accumulation, which prompts social upheaval (Leng et al., 2022).

By harnessing energy as a conduit for electricity, Industry 2.0 ushers humanity into the "Electric Age." The division of labour in the manufacturing process is evident across the entire society, and the door is opened to the assembly-line mass production model. Information technology (IT)-based industry 3.0 offers mass customisation, whereas industry 4.0 combines IT and operational technology (OT) in a cyber-physical system to enable mass customisation/personalisation with intelligence. Industry 5.0 reflects the value of humanistic care and integrates human subjectivity and intellect with the effectiveness, artificial intelligence, and accuracy of robots in industrial production, accomplishing the progression toward the symbiotic ecosystem (Leng et al., 2022).

Industry 4.0 offers enormous advantages in terms of higher quality, quicker turnaround times, and general optimisation. Despite this, only 29% of organisations globally use Industry 4.0 technologies at scale, giving them a chance to realise paradigm-shifting effects (Soomro et al., 2021). A higher level of intelligence, and consequently a higher level of flexibility and performance, can be obtained in industrial manufacturing processes thanks to the technologies brought by Industry 4.0. So, it is expected that Industry 4.0 will enable the three key components of production digitisation, automation, and intelligent data exchange (Freund & Al-Majeed, 2021). Due to uncertainties on how Industry 4.0 technologies might collaborate to accomplish advantages, industries can be hesitant to deploy these new technologies (Dos Santos et al., 2021). The automotive, agricultural, apparel, paper, and other industries are among those being impacted by the digital transition. Companies must be aware of potential changes brought on by the digitalisation process and react swiftly and effectively (Zauskova et al., 2022).

The fourth industrial revolution, or Industry 4.0, is distinguished by connecting distributed artificial intelligence that has been multiplied and made accessible to the human operator. Cyber-Physical Systems (CPS), which are computers with networks of tiny sensors and actuators installed as embedded systems in materials, equipment, and machine parts and connected via the Internet, can describe the multiplied and dispersed artificial intelligence in greater depth (Rauch et al., 2020).

Boston Consulting Group (BCG) combines all technologies and concepts with the aim of identifying pillars of Industry 4.0. The nine pillars of Industry 4.0 are the industrial Internet, advanced manufacturing, additive manufacturing, simulation, horizontal/vertical integration, cloud, cyber-security, augmented reality, and big data analytics (Soomro et al., 2021).

The Industrial Internet of Things (IIoT) (Danys et al., 2022) and Cyber-Physical Production System (CPPS) (Coelho et al., 2022; Nikolakis et al., 2020) respectively, and their specialisation to industry, Digital Twin (DT) (Hassani et al. 2022; Jia et al., 2022), Internet of Things (IoT) (Twahirwa et al., 2022; Vitanova, 2021), and Cyber-Physical Systems (CPS) (Bellman et al., 2020; Radanliev et al., 2021), are thought to boost the efficacy of Facilities management (Nota et al., 2021). Based on the connection offered by the Industrial Internet of Things (IIoT) and the utilisation of many digital technologies, including cloud computing, big data, and artificial intelligence, Industry 4.0 has been proposed as a new stage of industrial development (Dos Santos et al., 2021).

With its innovative perspective, Industry 5.0 will assist in addressing the issue of the disconnect between societal requirements and manufacturing. The Industry 5.0 concept has a more human-centric focus than previous industrial revolutions, which focused more on the economic side of sustainability (Leng et al., 2022). The goal of Industry 5.0, which is thought of as the next stage in industrial evolution, is to combine the creativity of human specialists with effective, intelligent, and precise machinery to provide manufacturing solutions that are more user-friendly and resource-efficient than those of Industry 4.0 (Maddikunta et al., 2022).

In order to combat a resurgent strategic drift, Industry 5.0 is a crucial driving factor for industrial progress. This approach is the ideal instrument for fostering human-machine cooperation inside intelligent cyber-social systems and ensuring a sustainable, human-centred, and resilient enterprise. Only when industrial systems use digital strategy to advance digital development is a complete shift to

Industry 5.0 possible (Babkin et al., 2022). Industry 5.0 development concept points to significant advancements in the automation, robotisation, and digitisation of hypothetical processes that support economic growth, as well as in relation to sustainable development and climate strategies, particularly in the environmental field, with clear reserves and risks (Majernik et al., 2022).

Research Methodology

The usage of information and communication technology has led to a progressive increase in interest in bibliometric study. The topicality of the sphere is also demonstrated by the number of publications devoted to the bibliometric analysis of the concept of Industry 4.0. The bibliometric analysis was carried out by, to name a few, Muhuri et al. (2019); Nedjwa (2022); Rosario and Dias (2022); de Freitas Vilela and Filho (2022); Khoshroo and Talari (2022); Moiceanu and Paraschiv (2022); Kumar et al. (2022); Machado et al. (2022); Razmjooei et al. (2023); and another.

We shall conduct a bibliometric examination of Industry 4.0's and Industry 5.0's ideas in this academic article. The scientific database Web of Science, which is now the most well-known independent scientific database in the world, provided us with the data we required for the investigation. One of the main reasons why the Web of Science database was chosen is the fact, as already mentioned, that it is one of the most respected and world-famous scientific databases. In this database, we can find a number of publications in the world's most famous journals that deal with the investigated issues. The database contains several journals, conference proceedings, and book chapters that are recognised worldwide and written by renowned academics. In addition, data from the Google Scholar database cannot be processed through VOSviewer. We found the information by searching for "Industry 4.0" and "Industry 5.0." It suggests we were only concerned with establishing that link. We received a total of 20,151 articles for the phrase "Industry 4.0" from the WoS database between the years 2012 and 2022. 293 articles were identified for the phrase "Industry 5.0" between 2016 and 2022. In the case of the search for the term Industry 5.0, publications from earlier years were also found, but the connection was not with the current issue (it was just a mention of the term industry in the table, while the value five (5) was given in the adjacent column). All data obtained from the Web of Science database had to be rechecked or modified, as an error occurred with keywords that contained 4.0 or 5.0. In some scientific publications, keywords are separated by a period. In such cases, however, the term Industry 4.0 was divided into two keywords, namely *Industrie*s *4* and *0*. This had to be corrected so that the results of the bibliometric analysis of the keywords were correct.

We graphically processed individual graphic displays in MS Excel. The VOSviewer software was used to do a bibliometric analysis of keywords and co-authorship by country of origin. Clusters will be found for both analyses, and they will be separated by colour. There are two key parts to the bibliometric map. Links and bubbles are the subject. The size of the node represents how often the keyword occurs, and the more frequently it occurs, the larger the bubble. The connection between the bubbles depicts the co-occurrence of phrases (i.e., keywords that occur or occur together). The frequency of concurrent or consecutive occurrences of phrases, or the co-occurrences of keywords, is represented by link thickness. It is true that the denser the relationship between the bubbles, the more frequently common occurrences between keywords are likely to occur. Each colour represents a thematic cluster, and the nodes and connections within each cluster may be used to describe both the connections (links) between topics (bubbles) that occur inside a specific topic as well as the coverage of topics (bubbles) within that topic (cluster). Tab 1 provides an overview of the key phases of this study's production.

Table 1. An overview of the steps in the article (Source: on processing)

Searched Used Terms	Searched Used Terms	Searched Used Terms	Searched Used Terms	Searched Used Terms
Industry 4.0	2012 – 2022	Web of Science™	Bibliometric analysis	VOSviewer
Industry 5.0	2016 – 2022			

Research results

The data were obtained from the Web of Science database and subsequently processed using VOSviewer and MXS Excel. Based on the results, it was possible to obtain the detailed information necessary for bibliometric analysis.

From Figure 2, we can see how the publication trend dealing with Industry 4.0 has developed over the years. The first publication about Industry 4.0 published in the WoS database dates back to 2012. In total, only two publications were published that year. The trend continued to increase in the following years; the highest increase was recorded in 2019 when 4,252 publications were published. The year-on-year increase was 2,192 publications. There was a slight decline in 2020, while the number of publications increased again in 2021. In 2022, 3,848 scientific publications were published in the WoS database.

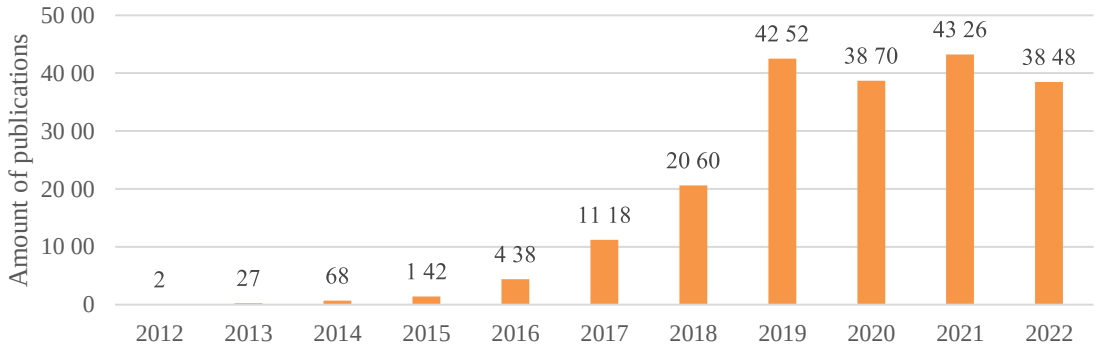

Fig. 2. Annual growth of documents' number related to Industry 4.0 in WoS during the period 2012-2022 **(**Source: Own processing)

If we follow the development trend of publications devoted to Industry 5.0, it is still growing. From 2016 to the present, the trend has been increasing. For the first time, the term "Industry 5.0" appeared in the WoS database in 2016, when one publication was published. The development trend gradually doubled in 2 years. In 2021, 58 publications were published. The following year, the number almost quadrupled to 201 publications.

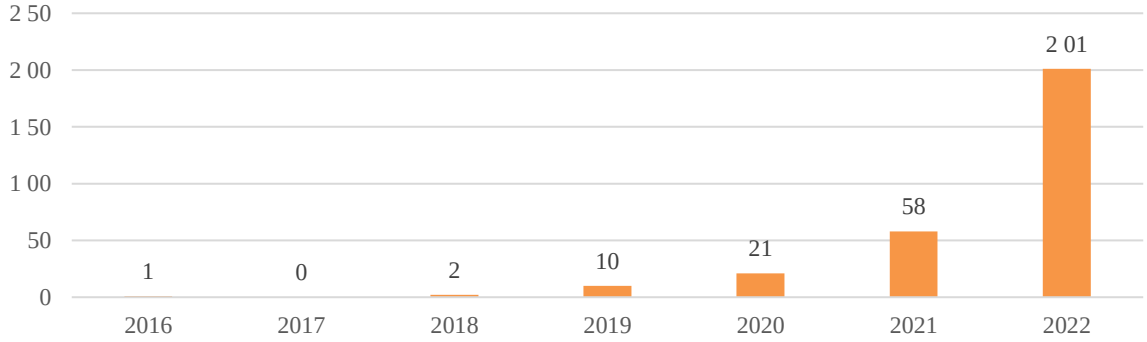

Fig. 3. Annual growth of documents' number related to Industry 5.0 in WoS during the period 2016-2022 **(**Source: Own processing)

From the point of view of the countries that are most devoted to the issue of Industry 4.0, it is necessary to mention Germany, with 2,450 publications and Italy, with 2,318 publications. China has the third-highest number of scientific articles (1,515), followed by the USA (1,220), India (1,198), and Great Britain with 1,277 publications. For Great Britain, we counted publications for England (1,064), Scotland (121), Wales (69), and Northern Ireland (23). Among the countries of the Visegrad Group, Poland (859) and the Czech Republic (842) are the most active in the field. In the third place, there is Slovakia, with a total of 539 publications, while in the overall ranking, it is in the 15th place. Hungary has the fewest publications from the Visegrad Group (V4), approximately 282. Of the neighbouring countries of the Slovak Republic, Austria has 509 publications, and Ukraine has 234 publications.

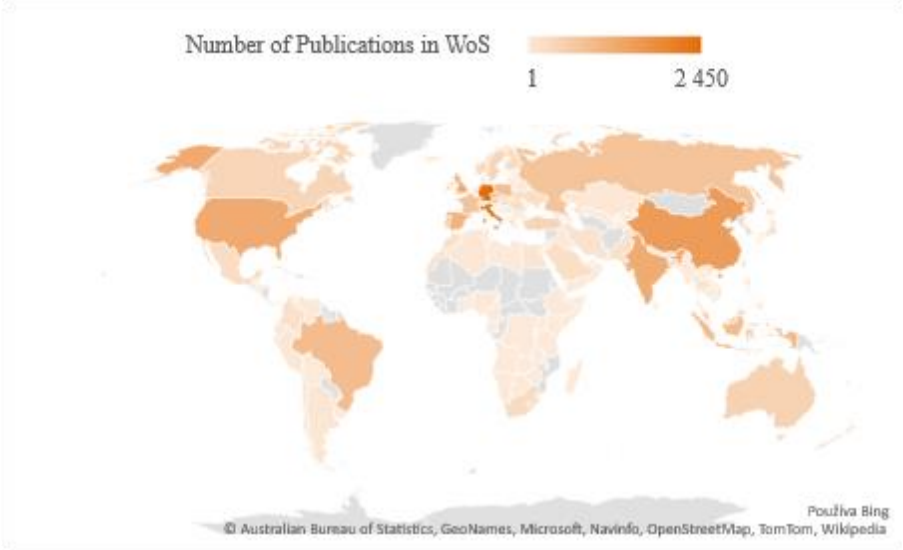

Fig. 4. Number of documents related to Industry 4.0 in WoS during the period 2012-2022 according to countries (Source: Own processing)

The term "Industry 5.0" is mostly covered by China, with 45 publications, followed by India with 42, the USA with 38, Italy with 37, and Great Britain with 27 publications. Great Britain's publications consisted of England (24) and Scotland (3). Poland (8) has the most publications from the V4 countries, followed by Slovakia (6), Hungary, and the Czech Republic (3). Austria has 8 publications, and Ukraine 2. Germany has the same number of articles as Australia (19), and they are ranked 6th overall.

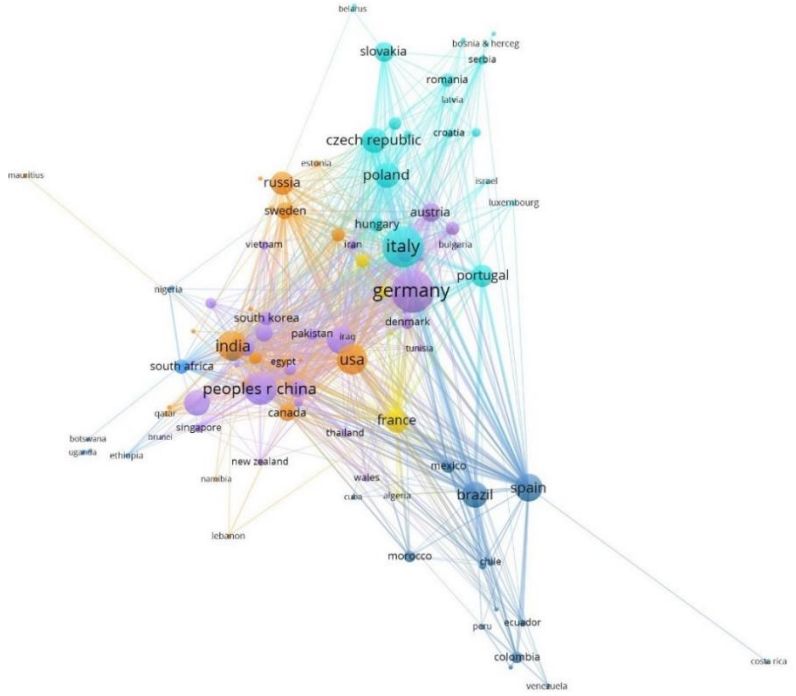

Fig. 5. Bibliometric map of the co-authorship countries for Industry 4.0 during the period 2012-2022 (Source: Own processing)

The largest cluster is shown in orange with 22 elements. These include countries such as India, the USA, Russia, and Sweden. The USA has the most occurrences, with 1,221 entries. The number of connections is 77, with a total strength of 1,341. Countries such as Italy, Poland, the Czech Republic, Slovakia, and Portugal are shown in turquoise. Italy has 73 connections with a total strength of 1,258 and 2,320

occurrences. China, Indonesia, and Australia are shown in purple; this cluster contains 19 countries. The most numerous country is China, with 1,515 occurrences, 76 links, and a total link strength of 1,275. Spain, Brazil, Mexico, and Colombia are highlighted in dark blue, while a total of 14 countries are shown in this colour. Spain has a total of 70 connections with a total strength of 817. Germany, Austria, and Greece are shown in dark purple. This cluster contains 10 countries, the most numerous of which is Germany (2,541). Germany has 75 links altogether, with a total link strength of 2,541. The blue cluster contains nine countries, including, e.g., South Africa, Norway, etc. South Africa has the most connections (58), with a total strength of 265. The smallest cluster is yellow, which contains only six countries, such as France, Belgium, and the Netherlands. France has 65 links with a total strength of 821.

Fig. 6. Number of documents related to Industry 5.0 in WoS during the period 2016-2022 according to countries (Source: Own processing)

The minimum number of documents for one country was set at 5, which reduced the number from 68 countries to 30. The most numerous cluster is the orange one, which contains 12 items. In this cluster, the most numerous country is India, with the number of publications at 42, the number of links at 25 and a total strength of links at 68. Subsequently, this group also included Spain, Ireland, Portugal, etc. The remaining three clusters have six items each. In the turquoise cluster, the most numerous country is China, with 45 publications, a total of 17 links and a total link strength of 49. In addition to China, this category also includes Australia, South Korea, etc. The dark blue cluster contains the USA, Sweden, Slovenia, and Poland. The USA is the most numerous, with 38 publications, a total link strength of 61, and 25 links. The last cluster is purple, where Italy, Germany, and Greece are located. Italy has the most significant link strength (39), with 37 publications and 18 links.

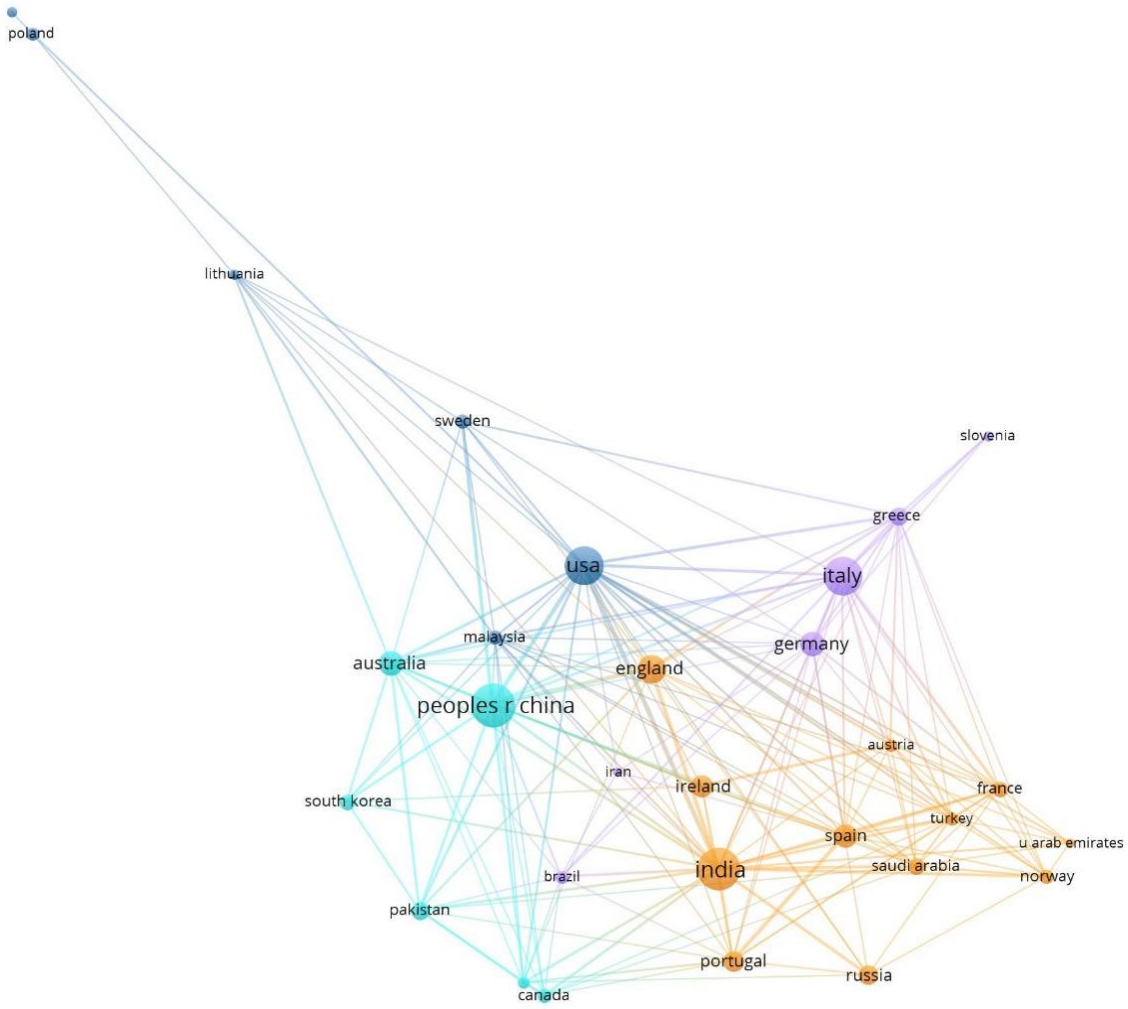

Fig. 7. Bibliometric map of the co-authorship countries for Industry 5.0 during the period 2016-2022 (Source: Own processing)

The minimum number of documents for one keyword was set at 5, which reduced the number from 42,288 keywords to 3,321. Six clusters were created, the largest of which contained 268 items and is shown in orange. The keyword with the highest occurrence in this cluster is 'Industry 4.0', with an occurrence of 8,649 words and a total link strength of 41,610 and 998 links. The 'Performance' had the second-highest occurrence (845), with 785 links and a total link strength of 6,238. A group with 224 elements is shown in turquoise. The most numerous word is 'Model' (851 occurrences), with a link strength of 6,222 and a total link strength of 851. The keyword 'System' has 772 links, with an occurrence of 792 and a total link strength of 4,949. The third cluster is shown in purple, with a total number of 215 elements. The cluster contains words such as 'Internet' or 'Internet of Things'. The 'Internet' has a total link strength of 9,218 with 832 links and a peak of 1,163. The dark blue cluster contains 176 elements. Terms such as 'management', 'future', 'framework', and 'sustainability' are included here. 'Management' appears 1,290 times, with a total link strength of 10,142 and 866 connections. The dark purple cluster contains 80 elements, with the most numerous word being 'design' (1,218), with 833 links and a total link strength of 7,508. The smallest cluster is shown with 37 elements. 'Big data' has a link strength of 8,247, with an occurrence of 1,093 and a total number of links of 838.

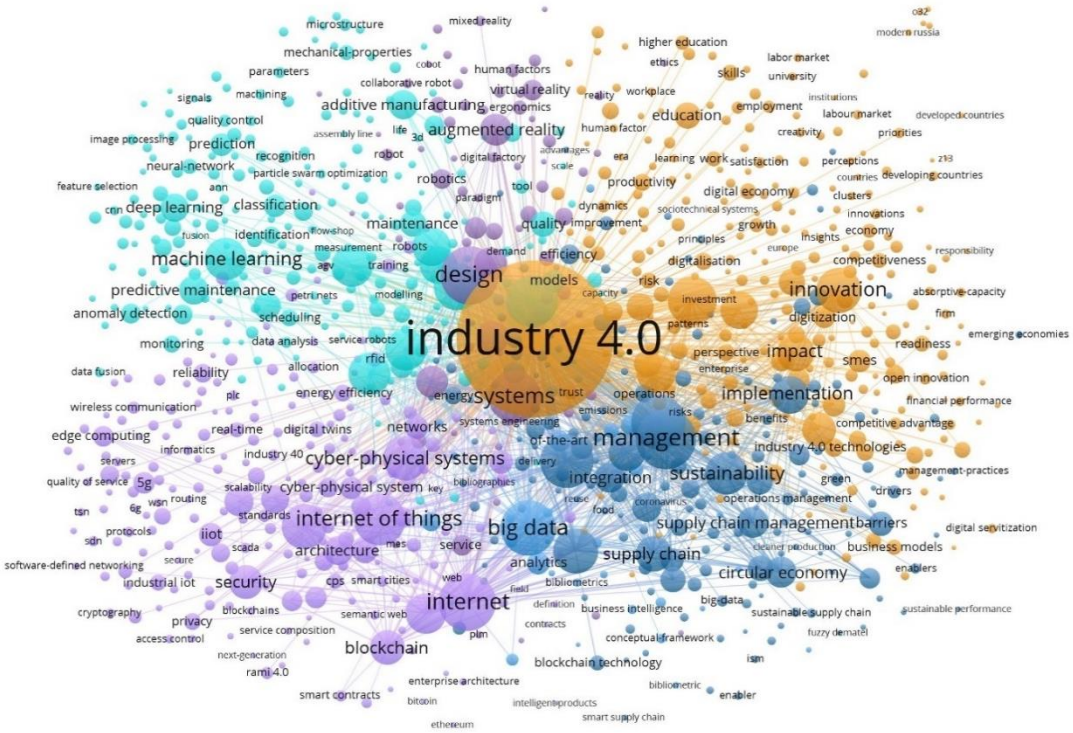

Fig. 8. Bibliometric map of the keywords Industry 4.0 during the period 2012-2022 (Source: Own processing)

The minimum number of documents for one keyword was set at 5, which reduced the number from 68 keywords to 30. The most numerous is the orange cluster, which contains 23 items. The most numerous keyword is ‘design’ with a frequency of 28 and a total link strength of 2,127 and 58 links. The second most numerous word is ‘framework’, with a frequency of 25, 64 links and a total link strength of 154.

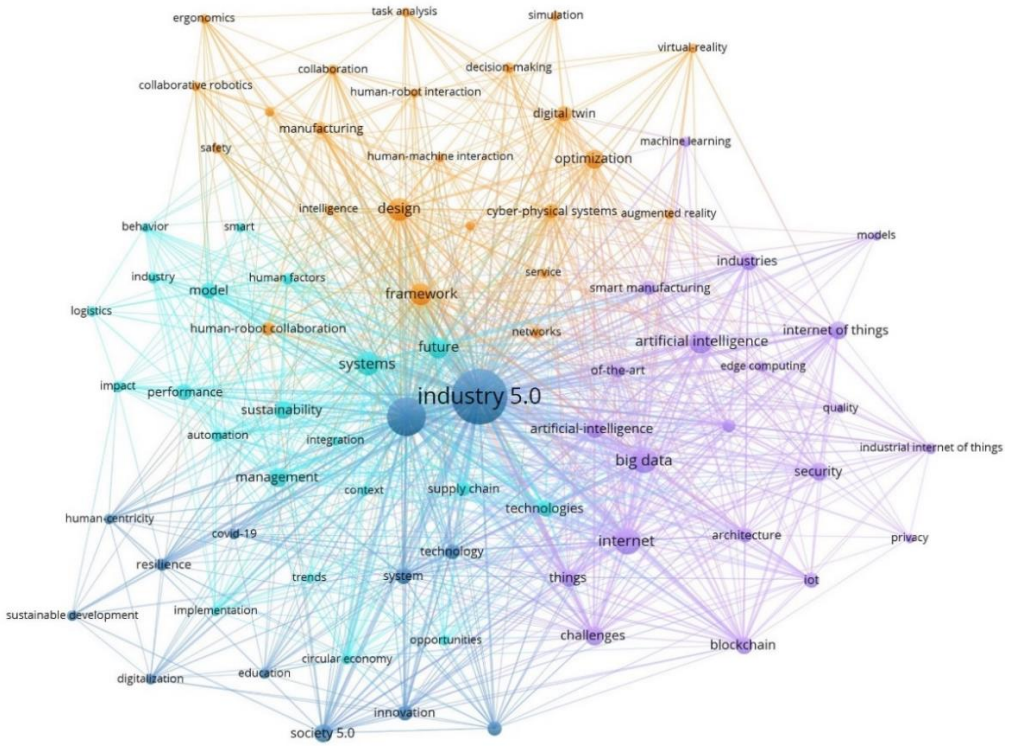

Fig. 9. Bibliometric map of the keywords Industry 5.0 during the period 2016-2022 (Source: Own processing)

It is followed by a turquoise and purple cluster with a frequency of 21. The most prominent word of the turquoise cluster is ‘system’ with link strength 139, frequency 30 and 56 links. Keywords such as future, management, or sustainability follow. The purple group contains words such as ‘big data’, ‘artificial intelligence’, and ‘Internet’. It is the internal one that has the most connections (37), with a connection strength of 59 and a total occurrence of 37. The smallest cluster is blue, containing 13 elements. The most prominent keyword is ‘Industry 5.0’, with a frequency of 153, a link strength of 558, and 76 links. It is followed by ‘Industry 4.0’ with 72 links, a frequency of 78, and a link strength of 392.

Figure 10 shows the most numerous WoS categories used for ‘Industry 4.0’. These are categories that contain more than 1,400 publications. Engineering Industrial is the most used category; it has been used up to 3,347 times. Next comes the Engineering Manufacturing category, to which 3,174 publications are assigned. Over 3,000 entries went to Engineering Electrical Electronic (3,115). Computer Science categories are also frequently used, namely CS Theory Methods (2,872), CS Information Systems (2,463), or CS Artificial Intelligence (2,157). They are followed by categories such as Automation Control Systems (1,942), CS Interdisciplinary Application (1,854), Telecommunication (1,585), and Management (1,463).

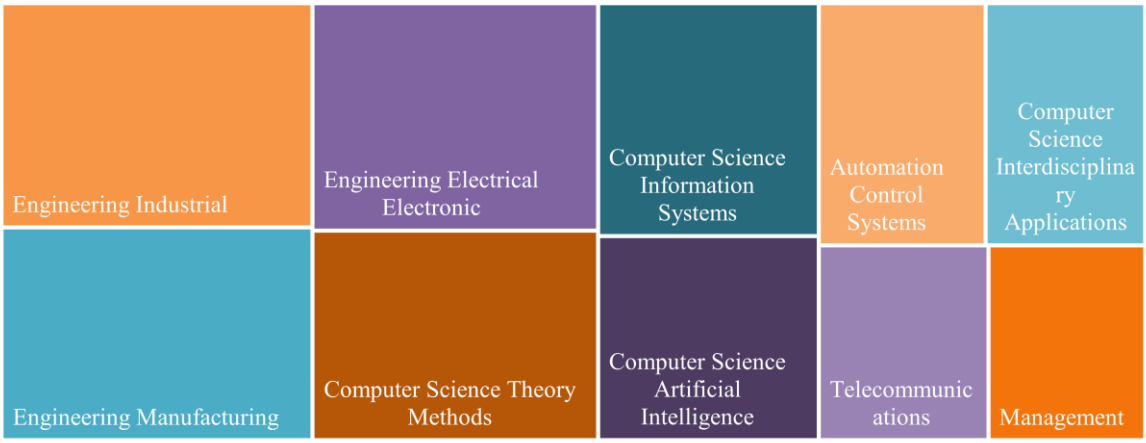

Fig. 10. WoS categories of documents related to Industry 4.0 during the period 2012-2022 (Source: Own processing)

Scientific worker Elena G. Popkova from the Moscow State Institute of International Relations currently has the most articles in the WoS database devoted to Industry 4.0. The author is listed 45 times as an author or co-author of publications that deal with the issue under investigation. Radek Martinek has 42 publications; he works at the Technical University of Ostrava.

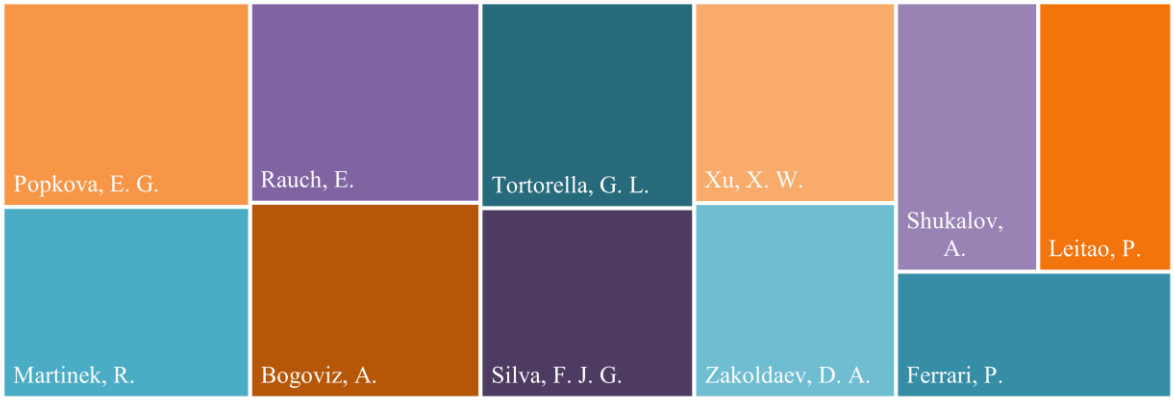

Fig. 11. The most published authors devoted to Industry 4.0 during the period 2012-2022 (Source: Own processing)

The third author is Erwin Rauch, who has written 41 publications and works at the Free University of Bozen-Bolzano. Other important authors include Bogoviz (40), Tortorella (39), Silva (36), Xu (36),

Zakoldaev (35), Shukalov (34), Leitao (32), and Ferarri (31). From Slovakia, Maria Kozlovska, who works at the Technical University of Košice, has the most publications (21).

We also created a bibliometric map to identify scientific alliances. Due to the large amount of data and the fact that some of the more than 1000 items were not interconnected, we decided to display only the most extensive set of connected items of 513 items. The total number of clusters after adjustment was 9, while the minimum number of items in one cluster was 30, which eliminated the smallest clusters. The most numerous cluster contains 72 items. It is shown in turquoise. Brigit Vogel-Heure has the most documents from this cluster, namely 33, while the number of links is 14, and the total strength of the link is 18. This cluster also includes authors such as Christian Diedrich, Petr Novak, and Arndt Leuder. Authors such as Guido Guizzi, Silvestro Vespoli, Dmitry Ivanov, Maurizio Faccio, Marco Macchi, and Fernando Castano can be found in the pale purple cluster. 72 authors were also placed in this cluster.

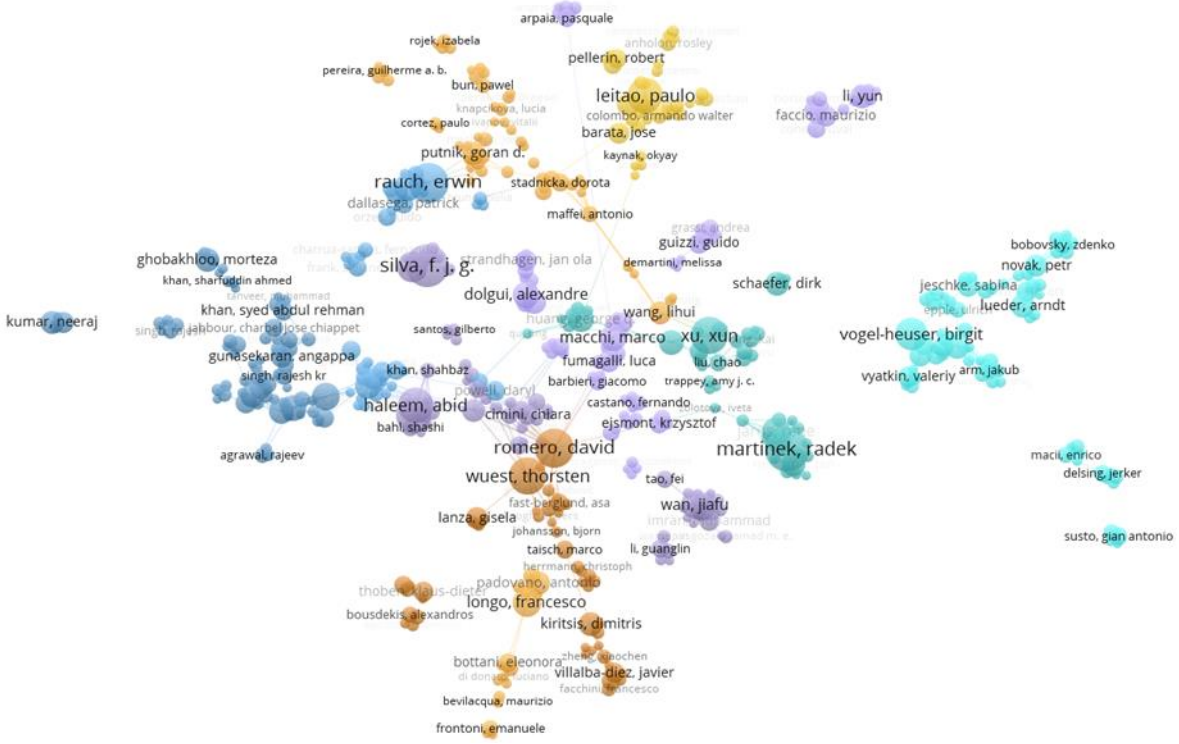

Fig. 12. Bibliometric map of the co-authorship for Industry 4.0 during the period 2012-2022 (Source: Own processing)

The orange group consists of 70 authors, such as Antonio Maffeim, Lihiu Wang, Gaultiero Fantoni, Francesco Longo, Antonio Padovano, Eleonora Bottani, and others. The dark blue cluster contains a total of 68 authors, such as Rajesh Singh, Jose Arturo Garza-Reyes, Sunil Luthra, Yigit Kazancoglu, Anil Kumar, etc. F. J. G. Silva, Jiafu Wan, Di Li, and Abid Haleem, Paolo Gaiardelli were included in the dark purple cluster. The dark turquoise cluster included authors such as Radek Martinek, Xun, Xu Ray R. Zhong, George Q. Huang, Dirk Schaefer, Rene Jaros, and others. The brown cluster grouped authors such as David Romero, Thorsten Wuest, Gisela Lanza, Dimitris Kiritsis, and many others. Erwin Rauch, Dominik T. Matt, Guilherme Luz Tortorella, and Patrick Dallasega were placed in the blue cluster. The smallest cluster is yellow, with authors like Paulo Leitao, Damien Trentesaux, etc. The creation of scientific alliances in the case of Industry 5.0 makes no sense, as this map has no informative value for the reader.

Fig. 13. The most published authors devoted to Industry 4.0 during the period 2012-2022 (Source: Own processing)

Additionally, articles devoted to Industry 4.0 were published by the professional association IEEE. A total number of 4,446 publications were published until 2022. Another publisher is the Dutch academic publisher Elsevier, with 4,321 publications. Publishers Springer Nature (2,418), MDPI (1,966), Emerald Group Publishing (687), Taylor & Francis (672) and IOP Publishing Ltd (628) follow.

Discussion and conclusions

The paper written by Grabowska et al. (2022) set out to find areas in which the idea of Industry 4.0 may be made more sustainable and humane. Additionally, the authors used Web of Science data that was transformed by utilising VOSviewer tools. The analysis of the dynamics of the rise in publications in the Industry 4.0 and Industry 5.0 segments is one of the most significant findings. For Industry 4.0, the research period for the authors was from 2012 to 2020, and for Industry 5.0, from 2020 to 2021.

Madsen and Berg's (2021) study provides an exploratory bibliometric analysis of the emerging literature on Industry 5.0, which is a new visionary concept for the future of the industry. The authors' aims were to map the field and provide a preliminary picture of the emergence and status of the scientific literature on Industry 5.0. Bibliometric data covering the period from 2015 to 2021 were extracted from the Scopus database. The majority of the publications belongs to engineering (45); computer science (40); business, management and accounting (17). The trend of publications about Industry 5.0 has a growing tendency. These growing trends support the findings of our research.

According to Cannavacciuolo et al. (2023), Industry 4.0 is a developing subject that is receiving more and more attention from the scientific community. The findings of this study are also valuable because they highlight the crucial role that governments and public agencies played in facilitating the socio-economic adjustments required to fully take advantage of Industry 4.0's technological advancement.

Kumar et al. (2022) gathered eight hundred and ninety-one articles from 2014 to 2020 from the Scopus database to carry out their research work. Researchers aimed to conduct a bibliometric investigation and visual evaluation of IoT in Industry 4.0 evolution to link the disparity in the available literature analysis and research directions. They used VOSviewer and Biblioshiny 2.0. Kumar et al. found out that, the paper "Intelligent Manufacturing in the Context of Industry 4.0: a review" by Zhong et al. (2017) was rated first with 754 citations, followed by "Industry 4.0: state of the art and future trends" by Xu et al., (2018). Industry 4.0 appeared first in 2014 with the application of IoT in Industry 4.0 with an overall appearance of 528.

The findings of the comparative bibliometric analysis Jafari et al. (2022) performed on the two collections of literature show that there is a growing trend in addressing the societal, human, and sustainability aspects, which are the key components of Smart Logistics in Industry 5.0 [6], in order to emphasise the coherence between technological advancement and human-centric socio-economic transition. The analysis of the most often used phrases demonstrates that Industry 4.0's Smart Logistics

focuses exclusively on the technological underpinnings. On the other hand, Industry 5.0 significantly promotes interaction between people, technology, and the environment through human-robot collaboration, collaborative robots, man-machine systems, etc. In addition to emphasising the adoption of new technologies in Smart Logistics operations. The authors agreed with our conclusions.

Authors researched Industry 4.0 in the context of shipping (Yang et al., 2023), the Internet of Things (Kumar et al., 2022), supply chains and circular economy (Hettiarachchi et al., 2022), artificial intelligence and machine learning (Mateo & Redchuk, 2022), Lean management tools (Nedjwa et al., 2022), operations management (Sordan et al. 2022), maritime industry (Razmjooei et al., 2023), digital twin and smart manufacturing (Moiceanu & Paraschiv, 2022).

Based on the results, it can be concluded that Industry 4.0 is a field of constant interest for scientists, on which they are constantly working. The rapidly growing trend of publications stopped in 2019 and subsequently decreased but increased again in 2021, only to decrease the following year. These trends are not caused by the emerging interest in Industry 5.0. Industry 5.0 is a constantly emerging term, and its significant growth can be expected in the coming years.

Countries such as Germany, Italy, China, the USA and India are among the most publishing countries about I4.0. China, India, the USA, Italy, and Great Britain mainly deal with the term 'I5.0'. As can be seen, the countries that are dedicated to Industry 4.0 are also dealing with the concept of Industry 5.0. From the point of view of keywords, the most frequently used for the term 'Industry 4.0' are 'design', 'management', 'Internet', 'big data', 'model', and 'Industry 4.0'. The term 'Industry 5.0' can be characterised by terms such as 'big data', 'system', 'design', or 'Industry 5.0'. Publications are most often included in categories such as Engineering Industrial, Engineering Manufacturing, Engineering Electrical and Electronic, Computer Science Theory and Methods, Computer Science Information Systems, etc. Authors such as Popkova, Martinek, Rauch, Bogoviz, and others have the most publications about Industry 4.0 in the WoS database. The most frequent publications on the researched issue are published by IEEE, Elsevier, Springer Nature, MDPI, and others.

The summary of theoretical launching points from the fields of Industry 4.0 and Industry 5.0 is the scientific article's additional value. This analysis is essential for authors dealing with Industry 4.0 and Industry 5.0 issues. Our study brings up-to-date information from the theoretical field, and at the same time, we inform scientific authors about the most published authors in the researched field. Using this, they can find their scientific articles, which will make their work easier for scientists when comparing research or expanding knowledge in the researched area. At the same time, we provide the authors with information about the most frequently used keywords that are used in the investigated issues of Industry 4.0 and Industry 5.0. If authors want to find out about publications from the country in which they are conducting their research, they can find in this scientific publication how many similar scientific contributions are in the Web of Science scientific database as of 2022.

A limitation of the research can be considered the fact that the bibliometric analysis was performed only from the data of the Web of Science scientific database. Data from this database is considered the most relevant. On the other hand, publications by authors that were not published in the most famous indexed journals were omitted from the research. A more extensive examination of the issue with a focus on other scientific databases such as SCOPUS or Google Scholar will be the intention of the authors in their further in-depth research on the examined issues of Industry 4.0 and Industry 5.0.

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THE PLACE AS A BRAND. THEORY AND PRACTISE OF THE PLACE BRANDING

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Abstract

Research purpose. The purpose of the research project was to evaluate the status of place branding as a scientific discipline and to check whether this concept has been concretised during exploration and articulation. An additional objective was to check the theoretical status of place brands.

Design / Methodology / Approach. The study used an approach based on the analysis of 'place brand' models developed in the literature since models are central to the scientific procedure. These models were then confronted with the empirical observations of the authors using the Flexible Pattern Matching (FPM) method.

Findings. A consulting and practical approach is noticeable, especially in the ever-new 'process models' (how to create and manage 'place brand'); moreover, these models are scientifically insignificant and practically unworkable. Descriptive models (what a 'place/territorial brand' is) do not reveal signs of concretisation. There is undoubtedly a phenomenon of 'forcing' empirical data.

Originality / Value / Practical implications. Based on the analyses done, it can be concluded that none of the examined models meets the requirements of lawlike generalisations. In the practice of place branding, carried out by territorial units, the only common element is the usage of the name and logo of the place. It can also be argued that the basic concept of 'place brand' is poorly defined. The research method used (FTM) has not been applied in the analysis of place brands so far; however, the examination done in this article proves its usefulness.

Keywords: Place branding; Place branding model; Place marketing; Flexible pattern matching

JEL codes: B40; M30; H70; Z18

Introduction

The starting points for the presented considerations were the following comments from recognised experts.

- "Knowledge is 'scientific' if it is impartial, systematic, and more complete and accurate than 'popular' knowledge at the time" (Machlup, 1956, p. 163);
- The scientific method is described as a procedure with clearly separated two phases: discovery and justification (in marketing theory, see, e.g., Hunt, 2015, p. 25). However, as Haack (1997) states, "but the dichotomy is too crude. A better picture would include something like an initial phase in which an inquirer forms a vague idea, and subsequent phases of exploration, articulation, testing, modification, and presentation" (p. 502);
- Hunt (2015) also claims that marketing should have a theoretical basis, perceiving marketing only as a practical discipline focused on advice, applications, and consulting, which is pernicious, leads to the marginalisation of the discipline in academia and results in its stagnation (Hunt, 2015).

Place brand as a concept and place branding as a process which allows building a brand of the place became important due to the competition in the global world going along the marketisation policies

practised by local and regional governments (Anholt, 2007). The brand of a place has its market value, which is built and later developed to attract foreign investments, encourage tourists to visit or increase the attractiveness of the place of residence. The place brand and its promotion are tools used in the socioeconomic development of a given local/regional/country government. For this reason, this approach is used in practice and in consulting activities. However, it should be emphasised that the place brand does not mean the market value defined in the price because the market value of a brand consists not only of its tangible and measurable resources. When it comes to the value of the place, the intangible dimension of the place, which is a logo, an image, a reputation, and a timeless and inalienable value, should be noticed. This means that the place brand performs marketing functions, and the representatives of this view refer to many scientific disciplines, finding justification for their considerations. To sum up, the brand of a place is a concept resulting from marketing activities undertaken by city managers; therefore, it must demonstrate the specificity of a place in a material, visual, or a discursive way to attract attention and distinguish it from others (Govers & Go, 2009).

The above assumptions lead to the question: is it possible to indicate a model of a place brand that allows it to be adapted to a specific place (city, region, country)? What could be the sources of such a model, theoretical or practical? Normative or descriptive? Such questions influenced the authors' decision to collect and study the place brand models presented in the literature, to answer further questions arising from the literature reviews:

1. Is 'place branding' a scientific discipline?
2. Has the initial 'vague idea' (Haack, 1997)* of the 'place brand' become more concrete during exploration and articulation?
3. What is the theoretical status of the term 'place brands'?

**Haack describes the 'vague idea' as an initial phase of scientific inquiry (Haack 1997, p. 502). Hunt (2015) writes, "many, if not most, major scientific discoveries are flashes of perceptual insight and are not the result of following some rigorously prescribed procedure" (p. 25). Such discoveries, perceptual insights, and vague ideas are later, in scientific procedure, justified or rejected.*

In the presented study, authors applied an approach based on the examination of place brand models discussed in the literature on the subject because "models are a central necessity of scientific procedure" (Rosenblueth & Wiener, 1945, p. 316). In scientific consideration, a model is a representation of an idea, an object, a process, or a system that is used to describe and explain phenomena that cannot be described directly. It should also be added that theoretical models are crucial for conducting research as well as for communicating the results.

The purpose of the paper is neither clarification of major concepts (e.g., place marketing vs place branding vs place promotion vs public diplomacy) nor the description of the history of the discipline; however, the authors accept three theses to be widely shared in the literature on the subject:

- Place marketing is chronologically the most recent extension of the field of marketing studies (Kotler, 2005);
- The conversion in terminology from 'place marketing' to 'place branding' occurred around 2000 (Lucarelli & Berg, 2011);
- The relationship between these terms is disputed and treated differently in the literature (Skinner, 2021; Vanolo, 2017).

Literature studies of research and consideration of the place brand concept allowed identifying a research gap, which is the lack of practical analysis of the developed models. Place branding is derived from the practice of territorial marketing used by local authorities as part of new public management, taking into account the achievements of business practice in the practice of place management. However, numerous and, at the same time, more and more complex models of the place brand make them exclusively theoretical and move away from the possibility of practical use (Green et al., 2016). Therefore, the authors tried to collect models, analyse them, and formulate conclusions.

In summary, it can be stressed that the very appearance of the term 'place branding' became an impulse to conceptualise this notion and to build theoretical models. The number and variety of models found in the literature on the subject indicate compliance with Haack's thesis, which says that attempts are made to concretise the initial vague idea.

Literature review

Despite the relatively short history of the discipline, the number of studies, articles, and books devoted to place branding is significant. As a result, there are also relatively large numbers of studies devoted to the analysis of the literature on this issue. The most recent and extensive examination is included in the article by Renaud Vuignier (Vuignier, 2017), in which 1,172 papers in this field were analysed, and in the article by Ma et al. (2019) in which 2,665 articles and reviews were analysed. It should be noted that relatively little attention was paid by the authors to the models of 'place / territorial brands' proposed in the studied literature, except for the considerations made by Kavaratzis (2005), Gertner (2011a) and Kumar and Panda (2019). It is important that the authors of the reviews point out that the discussed articles (Gertner, 2011b, p. 101) 'do not advance testable models or hypotheses' or that future studies could develop an integrated model in the context of nation branding (Hao et al., 2021).

The conclusions drawn from the review articles are not entirely consistent. For example, Gertner (Gertner, 2011b) states that out of 212 articles examined, only 13 contain 'testable hypotheses or models' (p. 95). In a more recent review article, Kumar and Panda (2019) mention 188 articles, and they list 20 models but only 5 of them have been empirically tested. The authors also add that the only construct common to these models is 'brand communication'. However, even this statement has been questioned. Mohamed Berrada, before developing his 'Holistic Place Branding Model', analysed 30 models from the literature on the subject and found that only 21 of them contained the 'brand communication (s)' construct (Berrada, 2018). The weaknesses of theoretical models were noted by Lucarelli & Berg (2011). Those authors point out that there is a lack of a coherent theoretical basis since at least three different approaches are used to create place brand(ing) models: “traditional branding, service marketing, and multi-attribute consumers' attitudes and perceptions” (Lucarelli & Berg, 2011, p. 20).

After studying the cited review articles, the following trends emerge, which are important for further analyses:

1. 'Borrowing' models from other fields of science (Kasapi & Cela, 2017; Lucarelli & Brorström, 2013)
2. Proliferation of models (Adeyinka-Ojo & Nair, 2016);
3. Complexity and multidimensionality of the constructs used (Balakrishnan, 2009; Berrada, 2018).

As literature reviews on the subject demonstrate, it can be concluded that at least several dozen models have appeared in 'place branding'. These models have a rather weak empirical basis because the research if referenced, is carried out using different methods, at different places, based on diverse research samples and analysing different data. All of them make the models inconsistent and complicated. This multiplicity and diversity led to the development of a model of models by Shahabadi et al. (2019), which is based on only nine previously created proposals, and a construct proposed by the authors consists of more than 40 variables. In summary, the reviews of the literature on place branding as a scientific discipline reveal an inability to explain the differences and inconsistencies in the presented models, which justifies a more thorough analysis of this topic.

Research Methodology

The 'Flexible Pattern Matching Method' (FPMM) (Bouncken, Qiu, Sinkovics, et al., 2021; Sinkovics, 2018; Trochim, 1989) was used to analyse models existing in the literature guided by the following premises:

- the method can enhance the "internal validity" and "reliability" of the research constructs used;
- it allows readers to follow the research process;

- it provides a theoretical framework for the empirical discoveries made;
- it allows for the effective formulation of analytical categories;
- it is useful in comparative analyses of 'case studies', which is essential in the context of 'place branding' because, as indicated by Vuignier, 36% of the text corpus is single case studies (Vuignier, 2017, p. 465).

This method is, therefore, particularly beneficial when the analyst has a large number of theoretical deliberations on the one hand and a large number of descriptive studies on the other, while the theory is inconsistent and unsubstantiated. The articles cited disclose that researchers studying place branding issues deal with such a situation. As Oguztimur and Akturan (2016) write, "methodologically, most of the studies are based on secondary sources or convenience samples and do not propose testable models or hypotheses" (p. 369).

According to the quoted literature, one may notice that a 'pattern matching' method is a recognised research mode in business, organisational and management studies. However, it has not been used so far in 'place branding' analyses. As Czakon and Glinka conclude, FPM is particularly useful when a given field of knowledge is rich in numerous and inconsistent theoretical approaches and models (Czakon & Glinka, 2021), and the interaction between the observational and theoretical realms remains unclear (Bouncken, Qiu, & Sendra Garcia, 2021).

There are three research approaches in the 'pattern matching' technique: (1) full pattern matching, (2) partial pattern matching, and (3) flexible pattern matching (FPM). FPM, as systematically categorised by Sinkovics (2018), is an iterative process harmonising theoretical constructs, patterns, and assumptions presented in the literature on the subject and observed patterns emerging from observed empirical data. As Trochim writes (Trochim, 1989), "we should assess the link or match between the theoretical and observed patterns" (p. 365). The research procedure is presented in Fig.1.

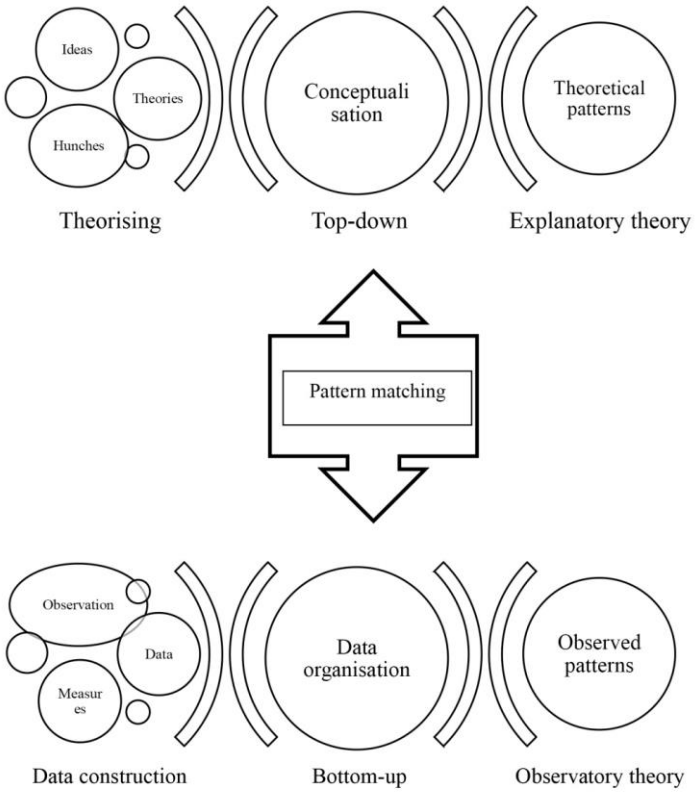

Fig. 1. Flexible Pattern Matching Source: adopted from (Sinkovics, 2018; Trochim, 1989)

According to the Flexible Pattern Matching model, the study was conducted in the following stages:

1. The theoretical perspectives found in the 'place branding' models have been identified. For this purpose, the following databases were used: EBSCO, Google Scholar, and Web of Science. Keywords searched for were as follows: 'place brand/branding' and/or 'territorial brand/branding' plus 'model(s) and/or 'modelling'. The time frame was set for the years 2002-2022. The designated time range resulted from the two variables: (1) the terminology change from 'place marketing' to 'place branding', which took place at the beginning of the 21st century, and (2) the emergence of the first model (Cai, 2002), which is considered universal in the literature, although originally developed for 'rural destinations' (Adeyinka-Ojo & Nair, 2016). Preliminary 193 articles were identified.
2. The models were also identified in sections devoted to the topic as 'literature review' or 'state of the art'. Finally, 44 articles, books, and chapters in multiauthored books that offered models of place brands were recognised. Additionally, three review articles dedicated to place branding models were acknowledged. In these three articles, the authors proposed their own solutions based on a review of previously developed models. These papers will be discussed separately.
3. The third stage of the examination divided the recognised models according to criteria: (see Table 1) (1) model source with publication date; (2) empirical basis - conceptual model, case study, other methods, such as surveys, multiple cases, combination of data gathering methods; (3) model type: process - PB, descriptive - TRBrand, composite; (4) whether the model was subsequently revised/modified/developed by the author, which meets the requirement of clarification (Haack, 1997); (5) whether the model refers to a known school of research, method, or theory coming from others disciplines as marketing and branding, due to the widely documented multidisciplinary nature of place branding (Vuignier, 2017). In Table 1, the acronym HST (Humanities, Social Sciences and Theology) is applied.
4. In the final step, theoretical data were compared with empirical data. For this purpose, reference was made to the authors' own research project, conducted since 2011 and focused on various aspects of the construction, maintenance and modification of territorial brands in Poland. (Adamus-Matuszynska & Dzik, 2017). The authors used various analytical methods to conceptualise the obtained data; however, the main method used was verbal-visual content analysis (Rose, 2016). Furthermore, during the project, the authors contacted more than 300 Local Government Units (LGU) in Poland, verifying the information obtained through telephone, video and personal interviews. A supplementary source of information was the consulting practice of the authors; in total, they participated in about 50 projects in the field of territorial marketing, including international projects. This allowed 'pattern matching' in the FPM model and the assessment of whether there is a link or a match between theoretical models and empirical data.

Table 1. Models analysed (Source: the authors' own research)

	Date and source	Empirical basis			Model Type				
	Proposed model	Conce-ptual	Case study	Other	PB	TRBrand	Comp.	Dev./Rev.	HST ref.
1	(Cai, 2002), modified (Cai, 2009)		X				X	X	
2	(Anholt, 2002)			X		X		X	
3	(Kavaratzis, 2004)	X				X		X	
4	(Hankinson, 2004)	X			X			X	
5	(Laws & Scott, 2004)	X			X				
6	(Azevedo, 2005)	X			X			X	

7	(Kavaratzis & Ashworth, 2005)	X				X			
8	(Trueman & Cornelius, 2006)		X			X			X
9	(Baker, 2007)			X			X	X	
10	(Gnoth, 2007)	X			X				
11	(Dinnie, 2008)			X		X			X
12	(Gaggiotti et al., 2008)		X		X				
13	(Konecnik & Go, 2008)		X			X		X	
14	(Moilanen & Seppo, 2009)			X	X			X	
15	(Balakrishnan, 2009)			X	X				
16	(Govers et al., 2007)			X	X			X	
17	(Kavaratzis, 2009) II	X					X		
18	(Hudson & Ritchie, 2009)		X		X				
19	(Hankinson, 2010) II	X				X			
20	(Qian, 2010)*	X				X			
21	(Zenker & Braun, 2010)	X			X				
22.	(Hanna & Rowley, 2011)	X			X		X		
23	(Aitken & Campelo, 2011)		X		X				
24	(Lang, 2011)	X			X				
25	(Balakrishnan & Kerr, 2013)		X		X				
26	(Kavaratzis & Hatch, 2013) III	X					X	X	X
27	(Cleave, 2014)			X		X			X
28	(Buhmann & Ingenhoff, 2015)	X				X			X
29	(Arabzadeh & Aghaeian, 2015)		X		X				
30	(Bisani & Choi, 2016)			X		X			X
31	(Foroudi et al., 2016)			X	X				
32	(Dinnie, 2016) II			X			X	X	
33	(Hudson et al., 2017)		X		X				
34	(Uonaki et al., 2018)		X			X			
35	(Ageeva & Foroudi, 2019)			X		X			
36	(Pawlak & Hajduk, 2019)		X		X				X
37	(Shahabadi et al., 2020)		X				X		X
38	(Ojo, 2020)			X		X			
39	(Lucarelli & Cassel, 2020)			X	X				X
40	(Sang, 2021)		X			X			X
41	(Kvaratzis & Hatch, 2021)		X		X				
42	(Herezniak & Anders-Morawska, 2021)	X			X				X
43	(Nursanty, 2021)		X		X				

44	(Jain et al., 2022)		X				X		X
	Total	15	16	13	22	14	8	11	12

*Original source is hardly available. Comprehensive review and graphic presentation in (Berrada, 2018; Bicakcı & Zeynep, 2017)

Research Results

Research confirms previous findings in literature reviews that models are built mainly on the basis of case studies (Vuignier, 2017), which are unequally selected by researchers (Lu et al., 2022), and there is a lack of coherent and explicit theoretical base (Hao et al., 2021). Some models were empirically tested; No. 1 in (Ruzzier & de Chernatony, 2013), No. 6 in (Petrea et al., 2013); No. 22 in (Ranasinghe et al., 2017); No. 26 in (Walters & Insch, 2018) and No. 32 in (Warren & Dinnie, 2017). However, it is evident that random factors such as physical proximity to the researcher influence the selection of the analysed cases (Lu et al., 2022). Without a doubt, the "data forcing", i.e. fitting empirical data to a previously generated model, is confirmed in the analysis (Kelle, 2005). The conclusions coming from the presented research suggest that the examined models force empirical data, i.e., research procedures are conducted in such a way that the data are adjusted to the previously developed model. This is a methodological error (Konecki, 2009, pp. XV - XVI)

In three articles (Balakrishnan, 2009; Berrada, 2018; Shahabadi et al., 2019), an attempt to create a holistic and comprehensive 'model of models' was completed.

The comparison of models shows that the only shared component found in most of them is 'brand communications' (Shahabadi et al. (2019) model, it is 'expression'). The authors have been examining the activities (practices) of Polish local governments since 2011 and can state beyond all doubt that even this common component in the analysed models can be questioned. In the practice of Polish place branding, carried out by territorial units, the only common element is the usage of the name and logo of the place (Adamus-Matuszynska & Dzik, 2020).

Process models [PB], according to the terminology of De Almeida and Cardoso (2022), are scientifically worthless because they do not add new knowledge, do not reorganise existing knowledge, and do not question existing knowledge. Their practical (advisory) value is also very limited, if not non-existent. The explanation for this phenomenon stems from the facts that firstly (Kong, 2012), “similarities can be observed among the different frameworks” (p. 88); secondly, the branding procedures have been known for decades, but because they were created outside the place branding, mainly in the graphic design theory and practice (Chua & Illicic, 2007; Mollerup, 2013; Spies & Wenger, 2020; Wheeler, 2018), these procedures are neither known nor cited in the literature on place branding. This is an unambiguous example of the "silo mentality" described by Vuignier (2017). In place branding, it is implicitly or explicitly assumed that a territorial brand (TRBrand) is a multielement and multidimensional construct, i.e., the so-called component model - CM (De Almeida & Cardoso, 2022) widely accepted in the literature on the subject. However, in scholarship, this model is challenged because there is: no 'cogent underpinning theory' (Patterson, 1999), no analytical definition of a brand (Manning, 2010), the nomenclature is considered confusing or dysfunctional (Gaski, 2020), and the model is considered 'opaque and unwieldy' (Avis & Henderson, 2022, p. 351). Avis and Henderson posit that branding should return to the basic 'Label and Association Model' (LAM).

In the next step of the research procedure, a comparison of the models analysed with empirical data obtained during field research of the Polish LGU's place branding processes was made. In this article, there is no space to discuss all the phenomena found absent in the recognised models. However, the authors mentioned the most important examples questioning the processes and components present in the mentioned literature. Examples of inconsistency between models and practice have been confirmed in empirical studies of Polish local governments, which are as follows.

1. Funds. In the analysed models, it is assumed that funding for branding activities is provided and stable, while in Poland's case, it is a fundamental challenge. (e.g., Mazowsze region), An important factor is project financing, especially from EU projects. In the Polish literature on the subject, this issue was noticed already in 2012 (Zdon-Korzeniowska, 2012).

2. Organic development. There is no formalised process of creation and implementation of a place brand, and as a result, there are chaotic interactions between the administration, residents, and local businesses (e.g., the city of Tarnowskie Góry).
3. Rejection of the brand by the local community after its implementation (the city of Olkusz).
4. 'Debranding', which means that the place brand can be repealed while the place itself still exists. This phenomenon does not occur in commercial branding (for example, in Gorzów and Nowy Sącz, city brand projects were officially closed by resolutions of the City Councils).

In summary, each component existing in the examined theoretical models was disproved or not used in actual practice. It seems that the brand of the place has become a victim of the race to create more and more new models. One can get the impression that in the discipline, only the one who presents his/her model matters, regardless of whether it makes any sense. The authors of place brand models rarely empirically verified them, as well as references to the recognised theories outside of marketing and branding are rare and inconclusive.

Conclusions

In conclusion, the answers to the three questions in the Introduction to this article are as follows:

1. Is 'place branding' a scientific discipline?

Even if we accept the cited definition of Machlup (1956), it can be said that place branding does not go too far beyond common sense findings and does not have the value of lawlike generalisations. Assume more formal demarcation criteria between science and pseudoscience, such as those formulated by Paul Thagard, who defines pseudoscience using five combined criteria (Thagard, 2011), such as "lacks mechanical explanations, uses dogmatic assertions, or resemblance thinking, which infers the things are casually related merely because they are similar; practitioners are oblivious to alternate theories; uses non-simple theories that require many extra hypotheses for particular explanations; stagnant in doctrine and applications", it might be concluded that place branding is at best in the early stage of turning from common sense approach into a recognised scientific discipline (p. 27). However, it should be noted that this is not an objection but rather a conclusion resulting from the analysis of numerous theoretical thoughts of researchers for whom understanding the idea of place branding is essential for practical reasons.

2. Has the initial 'vague idea' of the 'place brand' become more concrete during exploration and articulation?

Knowledge of the research field is fragmented and does not fit into a system; it is difficult to confirm that there is a crystallisation of an 'initially vague' idea (Haack, 1997) idea. Andersson stresses that (Andersson, 2014) at least seven research approaches can be identified in the literature on the subject, of which only one is derived from mainstream branding. The first perspective involves place branding as a means to create, change, preserve or regain place identities and place images. In the second perspective, place branding is seen as part of growing urban entrepreneurialism. Papers discussing the theoretical relationship between branding and geography constitute the third research perspective. Research on place branding practices constitutes the fourth identified perspective. The fifth one discusses place branding as an undemocratic and socially excluding process that promotes social elites while systematically marginalising less powerful groups in society. Place branding as an integral part of strategies to make creative places is the sixth perspective identified in the literature. The seventh perspective is well-known in the literature as a country-of-origin effect (Andersson, 2014, pp. 150 - 151). These approaches are not found in the analysed models; it seems that even within the discipline, there is no flow of knowledge and concepts.

3. What is the theoretical status of considering 'place brands'?

In reviews of the referred literature, there are regular remarks that the theoretical foundations of the discipline are weak and that the definitions used are unclear, opaque and ambiguous. The examination of the models confirms this situation; the authors introduce their own nomenclature; the same (or similar) phenomena are called by different terms, despite the commonly declared multidisciplinary

nature of the research subject; references to theories outside of marketing and branding are rare and inconclusive. Instead, they relate to methods of collecting and analysing data, not to theoretical foundations. It seems that the authors of the models know about the existence of such disciplines as humanistic geography, sociology of space, urban planning, or cultural anthropology; however, they do not consider it useful or purposeful to use them in the created models of place brands, which will work either in theory or in practice. This is a highly worrying situation for the further development of the discipline and the construction of a widely shared theoretical foundation regarding place branding.

Summing up the list of place brand models and the analysis of their practical dimension by reference to Polish practice, it should be emphasised that the number and complexity of these models are proof and that the place brand concept is still at the stage of searching for both its theory that will allow for development and the methodology that will combine theory with practice. Place brand results from practice, but it should also serve it. Studies of Polish branding activities show that each authority chooses its own way to build a place brand due to the lack of a clear, simple, and practical model.

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BANKRUPTCY PREDICTION MODEL DEVELOPMENT AND ITS IMPLICATIONS ON FINANCIAL PERFORMANCE IN SLOVAKIA

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Abstract

Research purpose. Financial distress being a global phenomenon makes it impact firms in all sectors of the economy and predicting corporate bankruptcy has become a crucial issue in economics. At the beginning of the last century, the first studies aimed to predict corporate bankruptcy were published. In Slovakia, however, several prediction models were developed with a significant delay. The main aim of this paper is to develop a model for predicting bankruptcy based on the financial information of 3,783 Slovak enterprises operating in the manufacturing and construction sectors in 2020 and 2021.

Design / Methodology / Approach. A prediction model that uses the appropriate financial indicators as predictors may be developed using multiple discriminant analysis. Multiple discriminant analysis is currently used in prediction model development. In this case, financial health is assessed using several variables that are weighted in order to maximise the difference between the average value calculated in the group of prosperous and non-prosperous firms. When developing a bankruptcy prediction model based on multiple discriminant analysis, it is crucial to determine the independent variables used as primary financial health predictors.

Findings. Due to the discriminant analysis results, the corporate debt level of the monitored firms may be regarded as appropriate. Despite the fact that the model identified 215 firms in financial distress due to an insufficient debt level, 3,568 out of 3,783 Slovak enterprises operating in the manufacturing and construction sectors did not have any problems with financing their debts. The self-financing ratio was identified in the developed model as the variable with the highest accuracy. Based on the results, the developed model has an overall discriminant ability of 93% since bankruptcy prediction models require strong discriminating abilities to be used in practice.

Originality / Value / Practical implications. The principal contribution of the paper is its application of the latest available data, which could help in more accurate financial stability predictions for firms during the current difficult period. Additionally, this is a ground-breaking research study in Slovakia that models the financial health of enterprises in the post-pandemic period.

Keywords: Bankruptcy; Prediction model; Multiple discriminant analysis; Manufacturing and construction sector; Slovakia.

JEL codes: G17; G33

Introduction

Researchers from all over the world have become more interested in bankruptcy prediction during the past 50 years. The most accurate corporate failure prediction model has been the subject of several academic studies. When differentiating between prosperous and non-prosperous firms, authors frequently utilise the ultimate failure as the dividing line. However, financial distress has not yet been precisely defined. According to Dimitras et al. (1996), in previous and present studies of business failure prediction, researchers typically conduct their research by focusing on a few specific elements or stages of the business failure process based on their own expertise or interests. Whether a financial distress definition is applied in historical studies or a juridical definition of failure, such as bankruptcy, the criteria of failure are selected arbitrarily. Insolvency, default, and other related terms can be used to

describe a business failure (Pan, 2012). Typically, operations of the firm discontinue when it encounters a business failure. As a result, a reliable bankruptcy prediction model's development is crucial for current corporate firms. Numerous bankruptcy prediction models have flooded the literature since Altman published one of the most well-known bankruptcy prediction models in 1968. It refers not just to the increasing number of papers published but also to the variety of models used to predict business failure. In recent years, a growing variety of different predictive models have been used in an effort to develop a bankruptcy prediction model that is more accurate due to the advancement of statistical techniques and information technology (Shi & Li, 2019).

The main aim of this paper is to develop a model for predicting bankruptcy based on the financial information of 3,783 Slovak enterprises operating in the manufacturing and construction sectors in 2020 and 2021, which are both critical years in the context of the COVID-19 pandemic and its consequences on the financial performance of enterprises. Thus, it is essential to develop bankruptcy prediction models that consider how well businesses performed financially throughout the crisis. Manufacturing in Slovakia is a measure of the output of firms in the industrial sector of the economy. It is one of the most significant sectors, whose production accounts for around 85% of total production. However, the construction sector, which is among the most significant not only in the Slovak Republic but also globally, is another significant sector. A prediction model that uses the appropriate financial indicators as predictors may be developed using multiple discriminant analysis. The principal contribution of the paper is its application of the latest available data, which could help in more accurate financial stability predictions for firms during the current difficult period. Additionally, this is a ground-breaking research study in Slovakia that models the financial health of enterprises in the post-pandemic period, i.e., in a volatile economic context. Since company insolvencies have risen above pre-pandemic levels, this research highlights the importance of the creation of bankruptcy prediction models that take into account the financial performance of enterprises in these sectors.

The paper is divided into the following sections. The literature review, which focuses on literature, familiarises the reader with the main theoretical background of the bankruptcy prediction model developed in previous studies since interest in them is high. The research methodology provides an overview of the financial data that serve as the primary input for constructing a prediction model, focusing on describing the methodological steps of multiple discriminant analysis. The third part presents the results of the developed model based on different financial ratios as well as the discussion in which the main findings are discussed and compared to other relevant studies published worldwide. Not only the most crucial outputs but the limitations and future research on this topic are described at the end of this paper.

Literature review

The issue of business failure is not new, and the first research papers dealing with this topic appeared as early as the 1930s. Corporate failure was first addressed by Fitzpatrick (1932), who compared the development of indicators in solvent and insolvent firms. In the economic literature, the failure of enterprises is indicated by various terms, e. g. failure prediction, bankruptcy prediction, financial difficulties prediction, etc. The breakthrough period in corporate failure prediction was the second half of the last century. Beaver (1966) published the first paper devoted to future analysis and proved that financial indicators could be used even in anticipating the difficulties of business entities. The period in which this prediction model was created was specific primarily due to its static nature and simplicity in identifying the unique characteristics of firms in financial problems. Later, concurrently with the mathematical and statistical methods development, prediction models based on combinations of financial ratio indicators and other variables were developed. Such models account for the entirety of the financial situation of the firm in a single number, based on which it is possible to categorise a company as demonstrating or not a bankruptcy risk over a given period of time.

Research on the likelihood of financial distress after 1966 led to the development of new prediction models that could predict the probability of bankruptcy for each firm. Multivariate discrimination methods, which incorporate more factors in forecasting the enterprise development and indicate straightforward aspects of the corporate activity and to which weights of importance are assigned, were

quite popular in the early stages of development (Horvathova et al., 2021). Altman's model is considered the most famous model created using multivariate discriminant analysis. Traditional ratio analysis is criticised by Altman (1968) as being prone to misunderstanding and potentially misleading. In the same paper, Altman introduces a ground-breaking prediction model, known as the Z-score, based on multivariate discriminant analysis that may predict corporate bankruptcy. Numerous financial experts have modified the original model in the past. In order to improve the predictive ability, several later studies verified the original and modified Altman model and revised the weights of the indicators. Many researchers have developed general models based on multivariate discriminant analysis that can be used by any enterprise, such as Bilderbeek (1979), Blum (1974), Daniel (1968), Deakin (1972), Laitinen (1991), Lussier et al. (1996), and many others. However, because these models cannot predict how likely a firm is to fail, their explanatory power is partially limited. Similarly, most studies in the past have shown that the basic assumptions for the multiple discriminant analysis are often violated.

Considering these problems, newer methods involving logit and probit analysis were created over time, which do not require these assumptions to be met. Like multiple discriminant analysis, logit and probit analysis, which assign weights according to their importance, use multiple variables for prediction. Generally, logistic regression is among the linear models, the link function between a linear combination of predictors and the dependent variable. The best-known author of logit models is Ohlson (1980), who was the first to apply logit analysis in bankruptcy prediction. Using logit analysis, Zavgren (1985) also created his prediction model, which focused primarily on manufacturing companies when creating the model, and Wang (2004) developed a logit model for internet companies. Zmijewski (1984) applied probit regression when creating a prediction model. Performance, leverage, and financial liquidity are crucial factors contributing to the Zmijewski score. The probit model, unlike the logit model, assumes a normalised normal distribution of the random variable. Logit and probit models have the strength of having a straightforward interpretation of the findings since the output of the given prediction models is an estimate of the likelihood of corporate bankruptcy in the future. Many authors have conducted studies aimed at comparing prediction models with models developed in the past. Lennox (1999) focused on comparing models developed using multiple discriminant analysis and conditional probability models. Kordlar and Nikbakth (2011) compared multidimensional discriminant analysis, logit and probit analysis models. In their study, Araghi and Makvandi (2013) pointed out the difference between the accuracy of the logit and probit models, while Ingram and Frazier (1982) focused on comparing the logit model compared to the MDA model. The new data analysis methods and technological progress development have been reflected in the prediction models' development. New statistical methods do not require the fulfilment of any assumptions, which makes them easily applicable to any data. Thus, when developing prediction models nowadays, it is possible to encounter the application of new techniques, such as neural networks (Odom & Sharda, 1990), genetic algorithms (Varetto, 1998), fuzzy logic (Chen et al., 2009), or support vector machines (Min & Lee, 2005). Despite the existence of many alternative models that have been created using a variety of methodologies to obtain the best results, many authors claim that it is still challenging to estimate bankruptcy risk. Nowadays, there are several prediction models developed globally that describe the conditions of the business environment (Hu, 2020; Kliestik et al., 2020; Kovacova et al., 2019; Kou et al., 2021; Valaskova et al., 2020; Zhang et al., 2021; and many others).

The COVID-19 pandemic has altered the complementary roles of planning and analysis for enterprises, as stated by Toth et al. (2022), and the emphasis has shifted away from planning and toward assessing the macroenvironment and the company's financial position. The impact of the pandemic on the financial performance of enterprises has been enormous, and it has arisen interest in financial health diagnostics and new bankruptcy prediction modelling. Tomczak (2021) claims that the significance of evaluating a company's and a sector's financial health has expanded as a result of COVID-19. Managers, lenders, and investors must accurately assess the financial health of the firms they oversee. However, the pandemic has also accelerated the reconfiguration of the reciprocal links between states and markets (Amankwah-Amoah et al., 2021). The study by Boratynska (2021) focuses on how local economies were affected during the COVID-19 pandemic. When developing warning and recovery measures during the COVID-19 pandemic, business and restructuring professionals, financial institutions, and banking and public sectors' representatives may find it helpful to identify risk factors that determine the threat of corporate bankruptcy. Papik and Papikova (2023) highlight the importance of the bankruptcy model development

(re-evaluation), as the performance of enterprises may be significantly weaker during the crisis periods. The consequences of the pandemic have forced researchers and academicians to develop new default predictors for small and medium-sized enterprises (e.g. Ciampi et al., 2021; Mirza et al., 2023), proposing some innovative approaches to improve the predictive ability of models. Moreover, the changes in the macroeconomic and microeconomic environment require modifications and searching for more precise methods of financial health prediction (Brygala, 2022).

In the era of increasing internationalisation and globalisation, bankruptcy prediction is crucial not only for firms but for other interested groups. There are many prediction models that differ in the approaches and methods required for their development, the complexity of the input data, the number of variables, and the way the results are interpreted. However, in general, the existence of a large number of models is due to the fact that there is no universal use in different industries and economic conditions.

Research Methodology

The main aim of the paper is to develop a model for predicting the bankruptcy of Slovak enterprises operating in manufacturing (SK NACE 20, 21, 28, and 29) and construction sectors (SK NACE 41, 42, and 43) in 2020 and 2021 using appropriate quantitative methods. The production of firms as a part of the industrial sector of the Slovak economy is measured by manufacturing (Sujova et al., 2021). One of the most crucial industries in Slovakia, manufacturing contributes around 85% of the country's overall production. Construction is another crucial industry, ranking among the most significant not just in the Slovak Republic but worldwide (Spisakova et al., 2021). Generally, because it builds the infrastructure for cities, towns, and even countries, this industry is among the largest in the world. The coronavirus pandemic has lately impacted both of these significant businesses, severely affecting individual firms operating in the market.

For the prediction model development in Slovakia, the financial parameters from the ORBIS database, considered a source of business and financial data on more than 400 million private and public firms operating worldwide, were used as the input data. Financial data on 6,602 Slovak enterprises operating in the manufacturing and construction sectors in 2020 (for all independent variables, i.e., individual debt ratios) and 2021 (for the dependent variable, i.e., the corporate prosperity measured by the legislatively established limit value of the equity-to-debt ratio) were included in the dataset used to create the model. The firms that did not provide all the input data necessary for the crucial mathematical relationships determination during the monitored period were excluded from the created dataset since not all enterprises were suitable for the practical evaluation of financial ratios.

After the final adjustments (elimination of not available and outlying values), the final dataset comprises 3,783 enterprises; 2,592 operating in the manufacturing and 1,191 in the construction sector (982 small, 2,128 medium-sized and 673 large enterprises). Considering the legal form of enterprises, 88.76 % of the dataset are private limited companies, 10.26 % are public limited companies, and 0.98 % are companies of other legal forms. As the length of operation also plays an important role in the context of corporate competitiveness, financial stability and health, the dataset is formed of 34.13 % of enterprises established before the year 2000 and 65.87 % of enterprises were incorporated after the year 2000 (Bozkurt and Kaya, 2023). The descriptive statistics of variables entering the financial ratios indicators are summarised in Table 1.

Table 1. Descriptive statistics of crucial financial data (in thousands. euros)

SK	TOAS	SHFD	CULI	NCLI	EBIT
mean [€]	9,824.10	3,505.82	3,635.53	1,516.58	471.61
median [€]	1,540.79	477.61	640.00	119.48	56.29
st. dev. [€]	61,333.45	30,664.25	21,376.58	17,003.07	5,504.84
CV [%]	624.42	874.28	589.67	1,121.14	1,179.06
SK	**DEBT**	**P/L**	**INTE**	**CF**	**DEPR**
mean [€]	1,762.12	310.46	56.92	790.48	480.02

median [€]	261.95	31.58	7.37	110.68	79.10
st. dev. [€]	14,578.48	4,185.09	801.14	7,403.17	3,218.08
CV [%]	827.03	1,368.88	1,408.61	2,039.29	670.41

Note: TOAS total assets, SHFD shareholders' funds, CULI current liabilities, NCLI non-current liabilities, DEBT trade receivables, P/L net income, INTE interest paid, CF cash flow, DEPR depreciation and amortisation

Subsequently, the multiple discriminant analysis was used for the prediction model development, and its objective is to model one quantitative variable (i.e., a dependent variable) as a linear combination of other variables (i.e., independent variables). It is possible to use discriminant analysis if the classifications of the groups in the dependent variable (Y) are affected by at least one of the independent variables (X) while the following hypotheses are proposed:

H0: The dependent variable (Y) does not depend on any independent variables (Xi's).

H1: The dependent variable (Y) depends on at least one of the independent variables (Xi's).

The multivariate discriminant analysis was performed in these methodological steps: i) the data is thought to be roughly multivariate normally distributed since the sample size of the examined variables is big enough (multivariate central limit theorem); ii) by employing group averages and the outcomes of the ANOVA, the discriminant analysis may forecast group membership and detect any relevant differences between groups on any of the independent variables. The variable is probably statistically insignificant if the p-value exceeds the selected significance level (0.05); iii) the assumption of this method that the groups' variance-covariance matrices are equal is tested by the Box's M test; iv) the relationship between the groups in the dependent variable and the discriminant function is assessed by the canonical correlation measures (Eigenvalue and Wilk's lambda); v) the identification of the best discriminants of corporate financial health prosperity is realised by the values of the standardised canonical discriminant function and correlation coefficients; vi) the formation of the discriminant model, Z score equation, using the unstandardised discriminant function coefficient.

Generally, the financial health of a firm is evaluated using several ratios that are weighted to maximise the difference between the average value determined in the group of prosperous and non-prosperous enterprises. Based on the ratios mentioned by top researchers (Bellovary et al., 2007; Dimitras et al., 1996; Gregova et al., 2020; Kliestik et al., 2020; Kovacova et al., 2019), it is necessary to determine the independent variables as the primary predictors of financial health. The selected debt ratios and the relationships needed for the calculation are listed in Table 2.

Table 2. Summarised formulas of debt indicators (Source: Valaskova et al., 2021)

	Ratio	**Algorithm**
X01	Total indebtedness ratio	Current and non-current liabilities to total assets
X02	Self-financing ratio	Shareholders' funds to total assets
X03	Current indebtedness ratio	Current liabilities to total assets
X04	Non-current indebtedness ratio	Non-current liabilities to total assets
X05	Debt-to-equity ratio	Current and non-current liabilities to shareholders' funds
X06	Interest burden ratio	Interests paid to earnings before interest and taxes
X07	Interest coverage ratio	Earnings before interest and taxes to interests paid
X08	Debt-to-cash-flow ratio	Current and non-current liabilities to cash flow
X09	Equity leverage ratio	Total assets to shareholders funds
X10	Financial independence ratio	Shareholders' funds to current and non-current liabilities
X11	Non-current assets coverage ratio	Shareholders' fund and non-current liabilities to non-current assets
X12	Insolvency ratio	Current and non-current liabilities to receivables

The individual enterprises used to create a discriminatory model had to be divided into two relevant groups. The first group consisted of enterprises with the appropriate level of debt without significant financial difficulties, whereas the second group included more indebted firms with crucial financial distress. The discriminatory model was developed using the statute of the company in crisis, which states that if the equity-to-debt ratio, which symbolises the deteriorating degree of the financial independence of the enterprise, is less than 0.08, a firm is in a crisis (Kliestik et al., 2020; Gregova et al., 2020). The level of debt is inappropriately high, and the firm is in financial difficulties if the equity-to-debt ratio falls below this level. However, if this ratio exceeds the limit, the enterprise is not having significant financial problems. IBM SPSS Statistics software was used to perform the calculations and model development.

Research results

There are two possible future development strategies for the dependent variable: non-prosperous enterprise (marked by 0) and prosperous enterprise (marked by 1). The final dataset includes financial information on 3,783 Slovak enterprises classified into 3,568 prosperous enterprises and 215 non-prosperous enterprises.

Since multivariate discriminant analysis may be used to predict group membership, it is required to examine group averages and data from the ANOVA results to determine whether any significant differences exist between groups for any independent variables. According to the tests of equality of group means table (Table 3), it is not worthwhile continuing the investigation if there are no substantial group differences.

Table 3. Test of equality of group means (Source: own elaboration)

Tests of Equality of Group Means					
	Wilks' Lambda	**Sig.**		**Wilks' Lambda**	**Sig.**
X01_2020	0.985	0.000	X08_2020	1.000	0.645
X02_2020	0.959	0.000	X09_2020	1.000	0.648
X03_2020	0.981	0.000	X10_2020	0.989	0.000
X04_2020	0.997	0.001	X11_2020	0.999	0.024
X05_2020	1.000	0.613	X12_2020	0.999	0.024
X06_2020	1.000	0.957	size=large	0.995	0.000
X07_2020	1.000	0.662	size=medium-sized	0.999	0.024

Based on the results in the table, it can be concluded that all variables considered as statistical indicators may be used as the suitable discriminator, except for X05, X06, X07, X08 and X09.

The variance-covariance matrices are assumed to be identical in the multivariate discriminant analysis as a fundamental assumption. Box's M evaluates the null hypothesis that there is no difference in the covariance matrices among the dependent groups. Table 4 summarises the log determinants results. Although the log determinants of the variance-covariance matrices of each group differ, they should be equal.

Table 4. Log determinants table (Source: own elaboration)

Log Determinants		
Y_2021	**Rank**	**Log Determinant**
0	7	16.802
1	7	9.030
Pooled within-groups	7	10.987
The ranks and natural logarithms of determinants printed are those of the group covariance matrices.		

When using Box's M (Table 5) to test for similarity and the existence of significant differences, a non-significant M is considered. In the SPSS calculation, the presumption of different covariance matrices was used since Box's M cannot be regarded as identical in this circumstance.

Table 5. Box's M test results table (Source: own elaboration)

Test Results		
Box's M		5,734.855
F	Approx.	202.443
	df1	28
	df2	470,660.199
	Sig.	0.000
Tests null hypothesis of equal population covariance matrices.		

The multiple correlation between the predictors and the discriminant function is the canonical correlation, which provides a metric for the overall model fit and is considered the amount of variance explained (R^2). Table 6 summarises the canonical correlation results mutually with Wilk's Lambda, which emphasises the significance of the discriminant function. Despite the relatively low value of canonical correlation for Slovak enterprises (0.362), the model suggests a statistically significant canonical correlation.

Table 6. Eigenvalues and Wilk's Lambda table (Source: own elaboration)

Eigenvalues				
Function	**Eigenvalue**	**% of Variance**	**Cumulative %**	**Canonical Correlation**
1	0.151	100.0	100.0	0.362
Wilk's Lambda				
Test of Function(s)	**Wilks' Lambda**	**Chi-square**	**df**	**Sig.**
1	0.869	530.555	7	0.000

The discriminant coefficients (or weights) are used similarly to multiple regression. The relevance of each predictor (the sign reflects the direction of the relationship) is summarised in Table 7, much like what the multiple regression's standardised regression coefficients (beta's) accomplished. The self-financing ratio is one of the most crucial determinants of allocation to enterprises with or without financial difficulties with the best discriminating ability. Slightly worse discriminators are the variables' current indebtedness ratio and financial independence ratio. The developed prediction model likewise heavily weights indicators that relate to the firm size.

Table 7. Standardised canonical discriminant function coefficients table (Source: own elaboration)

Standardised Canonical Discriminant Function Coefficients	
	Function
	1
X01_2020	0.191
X02_2020	-0.890
X03_2020	0.597
X10_2020	0.614
X12_2020	0.098
size=large	-0.276
size=medium-sized	-0.253

The canonical structure matrix shows the correlations between each variable in the model and the discriminant functions. As an additional method for depicting the relative importance of the predictors, Table 8 provides the values of the correlation coefficients between the various independent variables and the discrimination function. The self-financing ratio is the best discriminator even when considering correlation coefficients because this ratio and the discrimination function have the highest correlation. The current indebtedness ratio and the total indebtedness ratio can be considered as other statistically significant variables. The threshold between significant and insignificant variables is typically set at 0.3, while these mentioned variables reached this value.

The non-standard coefficients of the canonical discriminant function can be used to determine the discriminant score of the prediction model for each Slovak enterprise operating in the manufacturing and construction sectors.

$$y_{SK} = 0.165 + 0.123X_1 - 1.130X_2 + 0.642X_3 + 0.232X_{10} - 0.723size_{large} - 0.511size_{medium-sized} \quad (1)$$

The discriminant function coefficients indicate how each variable contributes prejudicially to the discriminant function, which corrects all other variables in the equation. The categorical variables of size=large and size=medium-sized are introduced into the discriminant function analysis using dummy variables.

Table 8. Structure matrix table (Source: own elaboration)

Structure Matrix			
	Function		**Function**
	1		**1**
X01_2020	0.317	X08_2020[a]	0.038
X02_2020	-0.531	X09_2020[a]	0.003
X03_2020	0.359	X10_2020	0.277
X04_2020[a]	0.145	X11_2020[a]	-0.016
X05_2020[a]	0.002	X12_2020[a]	0.095
X06_2020[a]	0.010	size=large	-0.179
X07_2020[a]	-0.024	size=medium-sized	-0.095
They pooled within-group correlations between discriminating variables and standardised canonical discriminant functions. Variables are ordered by the absolute size of correlation within the function.			
This variable was not used in the analysis.			

Because SPSS utilises the model constant to perform an intended modification for centroid calculations, the weighted average of the centroid (weighted by the number of firms in the individual groups) is zero. The Z-score value may be compared to zero in this case; a positive number indicates a less prosperous organisation, whereas a negative number indicates a financially sound business. However, having enough discriminating abilities is required for the prediction model to be used in practice. Based on the classification table (Table 9), it is evident that 93% of the enterprises were correctly classified into one of the two considered groups.

Table 9. Classification results table (Source: own elaboration)

Classification Results					
			Predicted Group Membership		
		Y_2021	0	1	Total
Original	Count	0	121	94	215

		1	172	3,396	3,568
	%	0	56.3	43.7	100.0
		1	4.8	95.2	100.0
For SK, 93.0% of original grouped cases were correctly classified.					

Despite several models that have been developed using various techniques to obtain the best outcomes, many authors contend that it is still challenging to predict bankruptcy risk. Many prediction models that describe the aspects of the business environment were developed with a significant time gap in Slovakia as well.

In Slovakia, the development of a prediction model was initially addressed by Chrastinova (1998) and Gurcik (2002), who used multiple discriminant analysis to create a model for agricultural enterprises. To evaluate the future corporate prosperity of non-financial small and medium-sized enterprises, Hurtosova (2009) used logistic regression for the first time in the Slovak national context. An overview of bankruptcy prediction research is provided by Delina and Packova (2013), which chose three bankruptcy prediction models for the verification of data from Slovak enterprises. The authors applied regression analysis to develop a modified model with higher predictive performance than the original models. Based on data mining validation methods, they have proposed an approach to validate the performance of chosen bankruptcy prediction models. Sofrankova (2014) also concentrated on the description of selected prediction models in her study, which may detect early deterioration of the firm's financial situation. Kubicova and Faltus (2014) tested the resolution ability of indicators that included income tax components as well as the predictive ability of the bankruptcy prediction model using data from Slovak enterprises. Mihalovic (2016) focused on the bankruptcy prediction model development based on two various statistical methods. These include both the logistic regression function and the multiple discriminant function because financial ratios may be the best way for enterprises to identify between prosperous and non-prosperous firms. Adamko and Svabova (2016) studied the predictive ability of the global Altman's model using a dataset of Slovak enterprises. In order to create a model that is superior to those already in use in the Slovak business environment, Gavurova et al. (2017) evaluated the effect of including trend variables on model development and using decision trees in addition to discriminant analysis.

Consequently, a model with a prediction accuracy close to 85% was suggested using decision trees. In order to develop models for predicting bankruptcy in Slovak firms, Kovacova and Kliestik (2017) applied the logit and probit techniques. The findings indicate that the logit-based model performs somewhat better than the classification accuracy of the probit-based model. However, many other authors also dealt with the issue of creating prediction models in the conditions of Slovakia, such as Boda and Uradnicek (2019), Kliestik et al. (2020), Kovacova et al. (2019), Svabova et al. (2020), Valaskova et al. (2020), Valaskova et al. (2018), and many others.

When comparing the model developed for predicting bankruptcy for Slovak enterprises operating in the manufacturing and construction sectors in 2020 and 2021, financial indicators were used with a focus on monitoring the level of indebtedness, while the self-financing ratio, current indebtedness ratio, and financial independence ratio can be considered the most important predictors. Valaskova et al. (2018) determined the financial predictors that are crucial to the process of quantifying corporate prosperity and detecting financial threats according to the results of the multiple linear regression analysis. The final notation of the prosperity quantification model included six variables, with the current liabilities to total assets ratio being one of the most important indicators of financial prosperity. Boda and Uradnicek (2019) critically validated the usefulness of three prediction models that are used or were developed for predicting the financial distress of Slovak agricultural enterprises and identified three indicators: gross return on revenue, debt ratio, and days payables outstanding, which are associated with liquidity and solvency through revenue profitability, capital structure, and cash management discipline, respectively. Kovacova et al. (2019) presented in-depth insight and analysis of bankruptcy prediction models developed in the Visegrad Group countries, and based on the results, total liabilities to total assets and shareholders' funds to total assets are the most often regarded significant predictors in Slovakia. Kliestik

et al. (2020) also concentrated on an in-depth mutual comparison of the developed prediction models in the conditions of Visegrad Group countries, pointing out that the most commonly used debt indicators are total liabilities to total assets, shareholders' funds to total assets, cash flow to total liabilities, and shareholders' funds to total liabilities. As a result of the previous, major indicators of indebtedness were regarded significant discriminants of financial difficulties in the developed prediction models even before the outbreak of the COVID-19 pandemic. The use of the ratio of current liabilities to total assets in financial stability modelling has a positive perspective because this ratio is related to bankruptcy, indicating a greater probability of financial failure achieving a higher value of the ratio (Valaskova et al., 2020). Not only current liabilities to total assets but also shareholders' funds to total assets and shareholders' funds to total liabilities have a considerable impact on predicting the financial distress of firms. Ptak-Chmielewska (2021) checked and validated the effect of the financial crisis on bankruptcy prediction. The results showed that current liquidity, gross margin ratio, operating profitability of sales, and asset turnover are the most important explanatory factors in bankruptcy prediction. As declared by Matejic et al. (2022), compared to the pre-COVID-19 period, the chance of bankruptcy will continue to be high, making the remaining businesses more susceptible to future exogenous developments. The specific interest in the manufacturing sector is presented in the research by Pacheco et al. (2022), who also affirmed that estimates using financial information closest to the bankruptcy period could enhance the predictive power of the model. However, given these new circumstances into consideration, the present bankruptcy prediction models should be revalidated and adjusted to current market conditions. The significance of research outcomes for the academic community, financial institutions, stakeholders, and other interested parties is therefore highlighted, and the added value of the study outputs can be presented. Identifying key financial health predictors in a specific sector of the economy may be, however, perceived as a relevant contribution to the existing theoretical framework. A key element of strategic management is the ability of managers to foresee future events and business performance and the use of bankruptcy predictors as a basis for the decision-making process. Thus, predicting bankruptcy is more important than ever because it is one of the biggest threats to a company's existence.

Conclusions

The effectiveness of each model for predicting corporate bankruptcy depends on the data used as input and the processing method applied. However, these models are built based on empirical data from a particular economy. Only the economy from which empirical data was gathered during model development is typically able to use it successfully. Furthermore, it is hard to treat any one model as immutable or stable since its prediction ability may deteriorate due to changes in economic conditions in the country.

The main aim of this paper was to develop a model for predicting bankruptcy based on the financial information of 3,783 Slovak enterprises operating in the manufacturing and construction sectors in 2020 and 2021. Due to the discriminant analysis results, the corporate debt level of the monitored firms may be regarded as optimum. While the model identified 215 firms in financial distress due to an unacceptable level of debt, 3,568 out of 3,783 Slovak enterprises operating in the manufacturing and construction sectors did not have any problems with financing their obligations. The self-financing ratio, one of the most significant predictors of allocation to the group of firms with or without financial difficulties, stood up as the variable in the developed model with the best discriminating power. However, the current indebtedness ratio, the total indebtedness ratio, and the financial independence ratio can be considered other statistically significant variables. Generally, the model requires sufficient discriminating abilities to be applied in practice. The classification matrix, also known as the confusion matrix, provides this output by identifying the percentage of existing data points out that the model is correctly classified. It is evident from the results that the developed model has an overall discriminant ability higher than 93%.

The following limitation needs to be highlighted despite the contribution of this paper to the extant literature and its practical implications for the accurate prediction of future financial stability and development. The study has several limitations, such as the findings of the multiple discriminant analysis may not be comprehended, as well as those obtained using other techniques, such as logistic regression

or neural networks. Future research should involve more investigation to determine which method provides more accurate and precise outputs when predicting corporate financial health.

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IMPLEMENTATION STRATEGIES FOR SUSTAINABLE VEHICLE FLEET MANAGEMENT

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Abstract

Research purpose. Against the backdrop of climate change, pressure is growing in the transport sector to reduce CO_2 emissions. Numerous companies are therefore setting specific targets to curb the CO_2 emissions of their own vehicle fleets. As a rule, this requires the replacement of combustion vehicles by vehicles with alternative drives. In addition to the selection of suitable technologies, economic aspects play a prominent role in this transformation process. Based on a practical case study, potential implementation strategies for achieving a specific CO_2 target are to be examined for a parcel service provider. The focus here is on a fleet of diesel combustion vehicles from the small van class with a permissible total weight of fewer than 3.5 tons, which are to be replaced by vehicles with electric drive (BEV) in order to achieve a specific CO_2-savings target. The research objective can be easily extended if one considers, on the one hand, that climate protection cannot be limited to individual countries but has to take place on a global level and, on the other hand, that sustainable strategic planning of vehicle fleets also concerns other vehicle segments, such as company cars for individual transport or trucks with higher permissible gross weights.

Design / Methodology / Approach. In the first step, framework conditions and criteria are defined that are needed for an evaluation of the implementation strategies. In the second step, a practical case study is constructed. In the third step, different scenarios and strategies for the conversion of the vehicle fleet are designed in order to achieve the set CO_2-emission targets. In the last step, the economic and ecological effects of the different strategies and scenarios are measured and analysed with the help of the calculation tool "DIPO-tool", which was developed at the Ludwigshafen University of Business and Society LUBS for research and teaching purposes. To evaluate sustainability, in addition to the established metrics for Tank-to-Wheel (TtW) and Well-to-Wheel (WtW), a holistic life cycle approach is implemented that takes into account emissions during vehicle production.

Findings. Against the backdrop of expected further technological development and numerous parameters with a considerable leverage effect on economic and ecological evaluation criteria, it seems advisable from the point of view of sustainability to use alternative drives as soon as possible. From the point of view of economic efficiency, a more differentiated picture emerges depending on the framework conditions, e.g., subsidies.

Originality / Value / Practical implications. The originality of the approach lies in the application of a practical case study and the attempt to reduce the complexity of the decision problem by using an Excel-based calculation tool. The value of the study lies in the realisation that, due to the complexity, a simple optimisation approach does not seem viable but rather the evaluation and analysis of different scenarios. The practical impact can be described in the sense that the used DIPO-tool can provide effective support for sustainable implementation strategies for vehicle fleets.

Keywords: Case study; CO_2-management; Corporate Social Reporting Directive (CSRD); Fleet management; Sustainable mobility

JEL codes: R40; Q56

Introduction

Against the backdrop of climate change and increasingly concrete political measures such as the EU ban on new combustion engine cars from 2035, there are more and more companies that are defining concrete targets for reducing CO_2 emissions. To this end, numerous studies deal with the topics of sustainable transportation modalities and alternative drives. A joint study by HERE Technologies, DHL and the Bundesvereinigung Logistik e. V. examines the areas of CO_2 accounting, alternative drives and actions for sustainability in B2B-transport logistics with the project "Sustainability in transport logistics - fleets and alternative traction" (BVL, n.d.). The question is which departments influence electric vehicles procurement decisions in small and medium-sized enterprises (SME), in large-scale enterprises (LSE) and in public organisations (PO), and what are the differences compared to these departments' influences on internal combustion engine vehicles (ICEV) procurement decisions is the focus of a study conducted by Karlsruhe Service Research Institute (KSRI) at the Karlsruhe Institute of Technology (Guth et al., 2017). Another research direction is decision support through simulations. For this purpose, a study provides results based on the evaluation of 81 empirical mobility patterns of commercial fleets (Schmidt et al., 2021).

The focus here is particularly on companies that provide end-customer-related services, as consumer awareness of climate-friendly products, services, and processes is steadily increasing. These companies include parcel service providers, which have grown steadily in recent years as a result of e-commerce and have been given an additional boost by the corona pandemic.

The research objective of this paper is to analyse the effect of different procurement strategies for vehicles with alternative drives in terms of economic efficiency and sustainability. The research hypothesis is that it is possible to achieve defined climate protection goals and, at the same time, achieve an economic advantage through the selection of a specific procurement strategy. Methodologically, the calculation tool DIPO-tool is used to calculate the economic efficiency and sustainability of vehicles (Bongard et al., 2022). On the one hand, the results indicate that it is indeed possible to reconcile sustainability and economic efficiency goals. However, on the other hand, it also becomes clear that the results depend on a large number of parameters whose future development will be increasingly difficult to predict.

Literature Review

In 2021 alone, around 4.42 billion parcels were transported to recipients throughout Germany. This represents an increase of just under 8% compared with the previous year (Lehmann, 2021a; Lehmann, 2021b). If we look at the German top 5 parcel services based on their parcel volume (DHL [48%], Hermes [16%], UPS [12%], DPD [10%], and GLS [7%]), they have a combined market share of 93% (Meitinger, 2021). The German courier, express, and parcel services industry is one of the top performers in Europe, recording revenues of €18.9 billion in 2020. The visible increase in demand in online retail is forcing parcel service providers to adapt quickly to new circumstances (Lehmann, 2021a). There are also additional challenges, such as mandatory delivery times in the form of same-day delivery or overnight delivery (Bundesverband Paket und Expresslogistik e. V., 2021). Experts predict that the online trend will continue after the Corona pandemic, resulting in a further increase in parcel orders (FAZ, 2021; Schlautmann, 2021). Particularly on the last mile of the delivery process, there is the possibility of using CO_2-neutral delivery vehicles in the form of electric vehicles (BMWK, 2023a; DHL, 2023).

The reasons for this are the alternatives to internal combustion vehicles that are now available on the market and which, in terms of their intended use and general economic conditions, appear to be fundamentally suitable for completing emission-free tours on the last mile.

In the present work, the target of the market leader DHL that 60% of the vehicle fleet for the "last mile" should consist of fully electric vehicles by 2030 (BVL, n.d.) is taken as a basis. For the purposes of the paper, this target is formulated as a saving of direct CO_2 emissions in operation, so-called Tank-to-Wheel emissions (TtW), of 60% in 2030 compared to the base year 2022 for the fleet of the case study.

Numerous other parcel service providers (Imarc, 2023) are also looking at strategies to reduce emissions from their fleet of vehicles. Aramex has reduced fleet emissions by 20% from 2016 to 2020 and plans a long-term strategy to convert its entire fleet into electric vehicles where possible (Aramex, 2020). FedEx has even more ambitious goals. From 2025, FedEx wants to procure half of its delivery vehicles to be electric and 100% from 2030 (Werwitzke, 2021). UPS has a strategic goal of achieving CO_2 neutrality by 2050. There are no specific targets for electric vehicles, only the announcement that electric vehicles are part of the plans to improve environmental sustainability through a fleet of alternative fuel vehicles and advanced technology (FedEx, 2022).

The aim of this work is to use a case study to evaluate various strategies for achieving objectives with regard to economic and ecological criteria and, in particular, to take account of the framework conditions that are to be assumed. Against the backdrop of an increasingly unstable and uncertain corporate environment, a scenario-oriented approach is thus pursued that counters the mainstream of predictability of optimal solutions (Schwenker & Schencking, 2022).

The research hypothesis is that the vehicle fleet of a parcel service provider will be operated with 60% less CO_2 emissions in 2030 and that it is possible to determine an economically optimal procurement strategy for this. Different acquisition strategies for electric vehicles that are suitable for the intended use of a parcel service provider as well as different scenarios for important parameters, are to be investigated. Not only the target savings in 2030 are considered, but also the total CO_2 emissions over time until 2030.

The decision criteria are calculated using the DIPO tool, a professional solution for the holistic consideration of the economic efficiency and sustainability of vehicles in the field of fleet management and control. It consists of various Excel spreadsheets and was designed for teaching and research purposes at the Ludwigshafen University of Applied Sciences (Bongard et al., 2022; Bongard & Schröder, 2022) and continuously developed. In the expansion stage used, the calculation of LCA values, in particular, was advanced.

Due to the fact that individual countries cannot stop global warming caused by greenhouse gas emissions on their own, many countries have joined forces and agreed on common climate protection targets. The main goal is to greatly reduce greenhouse gases that are harmful to the climate, such as carbon dioxide, methane and nitrous oxide. The EU has committed itself to complying with the Kyoto Protocol adopted in 2005 for climate protection (BPB, 2020; UBA, 2013). The greenhouse gases emitted were to be reduced by 5.2% between the years 2008 and 2012 compared to the base year 1990 (UBA, 2013). The EU generated greenhouse gas savings of 8% during this period, exceeding this target. In the second commitment period between the years 2013 and 2020, the European Union set itself the goal of saving a further 20% of greenhouse gas emissions. This emissions reduction target was again significantly exceeded (EC, 2021).

The transport sector is receiving special attention. This sector has not yet been able to achieve the hoped-for reduction targets. In 2018, road freight transport emitted a total of 888 million tons of CO_2 and was thus responsible for around a quarter of all CO_2 emissions in the European Union (Eisenkopf & Knorr, 2021). Therefore, with the "Fit for 55" project, the EU wants to create new and, above all, more transparent specifications with regard to renewable energies and more effective energy efficiency. There should also be full integration into the emissions trading system (Schiffer, 2021). To this end, CO_2 certificates are to be traded in the transport sector from 2026 (Bundesregierung, 2021). Electromobility is the focus for achieving the climate targets. Increased use is to be made of climate-neutral means of transport with the appropriate infrastructure and, at the same time, an improvement in the economy is to be achieved as a result of the COVID-19 pandemic (Eisenkopf & Knorr, 2021; EU, 2022; Schiffer, 2021).

The German government has anchored future greenhouse gas reduction targets in the Federal Climate Protection Act. By 2030, 65% fewer emissions are to be emitted compared to the base year 1990. Then, 15 years later, no more greenhouse gases are to be emitted (BMWK, 2023b). To combat greenhouse gas (GHG) emissions, the federal government is promoting electromobility until the end of 2025. To this end, nearly two billion euros in innovation premiums for the purchase of electric vehicles will be passed on to buyers. In addition, the charging infrastructure for electric vehicles is to be expanded (BMWK,

2023a). The Federal Ministry of Economics and Climate Protection's subsidy program stipulated that purely battery electric vehicles can be subsidised up to a maximum net base list price of €65,000 with the condition that the vehicle model is listed on the list of eligible vehicles. The total subsidy for the purchase of a battery electric vehicle consists of three blocks (these are applied in equal parts): Environmental bonus from the state, innovation premium (until the end of 2022) and environmental bonus from the vehicle manufacturer (Energy Agency, 2023). Vehicles with an acquisition price of up to €40,000 will receive a total subsidy of €9,000 (all three parts to be applied), while vehicles with an acquisition price of over €40,000 and up to €65,000 will receive a total subsidy of €7,500 (all three parts to be applied) (BAFA, 2023). From 2023, only battery-electric means of transport that make a positive contribution to climate protection will be subsidised (Energieagentur, 2023).

As a result of the Russian Federation's war of aggression on Ukraine, Germany's energy dependence on Russia is becoming clearly noticeable. To compensate for the resulting disadvantages, the expansion of renewable energies is to be accelerated (BMWK, 2022). This will lead to electromobility experiencing a more robust upswing in the future.

Criteria for the economic efficiency of vehicles mainly concern the acquisition costs minus any subsidies and the residual value of a vehicle to be achieved, as well as running costs such as energy consumption or maintenance and repair costs. Numerous sources are available for a comprehensive consideration of economic efficiency criteria (Bertram & Bongard, 2014; Hacker et al., 2015; Wietschel et al., 2019).

When considering ecological sustainability, the literature uses generic terms such as life cycle assessment (LCA) or environmental accounting. These terms holistically encompass the phases of production, use and recycling or disposal of products (Koch et al., 2020). Other terms commonly used in this context are "Well-to-Tank (WtT)", which covers greenhouse gas emissions on the production side from the source to the vehicle tank, and "Tank-to-Wheel (TtW)", which stands for a purely consumption-based view. The term Well-to-Wheel (WtW) is the sum of energy and vehicle processes, i.e., indirect WtT- and direct TtW-emissions (Schmied & Mottschall, 2014). For this purpose, the terms "Cradle-To-Cradle" and "Cradle-To-Grave" refer to the entire life cycle, which in the case of Cradle-To-Cradle aims towards reuse (recycling) and in the case of Cradle-To-Grave towards disposal. The basis for the calculations is conversion factors as CO_2-equivalents (Schmied & Mottschall, 2014.). The conversion factors each refer to one type of energy and are used as TtW-CO_2e factor for the calculation of direct TtW-emissions, as WtT-CO_2e factor addition as a surcharge for the upstream chain, and as WtW-CO_2e-factor for the calculation of WtW-emissions. In this work, the CO_2-emissions TtW, WtW and an LCA surcharge for the vehicle manufacturing process are used as the decision criterion for assessing sustainability.

Research Methodology/Case Study

The supply chain of parcel service providers is characterised by the operation of regional delivery depots downstream to the end customer. The delivery depot in the case study has ten diesel-powered internal combustion vehicles and serves a region with a population of approximately 11,000. The depot has an area of 200 square meters. Parcel deliveries are made to both urban and rural areas. In the latter case, deliveries are made in a "compound", i.e., parcels and letters are delivered together. Deliveries are made in ten districts, each of which has a dedicated vehicle. Up to 150 parcels are delivered per district every working day. The route lengths vary from a few kilometres for districts close to the depot to 50 km for the most distant district. The average distance driven per vehicle is assumed to be 30 km/day. Since deliveries are made six days a week, this results in 312 operating days per year. Taking holidays into account, 302 operating days are assumed. Multiplying the average distance per vehicle by the 302 operating days results in a total mileage per vehicle of 9,060 km/year. This mileage serves as the reference value for further calculations. For the purpose of this work, peak loads, which can occur especially before holidays such as Easter or Christmas, are not considered. In 2022, the fleet will consist of ten Volkswagen T6 vehicles built in 2021 (Fig. 1). To achieve the set goals, the acquisition of a fully electric alternative in the form of an Opel Vivaro e-Cargo L is being considered (Fig. 2).

Fig. 1. Volkswagen T6 2.0 TDI BMT (Source: https://www.alle-lkw.de/transporter/kastenwagen/volkswagen-t6-2-0-tdi-transporter-navi-pdc-klima-a6929803.html)

Fig. 2. Opel Vivaro-e Cargo L (Source: https://www.opel.de/nutzfahrzeuge/vivaro/vivaro-e/uebersicht.html)

Both vehicles are fit for the purpose. The economic life is set at six years for depreciation purposes for both vehicles. The following assumptions are made for the calculation of the TCO (Table 1):

Table 1. TCO parameters for the base year 2022 (Source: author's compilation)

Cost components	Parameter name	Parameter unit	VW T6 (ICE)	Opel Vivaro (BEV)
Vehicle				
Net list price	P_list_price	Euro	€29,270	€37,490
Fuels/Energy				
Fuel consumption Diesel	P_fuel_consumption	Litre/100 km	10.147	
Power consumption	P_electricity_consumption	kWh/100 km		31.855
Other Costs				
Vehicle tax	P_veh_tax	Euro/p.a.	€160.00	€0.00
Vehicle insurance	P_veh_insurance	Euro/p.a.	€828.00	€596.43
Maintenance, service and care & Administration	P_veh_maintenance_repair_care	Euro/p.a.	€656.88	€457.66

The manufacturer's fuel consumption data was adjusted for practical calculations (Hacker et al., 2015). Due to the numerous start and stop operations of the delivery vehicles, an additional consumption of 39% is assumed for the combustion vehicle and of 15% for the BEV.

The data are processed with the DIPO tool (Bongard et al., 2022). For reasons of clarity, a detailed presentation of the calculations is omitted. The structure of the research design is outlined in the following figure (Fig. 3). The DIPO tool uses the TCO data of the two vehicles for calculating the cost and CO_2 values of the vehicles, taking into account one of the three scenarios in each case. These values are then transferred to a Strategy calculation worksheet, in which the relevant procurement strategies are mapped.

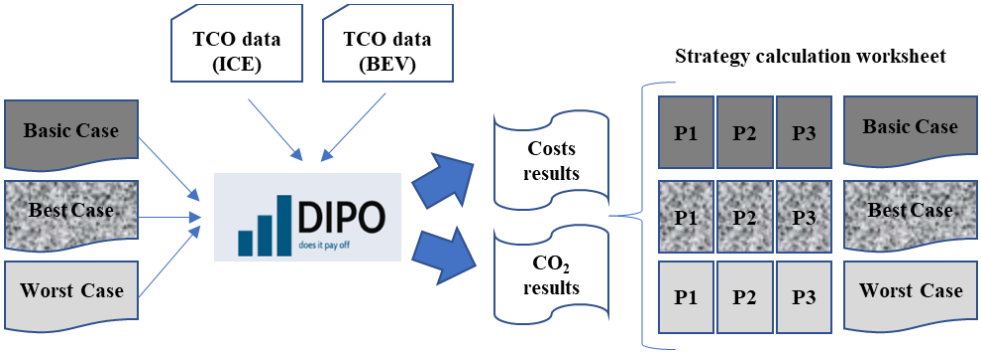

Fig. 3. Research design scheme (Source: author's compilation)

Target value calculation

To calculate the target value for fleet emissions in 2030, the amount of 24.5 tCO_2 is calculated for the ten diesel vehicles in the reference year 2022. This results in a target value of CO_2 emissions of the vehicle fleet in 2030 of 9.8 tCO_2. Since the emission target only refers to TtW emissions, the constellation of the vehicle fleet in the target year is easy to determine. 60% of the vehicle fleet, i.e., six vehicles, must be electrically powered. Three different strategies are to be pursued to achieve this target value in 2030.

Procurement Strategy 1 (P1)

In this strategy, the intention is to acquire alternative vehicles with the electric drive as quickly as possible in order to benefit from the subsidies that are granted in Germany. In the base year 2022, the premium for the BEV is €9,000. The number of vehicles purchased should be six. This will reduce the capital required for the acquisition, and, on the other hand, the company will continue to have proven combustion technology at its disposal.

Procurement Strategy 2 (P2)

This strategy involves purchasing six alternative vehicles as late as possible in 2029. This means that the subsidies are foregone, but capital is conserved, and there is also a chance that the purchase prices for BEVs will fall in the future as a result of technological developments.

Procurement Strategy 3 (P3)

With this strategy, the acquisition of the six alternative vehicles is spread over several years. Two vehicles are to be purchased in the base year and two more in 2026 and 2029. This strategy spreads the capital requirements over several years and also aims to benefit from the subsidies in 2022 and lower purchase prices over the years up to 2029.

Against the background of the numerous crises and unforeseeable developments of the recent past, there are discussions about whether one should not introduce in the management economics a departure from the computation of optimal solutions and turn more to the computation of scenarios (Hacker et al., 2015, Schwenker & Schencking, 2022). This view is followed here, and in this respect, three different scenarios are assumed for the different procurement strategies, which refers to the development of important parameters.

Basic Case

The basic case assumes moderately falling prices for BEVs and, at the same time, steadily rising diesel prices.

Best Case

The best-case scenario underlines an optimistic development for BEVs. Purchase prices fall sharply due to technological developments, and, at the same time, the price of diesel rises while the price of electricity falls.

Worst Case

In the worst case, the general conditions for BEVs deteriorate. Purchase prices and the price of electricity rise, while the price of diesel falls.

Assumptions are now made for various parameters for the different scenarios (Table 2):

Table 2. Scenario parameter (Source: author's compilation)

				Scenario	**1**	**2**	**3**
		Value in			Basic Case	Best Case	Worst Case
		2022	2026	2029	Price/ Inflation factor p.a.	Price/ Inflation factor p.a.	Price/ Inflation factor p.a.
Residual value	VW T6 (ICE)	€23,000	€15,000	€10,000			
Net list price	Opel (BEV)	€37,490			-2.0%	-5.0%	+5.0%
Subsidy		€9,000					
Fuel price in Euro/Litre		€1.80			+1.5%	+3.0%	-3.0%
Energy price in Cent/kWh		€0.50			+2.0%	-3.0%	+3.0%
Other costs					+5.0%	+2.0%	+10.0%
Present value discount rate		+5.0%					

For the decommissioned combustion engines, sales revenue is achieved in each case, which decreases in the course of the years. For the other parameters, certain values are assumed depending on the scenario. For the calculation of profitability, the calculation is dynamised by taking into account a calculation interest rate for discounting future cash inflows and outflows.

Results

The defined data are processed with the DIPO tool. In addition to CO_2 emissions, numerous other values are calculated as target values for the various procurement strategies in the context of fleet management. For clarity reasons, only selected results are indicated separately after sustainability and economy. In principle, the desired savings target can be achieved with all procurement strategies. However, there are significant differences when looking at the cumulative CO_2 emissions over time. The total sum of emissions (Fig. 3) is calculated from the WtW-values plus an LCA-share for the manufacturing phase. These shared values are 8.5 tCO_2 for the combustion vehicle and 19.8 tCO_2 for the BEV, which in turn are distributed proportionally over 13 assumed years of use (Wietschel, 2019). For electricity generation, a WtT-addition value of 421 gCO_2/kWh was considered (Helms et al., 2019).

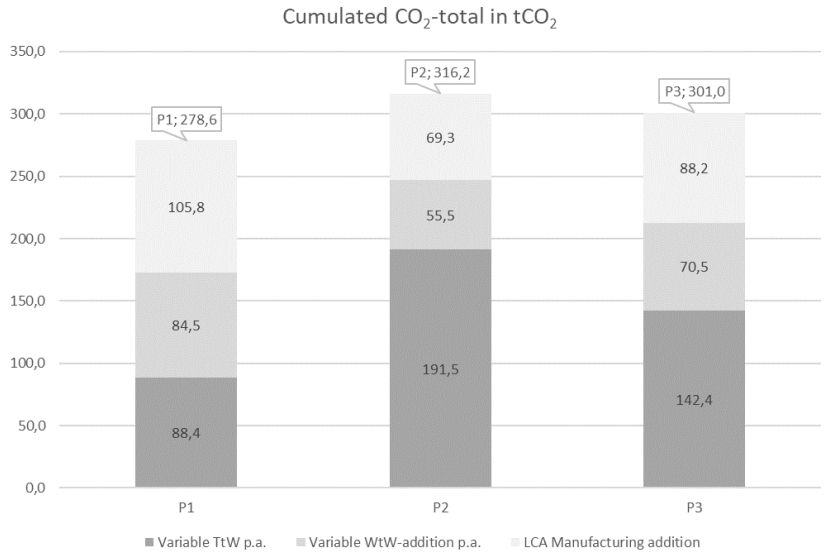

Fig. 4. Results procurement strategies (Source: author's compilation)

As can be clearly and comprehensibly seen, from the point of view of climate protection and sustainability, the best strategy is to procure BEVs as quickly as possible (P1) since the other strategies mean significant additional CO_2 emissions. Significant for strategy P2 is the high share of direct TtW-emissions.

In advance, it can be stated that the research hypothesis was confirmed that with the selection of a certain procurement strategy, one could achieve both the sustainability goals and gain an economic advantage over alternative procurement strategies.

In the following figures, the most economically advantageous procurement strategies are indicated by the addition of "Lowest value" in brackets. For the evaluation of economic efficiency, three criteria are used. To reflect on the scenario-based approach, the results are grouped by scenario.

The first criterion is TCO, which consists of depreciation and amortisation and cash-out costs, which are mainly fuel and electricity, respectively (Fig. 5).

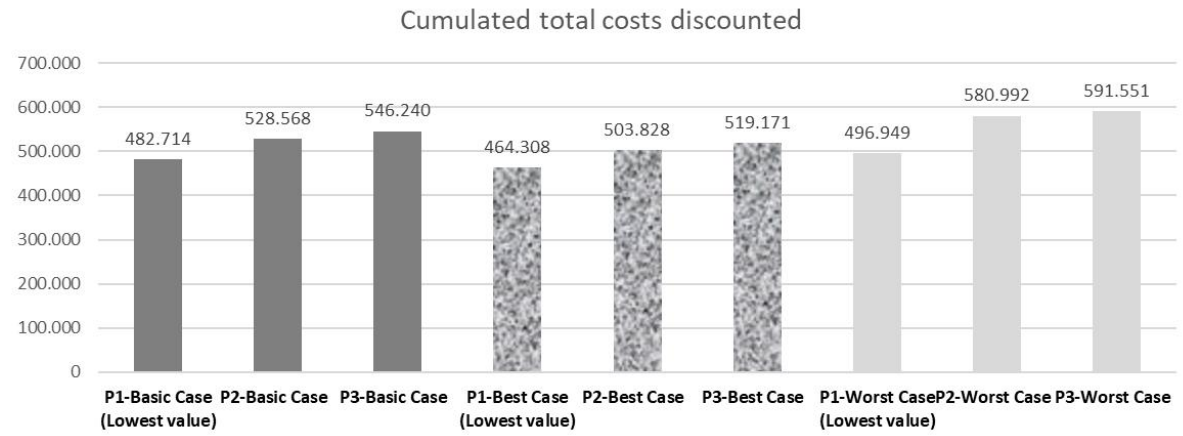

Fig. 5. Results cumulated total costs discounted (Source: author's compilation)

In each of the assumed scenarios, strategy P1 is the best option when considering TCO as an evaluation criterion.

The second criterion is only concerned with the costs affecting disbursement, which are mainly attributable to fuel or electricity (Fig. 6).

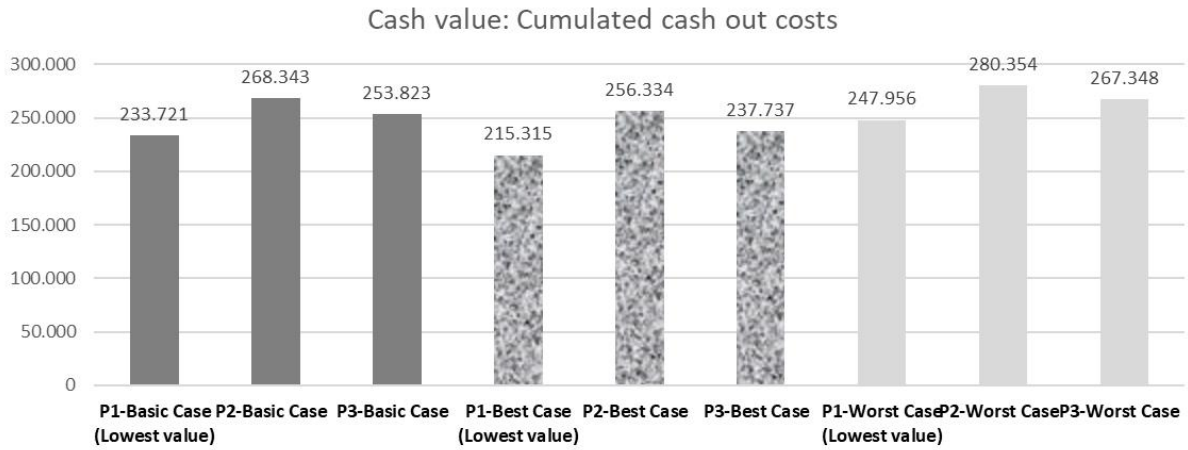

Fig. 6. Results cumulated cash out costs (Source: author's compilation)

Even with this economic efficiency criterion, P1 is the best procurement strategy in each of the assumed scenarios.

For the third criterion, an attempt was made to examine the effect of the subsidies paid in 2022. For this purpose, the criterion of cumulative investment was used, which means the discounted balance of payments for the purchase of BEVs and proceeds from the sale of combustion vehicles (Fig. 7).

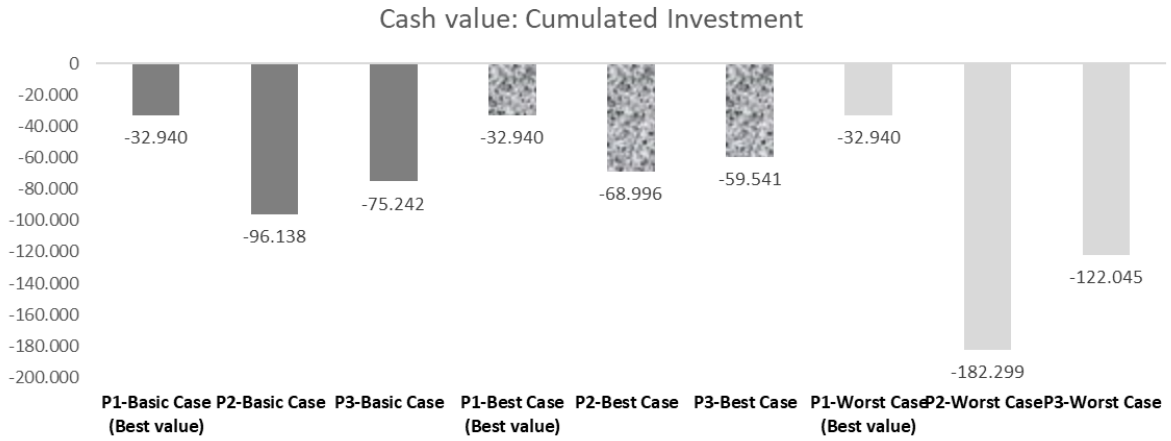

Fig. 7. Results cumulated investment with subsidy (Source: author's compilation)

With the subsidies, P1 is again the optimal strategy from an economic point of view since, in each scenario, the balance shows the lowest value. Without taking the subsidy into account, the picture is more differentiated (Fig. 8).

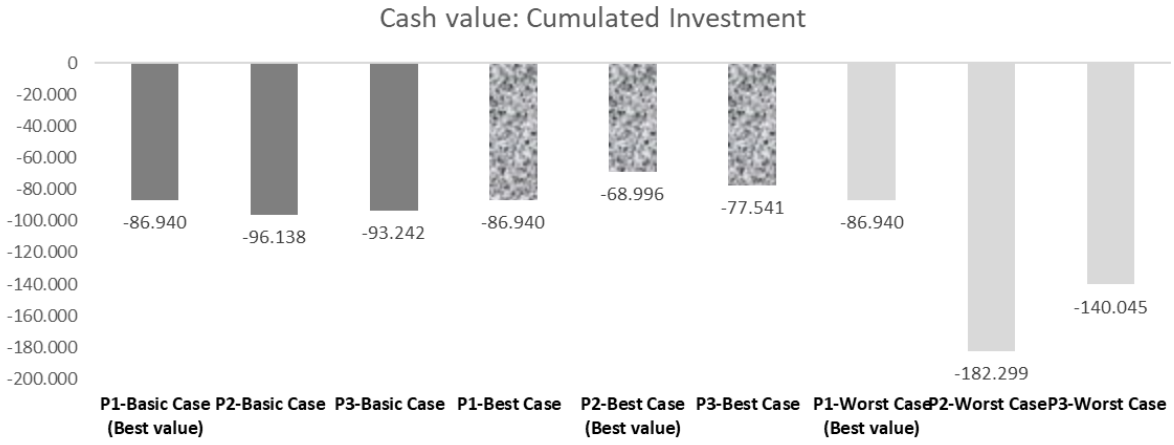

Fig. 8. Results cumulated investment without subsidy (Source: author's compilation)

Only under the assumption of the basic case or worst-case scenarios would strategy P1 be economically more advantageous. If the best-case scenario is taken into account, strategy P2 represents the optimal strategy. In this respect, the classical decision conflict between economic rationality and sustainability results here since the procurement strategy P2 exhibits the highest emission values of all procurement strategies.

Conclusions

As the most important realisation, one can state that the definition of CO_2-emission targets cannot be considered only on a goal year but under the inclusion of the accumulated emissions up to the reaching of the goal year. The achievement of set emission targets under the premise of selecting economically

optimal procurement strategies is possible but subject to the planned development of the set parameters. The implementation of such a scenario-based fleet planning to achieve defined emission targets under the premise of economic efficiency is a very complex matter, characterised by a large number of parameters and influencing factors to be considered. Numerous studies underscore the global relevance of this issue. An example of such studies comes from McKinsey & Company on the decarbonisation of US fleets (Chauhan et al., 2023). The challenges of balancing six different trade-off factors, such as the fastest route to greenhouse gas compliance and stakeholder expectations (factor 2) and the lowest cost of delivery to the customer (factor 5), are examined in a study by management consultants Roland Berger (Roland Berger, 2023). A global study on the electrification of fleets has been presented by the consultancy PTOLEMUS, which examines the market segments of company cars, light commercial vehicles, heavy goods vehicles and buses in six continents (PTOLEMUS, 2022).

The simultaneous calculation of TCO and CO_2 emissions based on recorded vehicle data by the DIPO tool has simplified this planning process considerably and reduced the effort to an acceptable level. A particular advantage arises from the fact that any changes to parameters, such as the elimination of subsidies, are immediately available to recalculate all relevant results for determining sustainability and cost-efficiency. Thus, this tool also underlines a future scope for the current developments in the area of reporting obligations for companies, which the EU enacted in 2022 with the Corporate Social Reporting Directive (CSRD) (BMJ, 2023). The next development step of the DIPO tool is to be able to design scenarios for the development of the CO_2-WtT-surcharges as well. This takes into account the fact that many countries would like to change the existing conventional electricity mix in favour of lower- CO_2-electricity generation. One option is renewable energies, but another is the controversial nuclear energy.

Restrictions in this research area arise mainly from the availability of relevant information, as many underlying values, such as procurement values or mileage, are not accessible internal company data. Future challenges for research in this area include, on the one hand, technological developments in the field of vehicle technology, where it can be assumed, for example, for electric vehicles, that better technical performance will become available at the same purchase price. On the other hand, the volatility of essential framework conditions is likely to play a role, such as energy prices or inflation. In addition, it must be taken into account what role government regulations will play in the future.

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ASSESSING CIRCULAR TEXTILE INDUSTRY DEVELOPMENT

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Abstract

Research purpose. Identify the main textile exporters in the global world that would have the greatest impact on the development of geared textiles.

Design / Methodology / Approach. TOPSIS analysis has been applied as the most widely used efficiency measurement technique. The six criteria in the current research have been selected to describe the leading players in textiles globally and are available in a public database. In addition to the TOPSIS analysis, a clustering method has been employed to identify distinct groups among the countries under examination. Through this clustering analysis, countries with similar characteristics and practices.

Findings. The analysis of the textile and clothing industry has revealed the top ten economies that make the most significant contributions to global textile production. Through a comprehensive assessment based on predetermined criteria, these economies have been closely scrutinised, resulting in the European Union securing the leading position, followed by Malaysia in second place and China in the third. The leading position of the European Union can be attributed to its robust economic infrastructure, strong policy frameworks promoting sustainability, and a growing commitment to circular economy principles within the textile sector. Malaysia's second-place position may be influenced by its strategic investments in the textile industry, favourable business environment, and initiatives to foster sustainable practices. China's third-place ranking can be attributed to its substantial textile manufacturing capacity, extensive supply chains, and efforts to integrate circular economy principles into its textile production. The research findings indicate that several factors influence the rankings, including the level of economic development, technological advancements, population size, availability of cheap labour, and the influence of fashion trends, among others.

Originality / Value / Practical implications. The circular textile industry is a relatively new field, with the European Commission announcing the EU Strategy for Sustainable and Circular Textiles in 2022. This strategic initiative aims to propel the development and adoption of circular textile practices throughout the European Union, setting a benchmark for other regions to follow. It is important to underline that the study was carried out on a global scale in order to assess the world's main textile exporters. In order to assess the progress of circular textiles, we employ the TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method. This approach allows us to rank and assess countries based on their implementation of strategies and initiatives for developing a circular textile industry. Furthermore, we utilise a clustering method to identify distinct groups or patterns within the data, enabling a deeper understanding of the similarities and differences among countries in their circular textile. This clustering analysis helps identify clusters of countries that exhibit similar characteristics or practices, facilitating the identification of best practices, knowledge sharing, and collaboration among countries within each cluster. The findings of this study hold significant value and practical implications for policymakers, industry stakeholders, and researchers.

Keywords: Circular textile industry; TOPSIS method; Clustering method.

JEL codes: C830; D160; D120; O440

Introduction

The global market has seen a rapid exchange of raw materials and products over the past decades, with exports and imports fuelling the development of the international economy. International links and

economic growth are increasing consumer demand. Businesses are producing more and more products, and consumption is increasing, leading to the irrational use of land resources. One of the largest irrational consumption industries is textile production. Textile production is the second most polluting industry in the world, behind the oil industry, which emits around 1.2 billion tonnes of greenhouse gases (more than international flights and maritime shipping combined) (Chen et al., 2021). In addition, the textile sector employs more than 1.5 million people, with more than 160 000 companies and a turnover of EUR 162 billion in 2019 (European Commission, 2022*).* In the context of the textile industry, the circular economy paradigm emphasises the need to shift from the traditional 'take-make-dispose' model to a more sustainable and regenerative framework. This entails implementing strategies such as recycling, upcycling, and reusing textiles, as well as promoting eco-design, product durability, and extended producer responsibility (Clark et al., 2016). By transitioning to a circular textile economy, numerous environmental benefits can be achieved. For instance, it can significantly reduce the extraction of virgin resources, decrease energy consumption, limit water usage, and mitigate pollution associated with textile production. Moreover, the circular textile industry offers opportunities for job creation, innovation, and the development of new business models. To accelerate the development of the circular textile industry, governments, businesses, and consumers must collaborate and align their efforts. Policy interventions, such as regulations that incentivise circular practices, can drive the adoption of sustainable production and consumption patterns. Additionally, fostering consumer awareness and education on the environmental and social benefits of circular textiles can stimulate demand and drive market transformation.

Literature review

Theoretical aspects of the circular textile economy

Today, one of the solutions to the global resource crisis and global warming is to change the entire supply chain from linear to circular. All industries are involved in this global change. One industry is fashion, with a global fashion industry worth USD 3,000 billion, representing more than 2% of the world's gross domestic product (GDP) (Shirvanimoghaddam et al., 2020). In just a few years, the circular economy has become a central tenet of industrial and environmental policy in China, Africa, the European Union (EU) and the United States, as well as to a growing list of corporations and local governments (see, for example, Ellen MacArthur Foundation, 2017) (Corvellec et al., 2022). As a result, the circular textile industry is increasingly mentioned in international agreements and policy strategies. One of the United Nations' goals for the textile sector is Goal 12 of the Sustainability Implementation Plans, which refers to sustainable production and consumption. Its concept is to change the supply chain to cover the entire cycle from product production to disposal (Muthu & Gardetti, 2020). We will discuss the circular textile industry later, but it is essential to identify the circular economy in general.

There are many definitions of the circular economy in the literature, and theoreticians and practitioners have different interpretations of the concept, and here are some of the relevant definitions (Table 1).

Table 1. The circular economy in Literature (Source: compiled by the author based on the sources cited)

Author and year	Circular economy
Suchek et al. (2021)	CE has a regenerative system that reduces resource input and waste, emissions and energy consumption by slowing, closing and straightening material and energy chains.
– Grigoryan & Borodavkina (2017)	A new business model that requires a transformation of processes, from production to relationships with end users and customers. This model is an effective way to improve companies' competitiveness and contribute to social responsibility development.
Kirchherr et al. (2018)	A business model for an economic system that changes the concept of end-of-life for products. Reducing material reuse or recycling in the production, distribution and consumption processes to achieve sustainable development, which has the impact of creating environmental and economic prosperity and social equity for the benefit of present and future generations.

Summarising the circular economy is a new business model that involves an economic or renewable system, an adaptable synthesis approach in which resources and waste inputs, emissions and energy losses are closed into a closed cycle of energy and materials. In the current literature on the circular economy, this model seeks efficient resource management by covering all objects and processes in the chain throughout the entire life cycle and is characterised by closed loops that encourage maintenance, reuse and recycling. The circular economy is an alternative to the traditional economy (production, use and recovery). We keep resources in the chain for as long as possible, try to maintain their value during their lifetime and use them to produce new products. This model is illustrated in Figure 1, which shows the cycle's closing.

Fig. 1. The circular economy model (Source: H^2AD, 2017)

The circular economy is based on this model. The circular textile industry promotes three main activities: resource reduction, litter, reuse and recycling, typical of the traditional waste management approach (Ozili, 2021). Reduction involves reducing waste at all stages of production (including minimal use of raw materials) and at different stages of consumption and use. Reusing in this space requires rethinking production to obtain easily recyclable or usable products for other applications. Ultimately, increased reuse will reduce the increased demand for production (Chen et al., 2021), but it is important to stress that other activities will be covered.

The main actors in this system are the users of the biological cycle and the users of the technical cycle. Other stakeholders related to this definition are the service provider, the product manufacturer, and the part manufacturer. The three main principles of this model are as follows: firstly, preservation and enhancement of natural capital. Secondly, longer product and material cycles in both cycles and, thirdly, waste design. The principles of the circular textile industry are described in more detail in Table 2, which presents the characteristics provided by the different authors and adapted specifically to the fashion industry.

Table 2. Characteristics of the principles of a circular textile economy (Source: compiled by the author on the basis of the sources provided)

Principles of the circular textile industry	Basic characteristics
Textile sorting	The process by which textiles are collected from consumers into dedicated containers from which they are redistributed to centres for further use, incineration, or reuse in the manufacture of new products (Nikolic & Kostic-Stankovic, 2022).
Biodegradation of textiles	Use living organisms or enzymes to help clothes decompose faster. This approach can bypass sorting, reducing overall costs and waste (Chen et al., 2021).
Textile refusal	When a product is abandoned, unnecessary, or its function becomes redundant, choosing a product that performs the same function. Abandonment also refers to abandoning materials to optimise production (Morselellto, 2020).

Rethinking Textile	Rethinking objectives and strategies related to using textiles, recycled materials, and virgin and reusable materials (Clark et al., 2016).
Textile recycling	Recycling - when a by-product material is converted into a product of different quality, functionality or value (Worrell & Reuter, 2014).
Reusing textile	Reuse of textiles through resale and rental, use of garments for transfer from the original user to another user (Chen et al., 2021).
Reducing textile use	Reducing the use of textiles and their further use in other products. Use fewer natural resources, energy, raw materials and waste (Kirchherr et al., 2017).
Textile renovation	The reuse of textiles that perform the same function. Refurbishment of textiles means that other materials can be used to refurbish them (Kirchherr et al., 2017).

The characteristics of the principles of the circular textile economy, as described by different authors, vary. However, the idea is to minimise the use of resources by rethinking each consumer's choices and motives when choosing used textiles or renewing existing textiles. Less than 1% of clothing is recycled globally, partly due to a lack of appropriate technology (European Commission, 2022). In this case, the responsibility of the technical users - the manufacturing companies or businesses in general - is very high. Since they must review their existing technologies, established strategies and sales policies, technical users should set strategies based on sustainability, green economy principles, socially responsible business and the public good. Integrating these principles is a long and complex process. The following section will look at the economic and behavioural theory and how it can influence the development of the circular economy. It is also noted that much of the literature on the circular textile industry has focused on the production side, exploring circular business models, strategies for creating circular value propositions and the benefits of such models. However, less attention has been paid to how consumption and consumers affect or are affected by the circular economy. Therefore, the following section analyses behavioural economics and its impact on the circular textile industry in the context of consumption.

To summarise the literature review on the circular textile industry, the concept of the circular textile industry currently needs to be widely accepted. This concept is derived from the circular economy. It is still a definition that has yet to be found in the literature. It is frequently used in legislation, at global meetings and, of course, in new agreements and strategies, both in the European Union and in United Nations agreements. However, the value of the textile sector is evident, with an estimated increase of USD 192 billion in the global economy by 2030 in the fashion industry (Chen et al., 2021). Therefore, this will certainly further the analysis and evaluation of the actors, processes and opportunities for increasing the efficiency of the circular textile industry.

Research Methodology

When analysing the circular textile industry globally, we must look at international, transnational agreements. One of the critical United Nations Sustainable Development Goals is the proposal for waste legislation, which aims to increase global competitiveness, promote sustainable business and create new jobs in the transition to the circular economy. In order to analyse the development of the circular economy, it is necessary to clarify and identify the indicators needed for the analysis.

Due to the topic's novelty, the indicators for a circular textile industry still need to be identified for proper assessment and calculation. Therefore, based on the indicators provided by the European Union for the circular economy - Eurostat database and scientific insights, the following data were selected: used clothing exporters (billion US dollars), used clothing importers (billion US dollars), footwear and headgear exporters (billion US dollars), footwear and headgear importers (billion US dollars), textile exporters (billion US dollars), textile importers (billion US dollars).

A multi-criteria decision-making approach, the Technique for Order Preference by Similarity to the Ideal Solution, is used to assess the performance of the circular textile economy. In the following, we will refer to this method as TOPSIS. This method defines the rationality of options when the distance between the ideal positive and the ideal negative is sought, the minimum distance between the optimal

alternative from the ideal solution and the maximum distance from the worst solution (Simanaviciene, 2016).

The sequence of the TOPSIS solution method is described below; the elements of the decision matrix are normalised according to formula (1) (Simanaviciene, 2016).

$$n_{ij} = \frac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}} \tag{1}$$

where:

x_{ij} - is the value of the j-th indicator of the i-th alternative.

In the next step, the weights of the criteria are calculated on the basis of the Criteria Importance Through Intercriteria Correlation (Criteria Importance Through Intercriteria Correlation). In the following, we will refer to this method as CRITIC. We construct the decision matrix X (formula 2) (Adali & Isik,2017). It shows the performance of the different alternatives with respect to the different alternatives.

$$\mathrm{X} = \left[\mathrm{x_{ij}}\right]_{\mathrm{m\times n}} = \begin{bmatrix} \mathrm{x_{11}} & \mathrm{x_{12}} & \cdots & \mathrm{x_{1n}} \\ \mathrm{x_{21}} & \mathrm{x_{22}} & \cdots & \mathrm{x_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \mathrm{x_{m1}} & \mathrm{x_{m2}} & & \mathrm{x_{mn}} \end{bmatrix} \mathrm{i} \in \{1,2,\ldots,\mathrm{m}\}, \mathrm{j} \in \{1,2,\ldots,\mathrm{n}\} \tag{2}$$

where:

x_{ij} - the efficiency value of the i-th alternative for the j-th criterion.

The decision matrix is then normalised according to formula (3):

$$r_{ij} = \frac{x_{ij} - x_j^{min}}{x_j^{max} - x_j^{min}}, i \in \{1,2,\ldots,m\}, j \in \{1,2,\ldots,n\} \tag{3}$$

where:

x_j^{max} - j-th largest value;

x_j^{mi} - the j-th smallest value.

Calculate the standard deviation. σj for each element of rij.

Also, we find the correlation coefficient with each normalised element and construct a symmetric matrix with Rij (4):

$$\sum_{j=1}^{n} (1 - R_{ij}) \tag{4}$$

where:

R_{ij} - the correlation coefficient between the two criteria.

The information content of the criteria is calculated in (5):

$$C_j = \sigma_j \sum_{j=1}^{n} (1 - R_{ij}) \tag{5}$$

where:

σ_j - the standard deviation of criterion j-th.

The weighting of the criteria considers both the standard deviation of the criterion and its correlation with the other criteria, as well as the correlation between the criteria. Taking this into account, the weight (wj) of the jth criterion is given by (6):

$$w_j = \frac{c_j}{\sum_{j=1}^{n} c_j} \tag{6}$$

Using the weights of the indicators nj j ω =, 1, and the normalised elements of the decision matrix, a weighted normalised matrix (7) is created:

$$v_{ij} = w_j n_{ij} \text{ for } i = 1, \dots, m; j = 1, \dots, n \tag{7}$$

The elements of the weighted normalised matrix are used to construct the 'ideal best' alternative according to formula (8) (Simanaviciene, 2016)

$$V^+ = (v_1^+, v_2^+, \dots, v_n^+) = \left(\left(\max_i v_{ij} | j \in I \right), \left(\min_I v_{ij} | j \in J \right) \right) \tag{8}$$

J - a set of indices with higher values for the indicators with better performance;

J′ - a set of indices for indicators with lower values that are better.

In addition, a "negative-ideal" alternative is generated according to formula (9):

$$V^- = (v_1^-, v_2^-, \dots, v_n^-) = \left(\left(\min_i v_{ij} | j \in I \right), \left(\max_I v_{ij} | j \in J \right) \right) \tag{9}$$

The distance between the comparative i-th alternative and the "ideal best" + A alternative is determined by calculating the distance in n-dimensional Euclidean space according to formula (10) (Simanaviciene, 2016):

$$S_i^+ = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^+ \right)^2}, \quad i = 1,2, \dots, m. \tag{10}$$

and between the i-th alternative and the "negatively ideal" alternative A, according to formula (11):

$$S_i^- = \sqrt{\sum_{j=1}^{n} \left(v_{ij} - v_i^- \right)^2}, \quad i = 1,2, \dots, m \tag{11}$$

The final step of the TOPSIS method is to determine the relative distance of each i-th alternative to the "ideally worst" alternative according to the following formula (12):

$$P_i = \frac{S_i^-}{S_i^- + S_i^+} \tag{12}$$

where:

S_i^- - the distance between the comparative i-th variant and the negative-ideal variant;

S_i^+ - the distance between the i-th comparator and the ideal best option.

A priority ranking of the alternatives is established based on the Pi index values. The rational alternative is the one whose Pi value is closer to one the closer the comparative i-th option is to a+, i. e. the Pi value is the highest (Simanaviciene, 2016).

When we look at the indicators of the circular textile economy, we see that it is a large dataset, so one solution is to classify the data. Cluster analysis refers to a variety of numerical data analysis techniques

for identifying and interpreting groups or clusters of homogeneous and distinct objects. A cluster is a group of similar objects. The main objective of cluster analysis is to group objects in such a way that differences within clusters are minimised, and differences between clusters maximised. Based on the steps and formulas are presented below (Bileviciene & Jonusauskas, 2011). Stages of cluster analysis:

1. Select the clustering objects.

2. Choose the attributes to be clustered.

3. Choose a quantitative measure to assess the similarity of the objects.

4. One of the methods to classify objects into clusters.

5. Interpret the results.

In the study, all clustering steps were completed. Next, a proximity measure is selected.

For the cluster analysis, one metric distance measure was chosen. The essence of the measures is that the higher the value, the more dissimilar the objects are. There is a variety of these measures; during the tests and calculations, the Euclidean distance square was chosen. The Euclidean distance squared must be applied with the choice of the centroid, median or Ward clustering method. The Euclidean square of the distance between objects X and Y is calculated using formula (13):

$$d(X,Y) = \|X - Y\|^2 = \sum_{i-1}^{M} (x_i - y_i)^2 \tag{13}$$

where:

m – number of attributes

The study uses Ward's method, taking a pair of clusters and calculating the sum of the squares of the deviations of the feature vectors from the centre of the joint cluster. The same is done with the other pair of clusters, and so on. The clusters that are merged are those with the lowest sum of deviations.

The Ward similarity measure is calculated as (14) (Bileviciene & Jonusauskas, 2011):

$$\mathrm{d(U,V)} = \frac{1}{\frac{1}{n_U} + \frac{1}{n_V}} \|\bar{U} + \bar{V}\|^2 \tag{14}$$

where:

$\bar{U}, \bar{V}$ – averages of the feature vectors of the objects forming the clusters;

n_u – number of objects in cluster U;

n_v - number of objects in Cluster V

In this work, also for comparison purposes, the data variables were standardised so that all variables have the same influence on the distance calculation. Using SPSS, the data were standardised and calculated again using Ward's method with Euclidean distance squares.

Research results

Data for 2020 were used in this work, as not all countries and indicators have been published in the The Observatory of Economic Complexity (OEC) database for 2021. The nine countries of the world and the European Union, which are the largest exporters of textiles, were selected. The selected countries and the EU are mutually exclusive, as the EU countries share the same circular textile economy policy, and it is, therefore, more valuable to choose the EU rather than individual countries for further research and conclusions. The top exporters analysed are the European Union, China, Malaysia, India, Hong

Kong (China), the United Kingdom, Indonesia, Vietnam, Turkey, and Bangladesh.

For the analysis of the circular textile economy, eight indicators, in other words, criteria, were selected. The list of benchmarks was selected taking into account public data available on The Observatory of Economic Complexity (OEC), relevant requirements and standards. The criteria analysed were: 1. Exporters of second-hand clothing (USD billion), 2. Importers of second-hand clothing (USD billion), 3. Exporters of footwear and headwear (USD billion), 4. Importers of footwear and headwear (USD billion), 5. Exporters of textiles (USD billion), 6. Importers of textiles (USD billion), 7. Population, total, 8. GDP per capita (current, USD). A detailed description of the indicators is given in Annex 1. All indicators are maximising.

The analysis of the markets of the selected countries starts with the European Union, a giant in the textile industry. The main sorting centres are located in Western and Eastern Europe. Only about 10-12% of second-hand clothing (only the highest quality) is sold in local second-hand shops. Also, importantly, the amount of textiles purchased per person in the EU has increased dramatically since 1996, as the market itself has reduced prices very sharply, resulting in shorter wearing times. (Nguyen & Mogaji, 2023). Unrecyled textiles are either incinerated or sent to a landfill.

In India and Pakistan, second-hand garment residues are imported and sorted by sorting companies. Worn clothing is extracted from "mixed rags" and sold locally or sent to Africa. The recycled yarns are used to make new sweaters. Cotton wipers made from second-hand clothes are exported to the USA.

The TOPSIS survey method requires criterion weights to ensure the reliability of the results. The criterion weights were calculated using the CRITIC method, and the results are shown in Table 3:

Table 3. Results of the weighting of the criteria (Source: authors' contribution)

Σ *σ	0,97818	0,92960	2,10293	0,93136	1,48138	0,96041	2,53131	2,30533
WJ	0,08004	0,07607	0,17208	0,07621	0,12122	0,07859	0,20714	0,18864

Knowing the weights and identifying the significance of the criteria (maximising and minimising), we calculate the ideal positive solution (V+) and the ideal negative solution (V-). The resulting ideal positive and negative solutions are shown in Table 4:

Table 4. The result of the ranking of the ring textile economies using the TOPSIS method (Source: authors' contribution)

Si+	Si-	Pi	RANK	Countries
0,16643	0,17027	0,50569	1	European Union
0,24493	0,16216	0,39834	2	Malaysia
0,21303	0,10678	0,33388	3	China
0,28597	0,01981	0,06478	4	Viet Nam
0,26322	0,01206	0,04382	5	India
0,29270	0,01240	0,04064	6	Bangladesh
0,27445	0,00890	0,03141	7	United Kingdom
0,29111	0,00942	0,03134	8	Turkey
0,28732	0,00520	0,01778	9	Indonesia
0,28187	0,00089	0,00316	10	Hong Kong, China

The table shows that the European Union is in first place and Hong Kong, China is in tenth place. Based on this table, we can conclude that the alternative is the European Union, in terms of the selected indicators, which has most appropriately developed a circular textile economy strategy. In terms of suitability, Malaysia is in second place, China in third place and Vietnam and other countries in fourth

place. A priority ranking of the alternatives has been drawn up (Table 4) and ranked from lowest relative distance to highest.

A cluster analysis was carried out using SPSS to group the ten alternative countries. The aim of this study is to group countries according to their common features/criteria set. It is important to note that there were no data gaps, hence the percentage of 0 in Table 5. Clustering was attempted in several ways, but the best option was found to be the hierarchical Ward's method with the Euclidean distance squared measure.

Table 5. Clustering study results (Source: authors' contribution)

Case Processing Summary[a,b]

Cases					
Valid		Missing		Total	
N	Per cent	N	Per cent	N	Per cent
10	100.0	0	.0	10	100.0

a. Cosine of Vectors of Values used

b. Complete Linkage

For hierarchical clustering, the best result was obtained using Ward's merging method with Euclidean distance measure. The results are shown in the dendrogram, Figure 2:

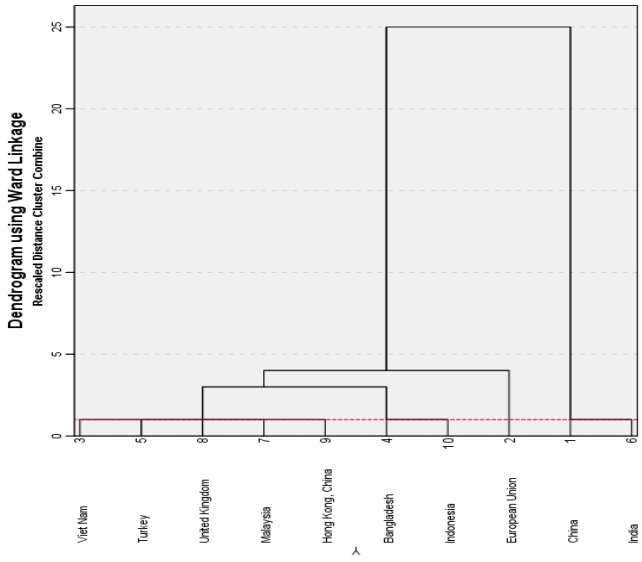

Fig. 2 Hierarchical clustering by Ward's join method with Euclidean square measure dendrogram
(Source: compiled by the author using SPSS software)

Ward's method separated two clusters consisting of eight and two countries each. However, in order to describe and interpret the result more precisely, it was chosen to group into 4 clusters, so a cut is made below, which separates the countries into the clusters to which they belong:

Cluster 1: Vietnam, Turkey, the United Kingdom, Malaysia, and Hong Kong, China.

Cluster 2: Bangladesh, Indonesia.

Cluster 3: the European Union.

Cluster 4: India, China.

Considering the layout of the clusters, it can be explained that, according to the circular textiles set of criteria, the distance between two clusters is defined as the maximum distance between the members, i.e., the distance between the two entities that are furthest from each other.

A comparison of the indicators selected by the studies shows that countries could have been clustered in this way because of the similarity of the data. Ward's method with the Euclidean distance measure allows for the identification of clusters based on the proximity of data points, facilitating the grouping of countries that exhibit similar characteristics and trends in their circular textile industry development.

The clustering analysis based on the provided data offers insights into the similarities and differences among countries in their circular textile industry development. It highlights countries that exhibit comparable patterns in terms of their trade activities, population, and economic indicators. Understanding these clusters can provide useful information for policymakers, industry stakeholders, and researchers to identify commonalities, share best practices, and foster collaboration in advancing the circular textile industry.

Moreover, in today's global market, products are often produced, purchased, disposed of, and recycled in different geographic locations, leading to a significant transfer of resources across the globe. High-level international policies, such as the Basel Convention (2018), have been established to regulate and prevent the transboundary movement and disposal of hazardous waste. However, the effective implementation of these policies has consistently posed challenges for both developed and developing countries (Qu et al., 2019). This highlights the interconnected nature of the circular textile industry and emphasises the critical importance of international collaboration and adopting resource optimisation strategies to address the complex and global nature of resource flows and waste management practices.

It is relevant to assess the existing research on circular textiles worldwide and compare it with the findings presented in this study. A database comparison of research articles was conducted using keywords such as circular economy, circular economy industry development, clustering, and the TOPSIS method. Most of the articles found employed qualitative research methodologies utilising the TOPSIS and clustering methods to evaluate the characteristics of circular textiles. However, a limitation observed in many studies was the lack of statistical data, relying mainly on literature reviews. One particular study examined the circular economy using the TOPSIS method to assess waste and identified ten strategies to provide optimal solutions for organisations. Among these strategies, the integration of CE design tools was found to be the most influential (Maliha et al., 2023). Another study analysed the network of companies in the textile industry using the clustering method, focusing on the textile companies with the highest connections (Sheresheva et al., 2022). Additionally, the research highlighted the challenges faced by the largest textile exporters, China and the European Union, emphasising the sustainability of textile reuse and recycling compared to incineration and landfill, with a particular emphasis on the benefits of reuse (Juanga-Labayen et al., 2022). These findings underscore the importance of international cooperation, promoting textile reuse, and exporting used textiles to economically disadvantaged countries.

In summary, the utilisation of the TOPSIS method in conjunction with Ward's merging method and the Euclidean distance measure in the clustering analysis significantly enhances our comprehension of the circular textile industry. This approach offers valuable insights into fostering sustainable practices, optimising resource efficiency, and facilitating collaboration among countries to advance a more circular and sustainable textile industry.

Conclusions

By analysing the literature, we can define the circular textile industry as a transformative approach that adopts a renewed economic business model. In this model, the focus is on reducing resources, inputs, emissions, and other energy losses by establishing a closed-loop system where materials circulate within a single chain. The principles of the circular economy are applicable to every aspect of the textile industry, making it imperative to take prompt action. Given the fashion industry's significant environmental impact and contribution to pollution, proactive measures are crucial. To drive circular textile industry development, the following key principles need to be considered: textile sorting,

biodegradation of textiles, textile refusal, rethinking textiles, textile recycling, reusing textiles, reducing textile use, and textile renovation.

The analysis of the circular textile economy shows that countries have not yet produced annual reports to assess the development of the circular textile economy. Therefore, in order to assess and further investigate the global situation, criteria have been selected that, based on the principles of the circular economy, would allow the evaluation of the main players in textiles and clothing. The main criteria chosen were as follows: exporters of second-hand clothing (USD billion), importers of second-hand clothing (USD billion), exporters of footwear and headgear (USD billion), importers of footwear and headgear (USD billion), exporters of textiles, (USD billion), importers of textiles (USD billion), population, total, GDP per capita (current, USD). Due to a lack of accuracy and data, the ten countries that are the leading players in textiles were assessed. The paper adopts a multi-criteria decision method, which ranked the countries according to the result obtained. Also, a hierarchical clustering Ward's clustering method was chosen, which groups countries into clusters based on similarity criteria.

The assessment of the circular textile economy, based on a set of criteria using the TOPSIS method, after ranking ten countries, shows the European Union is in first place, Malaysia in second place, and China in third place. The results of the clustering analysis using Ward's method with the Euclidean distance squared measure provide interesting insights into the grouping of countries based on the selected criteria. Cluster 1 consists of Vietnam, Turkey, the United Kingdom, Malaysia, and Hong Kong, China; Cluster 2 comprises Bangladesh and Indonesia; Cluster 3 consists of the European Union; Cluster 4 includes India and China. These countries might share similarities in certain aspects of their circular textile industry development based on the analysed criteria. Further exploration could shed light on the specific factors that contribute to their inclusion in this cluster. Overall, the clustering results provide a foundation for understanding the similarities and differences among countries in their circular textile industry development.

The literature analysis indicates that many sources related to the development of the circular textile industry are qualitative due to the lack of publicly available statistics for analysis. Assessing circular textiles faces challenges and information gaps, including the need for comprehensive data on resource efficiency, such as water and energy consumption, material waste, recycled inputs, and economic behaviour. Obtaining accurate and consistent data from stakeholders along the supply chain remains challenging. Additionally, tracking recycling and reuse rates requires reliable data on the volume of textiles recycled or reused, hindered by limited reporting and tracking systems. These challenges and information gaps present significant barriers to a comprehensive assessment and the progress of circular textiles. Future research should focus on improving data collection, enhancing transparency and traceability, and fostering collaboration to overcome these barriers and advance the circular textile industry.

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Annex

	Exporters of Used Clothing (2020) mln. Usd	Importers of Used Clothing (2020) mln. Usd	Exporters of Footwear and Headwear (Billion dollars)	Importers of Footwear and Headwear (Billion dollars)	Exporters of textiles, 2020 Billion dollars	Importers of textiles,2020 Billion dollars	Population, total	GDP per capita (current US$)
China	404	37,5	52,5	4,66	276	25,7	1,411,100.00	10,408.7
European Union	170685	936,9	45,13	63,57	179	738,7	447,479.49	34,191.8
Viet Nam	1,17	6,76	19,2	2,22	38,9	20,3	97,338.58	3,526.3
Bangladesh	0.000309	7,12	1,41	0,298	37,3	10,7	164,689.38	2,270.3
Turkey	52,5	29,5	0,938	0,55	28,5	9,29	84,339.07	8,536.4
India	64,2	93,9	2,44	0,863	29,7	6,27	1,380,004.39	1,933.1
Malaysia	56	105	206	0,976	3	5,14	32,366.00	10,412.3
United Kingdom	315	43,1	2,07	6,13	10	35,3	67,081.00	41,098.1
Hong Kong, China	7,78	5,78	0,574	0,05	4,94	10,4	7,481.00	46,101.0
Indonesia	1,62	20,3	5,34	0,971	11,9	7,7	273,523.62	3,870.6

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THE IMPACT OF INFLUENCER MARKETING ON THE DECISION-MAKING PROCESS OF GENERATION Z

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Abstract

Research purpose. Currently, the Internet is used by almost 5 billion users worldwide, of which 80% actively use at least one of the social networks. And marketing managers are well aware of this fact, as they had to switch to a new way of attracting potential customers. One of these methods is also influencer marketing as a form of marketing communication. In influencer marketing, the emphasis is placed on influencers with a significant impact on the community on which marketing activities and campaigns can be oriented. It is a method of non-violent and natural promotion of a product or brand, which acts on the consumer as a natural part of the space in which it is located. Especially one generation of consumers, Generation Z, is considered to be the target segment for influencer marketing due to their digital skills and inclination to social networks. The main aim of the article is to determine the impact of influencer marketing on the decision-making process of Generation Z. This also includes providing the theoretical background and analysis of influencer marketing from the viewpoint of Slovak and foreign authors.

Design / Methodology / Approach. General scientific methods were applied for the processing of the data as well as mathematical-statistical methods to evaluate the data collated from the results of the questionnaire survey and to statistical hypothesis testing. The important source for secondary data was scientific research, annual company reports, statistical databases, and published professional publications. In order to find out the impact of influencer marketing on the decision-making process of Generation Z, a questionnaire survey was conducted.

Findings. A successful marketing campaign on social media in cooperation with influencers requires the correct selection of the influencer according to their follower base, profile focus, credibility or reach, which is measured by Engagement rate. The number of followers is not as significant as the relationship that the creator has with their fans. When choosing an influencer, it is also necessary to take into account the way they promote products, ask them for originality and creativity, and prefer long-term collaborations to one-time contributions. These steps can bring a lot of benefits to the company, from which it will subsequently profit. Based on the analysis and results of the questionnaire survey, it is thus clear that the implementation of influencer marketing in marketing communication of Slovak companies targeted at Generation Z brings many benefits, including building relationships with Generation Z, increasing their loyalty and improving the company image.

Originality / Value / Practical implications. Finally, measures for effective influencer marketing usage targeted at Generation Z are proposed, and its benefits are highlighted.

Keywords: Influencer; Influencer marketing; Decision-making process; Consumers; Generation Z

JEL codes: M30; M31

Introduction

Consumers' growing mistrust of traditional marketing communication tools makes it increasingly difficult for companies to influence and attract consumers (Majerova, 2014). More marketers are using the opportunity of influencers to promote their brands and products on social media. Such use of influencers supports the development of influencer marketing, i.e., a communication strategy in which

the company motivates and selects influencers on social media to engage their followers in order to promote the company's offer. Companies choose individuals, groups or virtual avatars, as needed, whom they will pay for the service performed. Influencers have established networks of followers on online platforms such as social media. Some influencers have an enormous following and have achieved celebrity status, but they differ from celebrities in the source of their fame. Celebrities are characterised by success in one of the mandated or institutional environments, such as sports, music or acting, which differentiates them from influencers (Leung et al., 2022).

Based on the mentioned above, influencer marketing represents a new frontier of opportunity as it is seen as one of the fastest-growing tools for acquiring new customers online (Oliveira & Chimenti, 2021). However, there is still a need to explore the issue of influencers, their influence and thought leadership with regard to particular generational cohorts.

Especially, one generation of consumers, Generation Z, is considered to be the target segment for influencer marketing due to their digital skills and favour to social networks. For this reason, the main aim of the article is to determine the impact of influencer marketing on the decision-making process of Generation Z.

Generation Z includes people who were born between 1997 and 2012 and have been growing up in a digital world, which means they have never known a time without the Internet. According to research by the marketing agency Reed Brand Communications, this generation uses social media mainly for communication with friends, following famous personalities, entertainment and inspiration. They do not like "fake news" and fight against misinformation. Social networks, which are often detached from reality, cause envy and a feeling of need; therefore, marketing should not be too aggressive and exert pressure on this generation (Atherton, 2022; Lazo & Velasco, 2021).

Typical for this generation is the use of technology from an early age, and social networks have a major influence on them (Novotna, 2017). Similarly, Sak (2018) claims that people belonging to this group reject society and live only on the Internet. They take pictures almost of everything they do during the day and share them on social media (Horvathova et al., 2016). Jankova (2020), in her research, found out that the use of the Internet and social networks is among the most represented leisure activities of Generation Z and that almost everyone of this generation uses the Internet on a mobile phone every day.

Despite the popularity of influencer marketing as a marketing communication tool, there is still insufficient research focused on its impact on Generation Z, especially in Slovak conditions. For this reason, the main aim of the article is to determine the impact of influencer marketing on the decision-making process of Generation Z. This also includes providing the theoretical background and analysis of influencer marketing from the viewpoint of Slovak and foreign authors. In order to find out the impact of influencer marketing on the decision-making process of Generation Z, a questionnaire survey was conducted. Based on the analysis and questionnaire survey results, measures for effective influencer marketing usage targeted at Generation Z are proposed, and its benefits are highlighted.

Literature Review

Influencer marketing can be considered one of the most important new approaches to marketing in the last decade. It is a new marketing communication concept related to the word-of-mouth type of marketing and relationship marketing. Nowadays, key marketing decision-makers often operate within the influencer community because they consider all important decisions too risky to make alone and in isolation. It is more challenging to target a marketing campaign to potential customers as it becomes more and more difficult to identify them. Therefore, it seems an effective solution to focus on an influencer who has developed a wide range of followers around them, for whom he/she can seem to be a kind of role model.

Influencers represent personalities who can significantly strengthen the brand's marketing strategies or build and spread awareness of the company. They significantly affect market segments with potential customers and influence their purchasing behaviour. For their activities, they use traditional as well as new digital communication platforms, especially social media and the Internet. Influencers offer brands

the opportunity to deliver marketing campaign messages to the target consumer and thus influence their decision-making process when purchasing (Yesiloglu & Costello, 2020).

Sammis et al. (2015) look at influencer marketing as a combination of content marketing and native advertising, i.e., one that acts on the consumer as a natural part of the space in which it is located, while its purpose is to integrate its form and functional side with the content of the campaign in a non-intrusive way and so it is more challenging to observe. The influencer provides their fans with a trustworthy advertisement and review, which can be supplemented with a direct link to the e-shop or website, and can also use promotion in the form of a competition or with the help of so-called affiliate marketing when the influencer is provided with a special code that his followers can apply for a discount on selected products.

Sammis et al. (2015) also emphasise that influencer marketing through a well-known personality influences the building of solid relationships with customers. However, they also perceive a new wave of influencers, the so-called "everyday consumers" who can have a great influence on the purchasing behaviour of customers in a narrow circle of people and all the more effectively.

Ladrova (2017) sees influencers not only as a tool of marketing communication and a mediator of brand marketing of well-known brands but also as mediators of sales and distributors of products.

Influencer marketing based on social media has become an important factor in consumer purchasing decisions. The research results of Pick (2021) show that the perception of the credibility of the influencer serves as an important criterion determining the purchase attitude, and the attitude towards advertising; it also contributes to the creation of assumptions that are associated with the influencer and can positively or negatively influence consumer behaviour.

Specifically, the impact of influencer marketing on the attitudes of Generation Z was investigated by Duffet (2017; 2020). He found that the reach of influencer marketing is directly proportional to the respondents' activity on social networks.

Similarly, Greskova (2017) focused on the characteristics of Generation Z and their purchasing decisions. She defined them as a generation that spends a lot of time online; they like to follow influencers from whom they adopt a similar lifestyle, values and beliefs. She also considers Generation Z to be demanding customers who have the need to share their experiences with products with other people, especially on the Internet, either in the form of reviews or comments on social media and discussion forums.

Some authors consider Instagram to be the most suitable social network for influencer marketing, mainly because it has become the most used and fastest growing social media with more than a billion users per month and thus offers vast opportunities for marketing communication in all generations, but especially younger ones (De Veirman et al., 2017; Casalo et al., 2020; Pozharliev et al., 2022). The media, which was initially used to share the personal content of individuals, has become a full-fledged tool for the marketing activities of companies in the digital environment (Gajanova, 2018). Today, more than 200 million of them appear on Instagram, and in order to succeed, they share at least one post a day (King, 2020).

Kuligowski (2023) considers the most engaging contributions to be those that show behind the scenes of a company or a well-known personality, demonstrations of the work commitment of employees, such as production or live broadcasts, during which consumers can ask questions and the company immediately offers them feedback, thereby creating with them closer relationships and builds trust.

Regarding influencer contributions, Chodak et al. (2019) point to different effects of posts depending on their form (image, video, text, etc.). The results of their research showed that video had the highest reach and images had the highest levels of engagement and user interaction. These results point to the complexity of influencer marketing and that a marketing strategy must be carefully designed to achieve the expected results.

The proper influencer marketing application is cost-effective in promoting ideas, people and goods, which brings creative content to the company and offers ways to reach the target audience naturally (Kadekova & Holiencinova, 2018). There are also negatives regarding influencer marketing, such as

detrimental effect on attitude towards the brand, based on the disclosure of the sponsorship through higher awareness of the ad, which may ultimately have the effect of reducing the credibility of the influencer or emphasising the adverse reaction of consumers to posts focused only on products, which implies a significant financial motivation of the influencer. From the view of consumers, it is, therefore, essential that advertised products are presented with basic information (Jendoubi & Martin, 2020). The influencer must be familiar with the product and its features in order to be able to present it in a high-quality and appropriate way so that he can answer questions about the product. From this point of view, companies can include a clause in contracts with influencers to terminate the contract if the influencer fails to promote the product at the required level (Michulek & Krizanova, 2022).

In an effort to achieve the main aim of the article, based on the theoretical background and survey results, five research hypotheses were formulated and subsequently verified:

- Hypothesis 1: More than 50% of Generation Z consumers follow at least one influencer on social networks.
- Hypothesis 2: More than 50% of Generation Z consumers prefer Instagram when following influencers.
- Hypothesis 3: More than 50% of Generation Z consumers primarily follow influencer posts in the form of short videos and stories.
- Hypothesis 4: Regarding the content of influencer posts, 50% of Generation Z consumers prefer a review of the product.
- Hypothesis 5: 50% of Generation Z consumers have bought a product based on an influencer's recommendations at least once.

Methodology

The main aim of the article is to determine the impact of influencer marketing on the decision-making process of Generation Z. This also includes providing the theoretical background and analysis of influencer marketing from the viewpoint of Slovak and foreign authors. Based on the analysis and results of the questionnaire survey, managerial implications of influencer marketing are indicated. Finally, measures for effective influencer marketing usage targeted at Generation Z are proposed, and its benefits are highlighted. The important source for secondary data was scientific research, annual companies report, statistical databases, and published professional publications. In order to find out the impact of influencer marketing on the decision-making process of Generation Z, a questionnaire survey was conducted. The questionnaire survey was aimed at finding out the attitudes of Generation Z toward influencer marketing and the impact of influencer marketing on their decision-making process. To determine the sample size, the base file representing the number of people born in 1997 – 2012 (Generation Z) was obtained from demographic statistics of the Statistical Office of the Slovak Republic. The confidence interval of 5% was determined, and the confidence level was 95%; thus, the error rate of 5% was admitted. A sample size of 384 respondents was collected. The actual number of respondents who participated in the questionnaire survey was 520. The time required for the survey was September 2022. The survey was a questionnaire method through e-mail communication and social networks. The quantitative assessment method was applied to process the survey data.

General scientific methods (i.e., excerption, description, comparative analysis, deduction and induction) were used for data processing, as well as mathematical and statistical methods in the evaluation of data from the survey.

The marginal rate of 50% used in the hypotheses was set as the expression of the simple majority (Macfie & Nufrio, 2006).

The method of statistical hypothesis testing was chosen because it is one of the most important statistical inference procedures. Statistical hypotheses testing is defined as a statement of the assumption of unknown parameters in the basic set, which is formulated as a statistical hypothesis, and its validity is verified by statistical procedures based on selected characteristics. The role of statistical hypothesis

testing is to decide whether to accept or reject the hypothesis regarding the basic set in accordance with the information from the available choice. In the verification of the hypotheses, the methodology of statistical hypothesis testing was met (Rimarcik, 2007).

The test statistic for hypotheses 1– 5 was calculated by using the method of testing a single proportion by one-tailed testing because it is commonly used (Lombardi & Hurlbert, 2009; Ruxton & Neuhauser, 2010).

The significance level α was determined at 0.05. This means the probability of making an incorrect decision when the null hypothesis is true. α levels, so-called significance levels, are used in hypothesis tests. Typically, these tests are performed with an α level of 0.05 (5%), but other commonly used levels are 0.01 and 0.10. The test criteria were calculated according to:

$$T = \frac{p-\pi_0}{\sqrt{\frac{\pi_0*(1-\pi_0)}{n}}} \quad (1)$$

By using the tables of the normalised normal distribution, we find the critical value for the right-tailed test (2) for hypotheses 1 – 3 and the left-tailed test (3) in the case of hypotheses 4 – 5:

$$T > z_{2\alpha} \quad (2)$$

$$T < -z_{2\alpha} \quad (3)$$

Results and Discussion

Of the 520 respondents in the sample set, 306 (59%) were females, and 214 (41%) were male. The most numerous age category of respondents was from 21 to 25 years (41%), next - from 16 to 20 years (33%), and the smallest group of respondents was from 10 to 15 years (26%). Based on consumers' education, the most frequented category was consumers with a high school education (54%), while the social status student was predominant (62%). The results of the questionnaire survey show that 91% of respondents have encountered the term influencer marketing and know what the term means. The majority of them (89%) know this term most often from the Internet and other respondents from school and TV or radio. 35% of respondents perceive an influencer as "a personality with a great influence on their fans and followers", and 32% of respondents as "a well-known personality that people only know because of social media. Up to 72% of respondents follow at least one influencer on social media. Answering this question in the affirmative was crucial for the further continuation of the survey, as its other parts were dedicated to followers of influencers. Respondents most often follow influencers on Instagram (up to 57%), YouTube (35%), TikTok (31%) and Facebook (22%). Next, we investigated the impact of the influencer on the consumer's decision-making process and, thus specifically, whether it influenced their purchasing behaviour. The results of the questionnaire survey show that 48% of respondents have bought a product based on an influencer's recommendations at least once, 44% of respondents are not affected by influencers when purchasing, and only 8% of respondents indicate the influencer dissuaded them from buying. Regarding the post of influencers, respondents are most influenced and interested in more interactive posts such as video (36%), story (33%) and image or photo (21%). As the best content of influencers' posts, respondents indicate review of the product (47%), promo code for a discount (27%), contest (19%) and news (7%).

The results of our survey show some similarities as well as differences with previous investigations. For example, the research results by Zatwarnicka-Madura et al. (2022) also point out that Generation Z respondents prefer social networks Facebook, Instagram and YouTube. Social media is a crucial element of the modern world for the representatives of Generation Z, to which they devote much time. More than 80% of respondents systematically follow the activity of at least several influencers on social media networks, while almost every respondent follows at least four influencers. However, 38.8% of respondents primarily declared a high level of mistrust in influencers. This translates into little interest in activities promoted by influencers.

To verify the statistical hypotheses 1 – 5, we used the method of testing a single proportion. The results of the verification of these statistical hypotheses are shown in Table 1.

Table 1. Verification of statistical hypotheses (Source: authors)

Calculation of the sample proportion: $p = \frac{m}{n}$	**Satisfaction of the condition** $n * \pi_0 * (1 - \pi_0) > 9$	**Test criteria**	**Critical field**	**Inequality**	**Acceptance or rejection of the hypothesis**
Hypothesis 1: H_0: 50% of Generation Z consumers follow at least one influencer on social networks. H_1: More than 50% of Generation Z consumers follow at least one influencer on social networks.					
p = 0.72	130 > 9	10.03	1.645	10.03 > 1.645	H_0 rejected
Hypothesis 2: H_0: 50% of Generation Z consumers prefer Instagram when following influencers. H_1: More than 50% of Generation Z consumers prefer Instagram when following influencers.					
p = 0.57	130 > 9	3.19	1.645	3.19 > 1.645	H_0 rejected
Hypothesis 3: H_0: 50% of Generation Z consumers primarily follow influencer posts in the form of short videos and stories. H_1: More than 50% of Generation Z consumers primarily follow influencer posts in the form of short videos and stories.					
p = 0.69	130 > 9	8.67	1.645	8.67 > 1.645	H_0 rejected
Hypothesis 4: H_0: Regarding the content of influencer posts, 50% of Generation Z consumers prefer a review of the product. H_1: Regarding the content of influencer posts, less than 50% of Generation Z consumers prefer a product review.					
p = 0.47	130 > 9	-1.37	-1.645	-1.37 > -1.645	H_0 accepted
Hypothesis 5: H_0: 50% of Generation Z consumers have bought a product based on an influencer's recommendations at least once. H_1: Less than 50% of Generation Z consumers have bought a product based on an influencer's recommendations at least once.					
p = 0.48	130 > 9	-0.91	-1.645	-0.91 > -1.645	H_0 accepted

Table 1 shows that in hypotheses 1 – 3, the inequality applies, so we reject hypothesis H0, i.e., accept the alternative hypothesis H_1. On the contrary, in hypotheses 4 – 5, the inequality does not apply, so we accept hypothesis H_0.

It is evident that influencer marketing has become one of the most popular digital marketing tools. Influencers can naturally and very effectively implement product promotion into their profile activity and arouse buyers' interest. The advertising world has also begun to realise the importance of authenticity that influencers bring, as opposed to celebrities with a prescribed script. It is obvious that consumers trust influencers more than traditional advertising, for example, on television.

Based on previous research (Casalo et al., 2020; De Veirman et al., 2017; Duffet, 2017, 2020; Gajanova, 2018; Greskova, 2017; Pozharliev et al., 2022) and confirmed by our survey, it is possible to claim, that Generation Z perceives influencers positively. The majority of Generation Z follow at least one

influencer on social media, while almost half of them indicated the impact of the influencer on their decision-making process. However, this number may actually be higher, but consumers are not aware that they are making decisions based on influencer promotion. First of all, it is essential to realise the benefits of influencer marketing for the company. It is evident that influencers mostly have a positive effect on purchasing behaviour (Ladrova, 2017; Pick, 2021); thus, it is desirable that companies consider including them in advertising activities. While well-known celebrities do not bring enough credibility to the customer today, it could be appropriate to focus on an influencer who is similar to an everyday person and shows his private life, and thus the customer can identify with him better. The majority of Generation Z trusts an influencer more than a well-known celebrity. Their authenticity has brought them a high level of trust and authority with the consumer who follows them, and they want to identify with them.

However, a successful application of influencer marketing requires the correct selection of the influencer according to his follower base, profile focus, credibility or reach, which is measured by Engagement rate. The number of followers is not as important as the relationship that the creator has with their fans. It is also essential to choose the suitable social media on which the company wants its product or brand to be promoted. In Slovakia, the most popular social media among Generation Z include Instagram, Facebook, YouTube and TikTok, which is becoming increasingly popular. When choosing an influencer, it is also necessary to take into account the way they promote products, ask them for originality and creativity, and prefer long-term collaborations to one-time contributions. These steps can bring a lot of benefits to the company, from which it will subsequently profit.

The difference in the reach of influencers is often not only related to the number of followers, but a more meaningful indicator is the quality of their followers. This fact is measured by the Engagement rate, which is an indicator that shows the percentage of people who saw the content and subsequently reacted to it. This indicator is freely available for the company on many websites.

As for the actual implementation of the marketing campaign, consumers prefer images, videos or stories, i.e. the types of posts that are typical for social media. Regarding content, a promo code for a discount, a review or a competition attracts the most consumer attention. These responses did not vary much by generation, so it is the most appropriate type of post to engage and attract people to a business profile or even purchase it.

It is also vital for the company to find that consumers generally prefer long-term collaborations or ambassadorships to one-off collaborations between an influencer and a company. This statement is shared by many experts who claim that ambassadorship is the most suitable form of influencer marketing, which can benefit the company, the consumer and the influencer himself. It is, therefore, advisable to find an influencer who fits the company's focus and can natively present the product to his followers. If an influencer is so identified and satisfied with a business and its products that he decides to become a brand ambassador, his follower has no reason to question the recommendations or reviews he shares, which creates strong credibility between him and the follower.

However, this trust can also be affected by the number of collaborations on the profile. If a high percentage of posts on an influencer's profile is created in paid collaboration with a brand, the consumer could get the feeling of being sold and not trust such an influencer. Such influencers are often not creative in promoting the product, and their execution is often devoid of ideas and originality.

Conclusions

Based on the research, it is evident that the application of influencer marketing can be an effective way to affect the decision-making process of Generation Z. It can bring many benefits, such as building relationships with Generation Z, increasing their loyalty and improving the company image. Among other advantages, we can include acquiring new customers, which will subsequently be reflected in the increase in companies' sales, and optimisation of communication between the company and the Generation Z customer, which will be reflected in more effective feedback acquisition. Thanks to these benefits, the company can gain a competitive advantage.

The presented article follows the above that the issue of influencer marketing and its impact on the decision-making process of Generation Z has excellent potential for further research. It would be appropriate to examine and compare the differences in perception of influencer marketing by particular age groups and genders of Generation Z because this generation has a homogenous characteristic in certain areas, and at the same time, on the contrary, it is a very heterogeneous group.

However, the crucial limitation in our research is its territorial validity, i.e., national and cultural specifics of consumers from the Slovak Republic. This means that it is not possible to effectively apply these claims and recommendations to foreign implementation of influencer marketing in practice. So, when using influencer marketing, it is necessary to consider cross-cultural differences and modify the promotion through influencer marketing under the cultural characteristics of consumers. Influencer marketing in accordance with recipients' cultural characteristics is more effective because there is a different perception and response to promotion through influencers due to the cultural aspects of consumers.

Next, the results of the marketing survey and, thus, the applicability of the suggested recommendations are fully valid only in the case of consumers Generation Z. This means that it is not entirely possible to apply these claims and recommendations to general practice effectively.

On the other hand, the limitation mentioned above can be removed if the research is focused on consumers of the selected generational cohort, and in the case of foreign consumers, national and cultural specifics will be considered. Then the research results could be considered relevant and appropriate to use in the international environment.

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ITEM MATCHING MODEL IN E-COMMERCE: HOW USERS BENEFIT

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Abstract

Research purpose. During the last decades, e-commerce sales have been rocketing, and this tendency is expected to increase over the following years. Due to the digital nature of e-commerce, one actual item can be sold on various e-commerce platforms, which leads to the exponential growth of the number of propositions. At the same time, the title and description of this item might differ. All these facts make more complicated for customers the process of searching on online platforms and change business approaches to the development of competitive strategy by e-commerce companies. The research question is how we can apply a machine learning algorithm to detect, based on the product information such as title and description, whether the items are actually relevant to the same product.

Methodology. We suggest an approach that is based on a flexible textual data pipeline and the usage of a machine-learning model ensemble. Each step of the data processing is adjustable in dependence on domain issues and data features because we can achieve better results in solving the item-matching task.

Findings. The item-matching model is developed. The proposed model is based on the semantic closeness of text descriptions of items and the usage of the core of keywords to present the reference item.

Practical implications. We suggest an approach to improving the item searching process on different e-commerce platforms by dividing the process into two steps. The first step is searching for the related items among the set of reference items according to user preferences. The reference item description is created based on our item-matching model. The second step is surfing proposals of similar items on chosen e-commerce platforms. This approach can benefit buyers and sellers in various aspects, such as a low-price guarantee, a flexible strategy of similar products shown, and appropriate category-choosing recommendations.

Keywords: E-commerce; Item matching; Model; Entity resolution; Business Management; Marketing; Digitisation.

JEL codes: M30; M19; O31

Introduction

E-commerce has been an essential part of our lives in recent years. According to the Trend report "eCommerce in Europe" (eCommerce in Europe, 2023) value of this market in Europe is expected to grow by 12% per year between 2020 and 2026. A lot of e-commerce shops work in this market, and they suggest a wide range of goods of different categories and brands, such as foods, electronics, shoes, clothing, etc., produced by different manufacturers. At the same time, the same real-world products are sold by different e-shops. These tendencies impact both customers and sellers.

On the one hand, customers spend a lot of time searching for necessary items because they have to compare items from different online platforms, their descriptions, and photos; also, they have to solve the issue if these items are the same or only similar, and only after that customers are able to make a decision about buying the item which they were looking for. On the other hand, sellers spend a lot of time analysing the e-commerce market to assess the demand and supply of goods, and the price policy of their competitors in an attempt; as a result, to be competitive and to save their market share. So, the task of developing an item-matching model is relevant to nowadays requirements of sellers and customers of e-commerce platforms.

The product offers on e-commerce platforms usually include titles, text descriptions and images. To identify specific product items, attributes should be extracted for further processing. One of the main features of product descriptions on different online platforms is their heterogeneity with different levels of detail. However, some retailers have started to provide product offers with structured or semi-structured specifications and semantic annotations (i.e., Microdata markup). On the one hand, it makes the process of item-matching easier, but on the other hand, new challenges of entity resolution are rising. As one of the product characteristics, image processing can also be involved in the item-matching process.

As has been stated above, the problem of identifying similar products is vital for all participants in the e-commerce market. The main aim of our research is to develop a method which makes the search process on e-commerce platforms less complicated for both customers and sellers. To answer the research question, we propose a flexible textual data pipeline, which counts the speciality of domain and data, and a set of machine learning models to provide data processing. As a result, we developed an item-matching model based on the semantic connection of item text descriptions and running the tag core to represent reference items.

Literature Review

Product matching is a specific part of the Entity Resolution problem. The main goal of product matching is finding the most suitable item according to preference records. This issue has been explored for more than 30 years. Usually, researchers focus on the type of task (classification, clustering, etc.), the similarity metrics and the data features (unstructured, annotated, etc.).

In Köpcke et al. (2010), for similarity calculation, the authors used different non-learning approaches (COSY, PPJoin+) and learning-based match approaches (support vector machine, decision tree) for bibliographic and e-commerce data entities. Obtained results showed low match quality for the e-commerce domain and proved the necessity of further improvements by using other similarity measures or changing characteristics of the learning-based approach.

Product titles identify the product, but on different online platforms, the title of the same product can vary, and, as a consequence of that, traditional similarity measures may not show satisfactory results for matching item titles. Gopalakrishnan et al. (2012) proposed an unsupervised approach for solving item-matching problems based on the similarity of item titles. They proposed to enrich item titles with missing words which frequently appear in search engine results and calculate token weights based on their ability to enrich titles from search results; for matching-title pairs, authors proposed to use the Cosine similarity. In their experiment, they explored titles of cameras and appliances and such missing tokens as brand and model number; the following works planned to explore titles of products which may not consist of such representative tokens. Akritidis et al. (2018) also proposed clustering item titles to solve the item-matching problem; however, their approach did not depend on external search engines and was based on morphological analysis of items titles and consisted of two phases: construction of k-combinations of words and providing same statistics; usage forward index and statistics to define representative cluster tag of the item. Obtained results approve the necessity of solving the problem of incorrect division of identical items in different subsets.

Some researchers considered the item-matching problem a classification issue (Kannan et al., 2011, Köpcke et al., 2012). Kannan et al. (2011) used an approach based on exploring the semantics of item descriptions and finding the probability of items. To provide this approach, the authors used two datasets

with structured and unstructured data, with the main goal of matching records from the unstructured dataset with one or several structured records. The developed system is able to use any domain with offers and a storehouse of structured data. In contrast to the approach (Kannan et al., 2011), some researchers proposed a matching approach based on pattern extraction of Universal Product Code to identify similar items (Köpcke et al., 2012). Results showed low quality, so the authors planned to investigate the usage of other methods to improve the suggested approach.

Some online platforms use specific product identifiers (GTINs, EANs). The work suggested using schema.org annotations to cluster items from different sellers related to the same item and learn matcher using this clustering as a distant control (Peeters et al., 2020).

Four deep learning (DL) solutions (SIF, RNN, Attention, and Hybrid) are provided for matching text (Mudgal et al., 2018), the so-called framework Deepmatcher. The authors focused on the fact that DL could better solve this task instead of classical learning-based entity matching due to its ability to obtain good results on raw data. Four DL models and the Magellan EM system (decision tree, random forest, Naive Bayes, SVM and logistic regression) were applied to compare obtained results. They made experiments on 32 datasets of different sizes and from different domains: 11 of them are structured datasets, 6 datasets are textual and 6 dirty datasets. Experiments showed several challenges: DL models need a large quantity of training data to obtain good results, and limited capability of DL models to understand semantics from different domains. Primpeli et al. (2019) planned to repeat the results obtained by Mudgal et al. (2018). For the experiment, the researchers created a training dataset from schema.org annotated item descriptions; the total amount of records was 26 million, and 16 million clusters were created touching on the same items. Upon evaluating matching results, the gold standard dataset was created. The authors concluded that their results proved the results obtained by the previous researchers (Mudgal et al., 2018) about the advantage of using DL methods on textual data.

Other researchers also suggest using deep learning models, e.g., the task of product matching was solved (Peeters et al., 2020) by applying the BERT model, and obtained results proved higher efficiency in comparison with the Deepmatcher results (Mudgal et al., 2018).

Pre-processing is an important part of the successful solution of the product-matching task. The most challenging step is vectorising of data representation because all approaches of item-matching require numeric data, but the product description is text and image. Vectorising is used in text pre-processing to make any text machine understandable. Changing textual information in purposeful vectors allows using these word embeddings in further text processing, such as text classification, text clustering, sentiment analysis, etc.

There are some powerful approaches to vectorise the text. Mikolov et al. (2013) set to explore the combination of RNN and NLMs to obtain improved word representations for morphologically complicated words. The main goal of Singh et al. (2019) is to recognise unifiable news articles. So, the authors investigated different vectorisation techniques and obtained document embeddings for further document classification. They noticed that vectorisation methods, such as Word2Vec, TF-IDF, GloVec, SenteceToVec, and Doc2Vec, capture only semantic and syntactic meaning of words which are suitable for the task of clustering and classification but not very useful for more complicated tasks. More context-dependable embeddings can be obtained using ELMo, and BERT. Other researchers (Darú et al., 2022) used TF-IDF technique in pre-processing stage for performing the classification of item descriptions in Portuguese. Other authors (Krzeszewska et al., 2022) estimated if the choice of vectorisation technique influenced results of classification results in large text datasets; they made the conclusion that the accuracy of classification depended on the method of vectorisation. Researchers in the paper by Yang et al. (2022) proposed using the topic model (Yang et al., 2020) and BERT model to calculate the similarity between texts. The dataset used for the experiment consists of 1,02 GB of new text data. The authors compared the results of similarity estimation by using their proposed topic model and traditional TF-IDF on the step of keyword extraction. They proved their hypothesis that the new approach would perform better than the traditional technique because of its reflection of semantic relationships between words.

In our previous works, the issue of product matching was explored. In the paper (Cherednichenko et al., 2018), we collected data about mobile phones from different e-commerce platforms and grouped them

by similar features; this experiment showed rather good results because most phone characteristics are quantitative. However, many other items sold on online platforms often do not have such exact characteristics, so in another attempt of ours (Cherednichenko et al., 2020a), we provided an approach of item-matching based on the customer perception of items and their similarity. The results of our experiment showed a good perspective of combining text description and assessment of images with building an item-matching model. Also, taking into account the heterogeneity of text description of goods and the vast amount of propositions of goods, in our subsequent work (Cherednichenko et al., 2021), the reinforcement learning approach was explored. The developed model makes a search query from the obtained core of tags combined with different keywords.

Further experiments showed the dependency of results on the main platform during the core of tag building. Our further research has proved the necessity of creating some flexible methodology which allows changing setups depending on searching goals, types of data, etc. In Cherednichenko et al. (2022), we proposed constructing a flexible processing data pipeline for product categorisation. The main feature of this developed methodology is its flexibility, so new methods and the order of steps of processing data can be changed to obtain the goal.

Thus, we can summarise that despite the great interest in the product-matching task, there are a lot of open issues. Our previous research found some valuable techniques for item grouping, tagging, pipeline construction, etc. As the state-of-the-art shows, the machine learning models are promising enough to solve product-matching tasks. Therefore, the research question is how we can apply a machine learning algorithm to detect, based on their product information such as title and description, whether the items are relevant to the same product.

Research Methodology

The product-matching task is an essential step in e-commerce platforms, as it helps to streamline the buying and selling process and provides a better user experience for all parties involved. It involves matching products based on their characteristics, such as their name, description, category, and other attributes. This task is commonly performed in e-commerce platforms, where multiple sellers may offer the same product but with slightly different names, descriptions, or prices. Product matching aims at identifying and grouping these similar products, providing a better user experience for buyers and helping sellers to compete on a level playing field.

We suggest a step-by-step approach to identify groups of similar products, create the tag core for each group, and search for relevant items on websites. We can summarise our previous results and suggest a novel method for product matching. Our method involves three key stages: first, we use machine learning algorithms to determine the similarity between items, enabling us to group them into relevant product categories. This step is critical in minimising the number of items that need to be processed, making subsequent steps more efficient.

Next, we create tag cores by extracting the most relevant keywords from the item descriptions. This allows us to capture the essence of each item and facilitate more accurate and efficient searching.

Finally, we use machine-learning models to search for items on e-commerce platforms based on the extracted tag cores. This step enables us to efficiently search for items that match the desired criteria while minimising the number of irrelevant search results.

So, firstly the text descriptions of items should be processed, vectorised and clustered. Based on our experience, we would like to highlight that the outputs strongly depend on input data. That is why designing the only model is unrealisable.

In general, text mining deals with issues of the inference of structured information from collections of unstructured input texts. Approaches that are applied in text mining require task-specific text analysis processes that may consist of several interdependent steps and are realised with text analysis pipelines (Wachsmuth, 2015). One of the main problems is that text analysis pipelines are mainly constructed manually because their design requires expert knowledge. Wachsmuth et al. (2013) suggested creating an automatic pipeline for annotation text, which can be presented:

$$\Pi = \langle A.\pi \rangle ,$$

where A is a setting of algorithms;

π is a schedule of performing each algorithm.

Each algorithm needs specific input data and time for performing, and it ends up with specific output data. Time for performing and some restrictions must be considered in the schedule. In their work (Wachsmuth, 2015), the authors continued their exploration of pipeline development; their goal was to construct an efficient pipeline. In this case, they focus their attention on the optimisation schedule. Some authors provided a data cleansing pipeline which joins several interrelated stages of creation training set for further processing to solve the item-matching issue (Peeters et al., 2020; Primpeli et al., 2019).

We can say that the aim of the first stage is to build a multi-class classifier which can predict the product category and create groups of similar items. The high-level steps are presented in Figure 1.

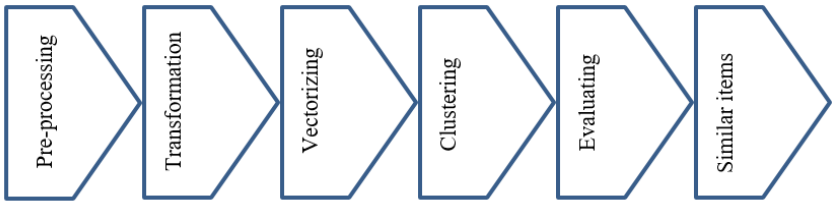


Fig.1. Pipeline of similar items' group creating

As shown in Figure 1, we suggest the following general steps:

1. Data pre-processing (extract text descriptions of items)

2. Data transformation

a. Removing articles (a, an, the), prepositions (in, of, at), conjunctions (and, or, nor), etc. from the item descriptions

b. Stemming

3. Vectorising

4. Clustering

a. Choosing the model

b. Experimenting

5. Evaluating the results of clustering

6. Creating groups of similar items.

The main goal is to make the pipeline as flexible as possible and allow users to change it (e.g., add their own functions, set their own order of action, and use other methods for data processing). As we found out, the clustering of item descriptions is related to the product category, language, data source, etc. The flexible pipeline gives the tool for researching the data and creating groups of similar items.

In one of our previous works, we suggested the creation of a flexible pipeline for solving the item-matching task. A pipeline is a chain of interdependent actions under data in which instructions transform data; the output data of one step is the input data of other steps. Our paradigm of the pipeline is as follows: given a set of unstructured item text descriptions, which are processed to obtain structured information. The main features of our pipeline are its flexibility and automation.

As similar items are created, we can describe each group as a set of keywords. Thus, the second step is to build the tags core for similar items.

Following the results in (Cherednichenko et al., 2020b), we hypothesise that if we know item groups with similar objects, then: 1) similar items have the same core of tags; 2) the group of a new item can be easily found if the core for a group of objects is known.

Having the cleaned tag list sorted by descending tag frequency, we can create the tags core based on the algorithm suggested in our previous work. This algorithm is based on the word2vec model and allows us to consider the semantic similarity of words.

The data pipeline of tag core creation is depicted in Figure 2.

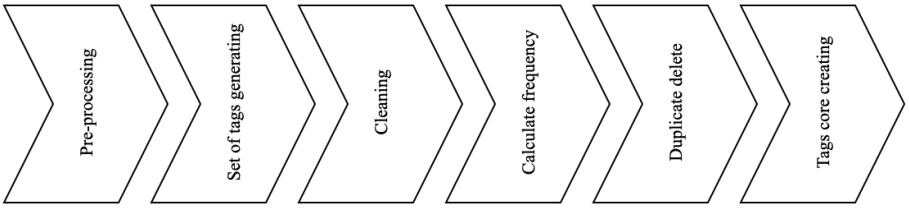


Fig.2. Pipeline of tags core creating

As shown in Figure 2, we suggest the following general steps:

1. Data pre-processing (represent each item as a set of keywords).

2. Generate the set of tags for the group of similar items.

3. Data cleaning (remove punctuation signs, numbers, out-of-vocabulary words, etc.).

4. Calculate the frequency for each tag to order the set of tags.

5. Delete duplicates.

6. Create the core of tags.

Thus, we have the tag core as a description of the group of similar items. It is the basis for searching for new items and categorising them. To build a similar item group, we suggest their text descriptions are similar in terms of semantics and apply some NLP techniques in the data pipeline. Despite the developed data pipeline, its flexibility is an important issue due to text data, as item descriptions are sensitive to each step of their processing.

Finally, the tag core can be implemented in the item-searching algorithm. We research the model using Reinforcement Learning (RL) approach (Cherednichenko, 2021). Reinforcement Learning has become increasingly popular in various domains owing to its successful applications. It is a machine learning type involving agent learning through interactions with an environment.

In our specific task, the agent interacts with an e-commerce platform by sending search queries. The environment responds with a list of items that match the query, ranging from a few to tens of thousands, making their processing quite challenging. The objective of the agent is to minimise the size of the list of items while obtaining a complete and accurate set of items that can be grouped into a single product category based on varying characteristics such as price, size, colour, and shipping, among others. The final-step pipeline is shown in Figure 3.

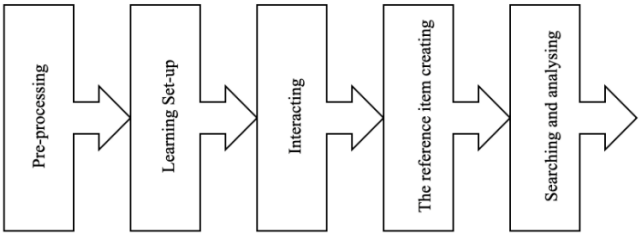


Fig.3. Item Searching

To implement the ideas of RL, we suggest the following steps:

1. Data Pre-processing (cleaning, tags core choosing, etc.).

2. Learning Setup:

a. Define the initial query.

b. Define the reward function.

c. Define the reference tags.

3. Interacting (query and evaluate the response).

4. The reference item creation.

5. Searching and analysing.

Overall, we propose a novel three-stage method that utilises machine learning algorithms for effectively identifying item similarity, creating a tag core, and searching items on e-commerce platforms. Our approach leverages a flexible textual data pipeline and an ensemble of machine learning models, allowing for adaptable data processing that can be tailored to specific domain issues and data features. By leveraging the power of machine learning, we can achieve accurate and efficient item matching, improving the overall user experience on e-commerce platforms.

Research Results

Let us provide the experimental results to show how the suggested approach can be applied and investigate how machine learning is beneficial.

Firstly, we experimented with similar item group creation based on vectorising the text description and clustering algorithm. As mentioned above, the flexible pipeline is a solution for this step. So, we consider the dataset based on items from Men's Shirts category. We collected the set of 381 item descriptions from Amazon.com (Amazon, 2023). After pre-processing text data (empty values drop, lowercasing, punctuation removal, etc.), we receive the set of tokens (pre-processed words) representing the items. Overall estimation of how pre-processing and cleaning work is depicted in Table 1.

Table 1. Overall estimation (Source: authors' contribution)

Number of the step	Step name	Dataset size	Size difference
1	Initial dataset	47 743,00	0,00
2	Non-alphabetic values drop	45 009,00	-2 734,00
3	Stop words drop	42 006,00	-3 003,00
4	Single characters drop	39 397,00	-2 609,00
5	Fully consonants values drop	32 745,00	-6 652,00

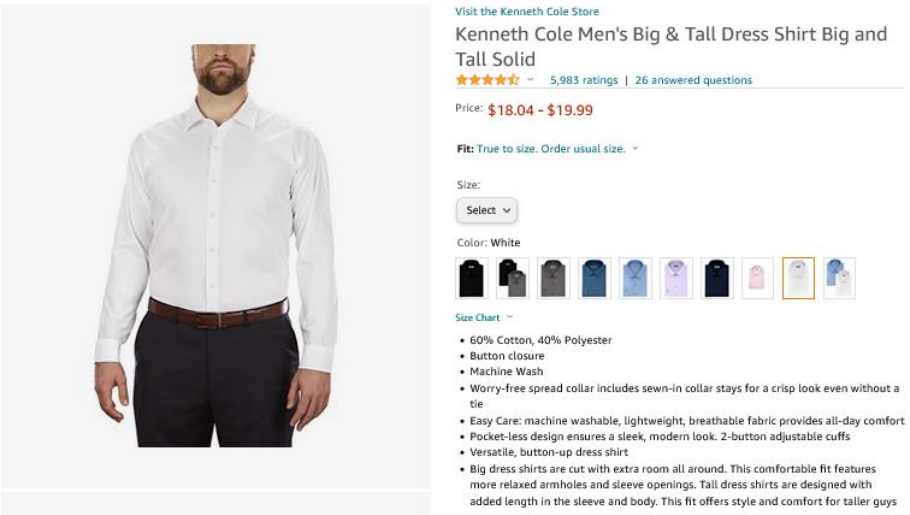
Number of the step	Step name	Dataset size	Size difference
6	Fully vowels values drop	32 562,00	-183,00
7	Unique values count	1 299,00	-31 263,00

Vectorising is a crucial step that can significantly influence the outcomes of clustering. We experimented with different vectorisers and implemented the K-means algorithm to group items. Table 2 shows the experimental results with vectorisers. We can notice that the vectorising model defines the outcomes, but the choice of the model should be made only based on a series of experiments. The suggested pipeline allows playing with different models to find the best one.

Table 2. Experimental results with vectorisers (Source: authors' contribution)

Vectorisation model name	Cluster id	Elements number Total
spaCy Tov2Vec model	1	229
	2	152
Custom-trained Word2Vec model	1	354
	2	19
	3	8
Google trained Word2Vec model	1	24
	2	125
	3	83
	4	37
	5	112

To perform the next step of our pipeline, we have chosen Google trained Word2Vec model with five clusters. As an example, descriptions and photos of similar items from cluster 2 due to chosen clustering model are shown in Fig. 4.



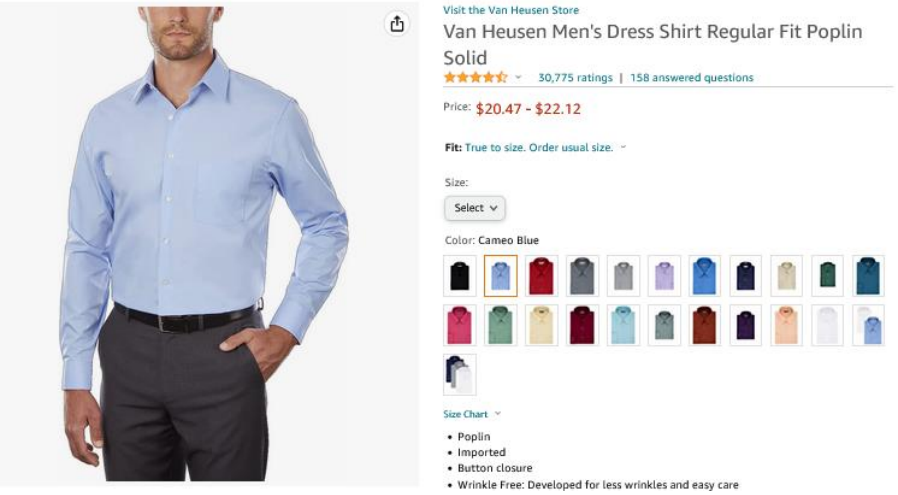


Fig.4. The examples of similar items (Source: extracted from Amazon, 2023)

The next step of the suggested method is the creation of the tag core for the cluster with similar items. In this step, we use the algorithm based on the word2vec model and the frequency of obtained tags in previous steps. The results of performing the second stage are represented in Table 3. The tag core was created for each group of similar items. As a similarity measure, we applied a cosine metric to compare vectors which represent keywords of the item description. We have played with different levels of thresholds, and the outputs obtained with a threshold equal to 0,75 are depicted in Table 3.

Table 3. The results of performing the second stage (Source: authors' contribution)

Clustering method	Cluster Number	The tag core (for similarity value > 75)
Google trained Word2Vec model	1	Snap, fit, shirt, button, flannel, comfort
	2	men, solid, dress, shirt, long, sleeves, button, regular
	3	short, sleeve, shirt, button, polo, casual
	4	western, fit, shirt, button, down, denim,
	5	long, sleeve, shirt, zip, casual, athletic, golf, men

Thus, the result of the second step of the proposed method is the sets of tag cores for each group of similar items. For further experimenting, we chose the tag core of the second cluster with the largest quantity of elements. The tag core we experimented with is 'men, solid, dress, shirt, long, sleeves, button, regular'. We presupposed that the tag core describes reference items for further searching on different e-commerce platforms. So, we try to search for items which are similar to the reference item.

Searching for items in accordance with customers' demands is the next step of our pipeline. To perform it, we chose the most popular online shops Anna Baluch (Baluch, 2023), Amazon (2023), Walmart (2023), eBay (2023) and AliExpress (2023). Searching was performed on the first seven pages of mentioned online platforms to check the relevance of created tag core. In our experiments, we use the obtained tag core to create a search query. The total match percentage and match percentage for the first pages of every considered online platform are shown in Table 4. In order to illustrate the results of this experiment, we made screenshots of the search results from different e-commerce platforms. We evaluate the results manually based on descriptions and images obtained from websites. The search results with photos and product titles are presented in Figures 5 to 8.

Table 4. The total match percentage and match percentage for the first pages of every considered online platform (Source: authors' contribution)

Online platform	Obtained results	The 1st-page match, %	Total match, %
Amazon	420	93,33%	79,76%
AliExpress	420	76,67%	70,71%
Walmart	280	92,50%	68,57%
eBay	420	90,00%	78,33%

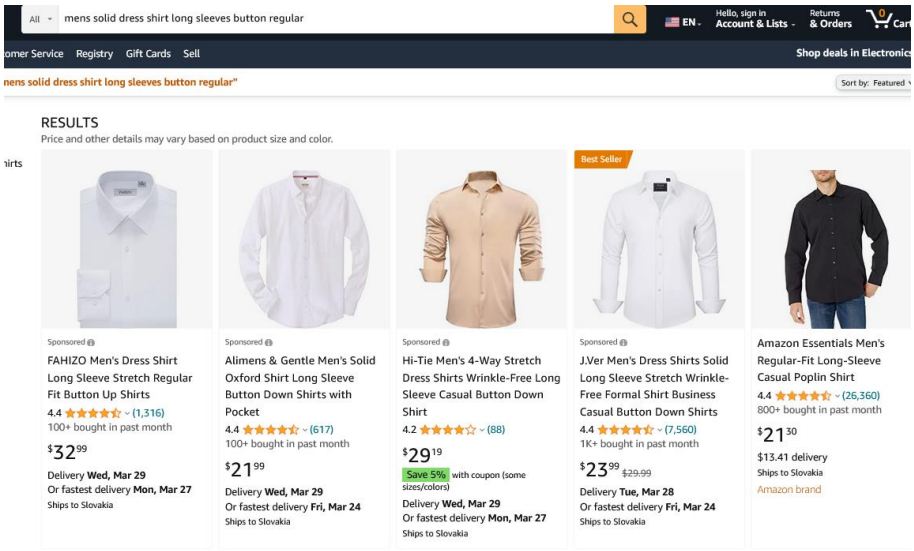


Fig.5. Results of searching query on Amazon (screenshot from Amazon, 2023)

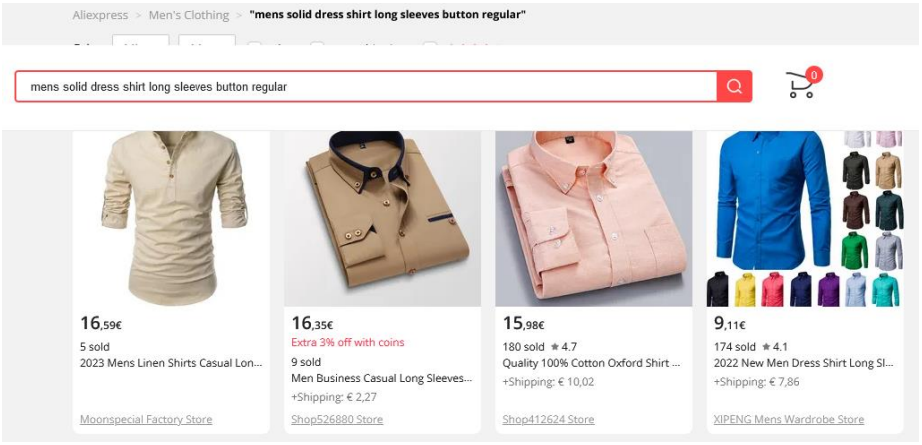


Fig.6. Results of searching query on AliExpress (screenshot from AliExpress, 2023)

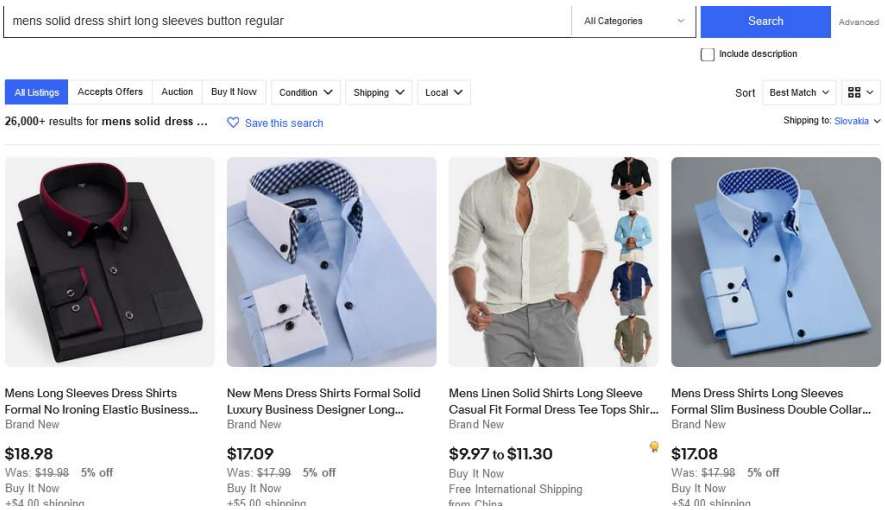


Fig.7. Results of searching query on eBay (screenshot from eBay, 2023)

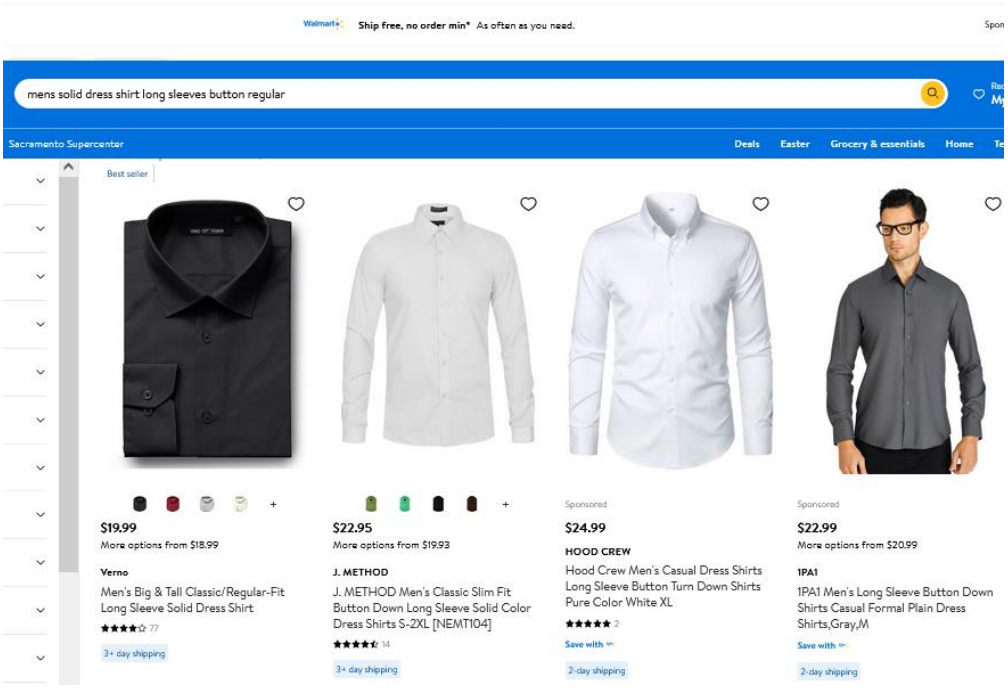


Fig.8. Results of searching query on Walmart (screenshot from Walmart, 2023)

We can see a high percentage, more than 90%, of results, match the first pages of every online platform except AliExpress. The total match percentage for every online platform is lower than for the first page. It is not easy to reach high quality because of the diversity in item descriptions. However, it is 75% on average, which proves the relevance of created tag core for searching for relevant items on different e-commerce platforms. Like the previous experiment (Cherednichenko et al., 2021), the current experiment proves that the best results we obtained on the e-commerce platform where we had collected data.

Discussion and Conclusions

In this work, we propose a three-stage pipeline to identify similar items. As a result of experimenting, we obtained a high match percentage of performing search queries in the most popular online shops (Baluch, 2023) Amazon (2023), Walmart (2023), eBay (2023) and AliExpress (2023). To perform product matching, various techniques can be used, including natural language processing (NLP), machine learning, and fuzzy matching algorithms. NLP techniques can be used to extract relevant information from product names and descriptions, such as keywords and synonyms, while machine learning models can be trained to identify similarities between products based on their text descriptions. Fuzzy matching algorithms can help to match products based on similar names or descriptions, even if they are not exact matches. So, we can summarise that we need to apply different machine-learning techniques to implement the suggested pipeline and improve the results of product matching.

Different e-commerce platforms offer varying methods for sellers to publish their products on the platform. For instance, Amazon, eBay, and others allow users to become sellers and add products themselves, which can increase the number of products available. However, inconsistencies may arise when adding new products and assigning categories. Misclassifying a product can lead to difficulty finding the correct item, making proper categorisation critical for all e-commerce platforms. This ensures efficient product search and better user experience by highlighting the correct categories.

To address these issues, an automatic tool capable of classifying any product based on its title within the product taxonomy is needed. This approach not only facilitates human work but also enhances the consistency of product categorisation on e-commerce websites.

The idea of creating a pipeline for text processing is not new. The analysis of information resources shows a lot of successful implementations, but most of them are not flexible or require special skills from users. Some researchers developed a pipeline that prepared a training dataset for further use of different methods to solve the item-matching problem (Peeters et al., 2020; Primpeli et al., 2019). The Magellan Entity Matching system (Konda, 2018) was developed to solve entity-matching problem, but it was not automated and focused on skilled users. Also, SpaCy (2023) provides users with the opportunity of creating their own pipeline based on default or customer-created functions. The Scikit-learn pipeline (Scikit-learn, 2023) is instrumental when users want to chain multiple estimators into one. In both mentioned pipelines, users are considered to have developer skills. In comparison, the suggested approach consists of all stages of identifying item similarity and searching reference items on different e-commerce platforms; also, it is oriented toward e-commerce managers who are not specialised in programming.

Our approach has the potential to benefit all players in the e-commerce market. For consumers, the proposed method can significantly reduce the time required to find the desired item on different online platforms. The quality of search results will also be significantly improved compared to manual searching, as the machine learning algorithms can effectively identify and group similar items, reducing the number of irrelevant search results.

For sellers, the proposed pipeline can provide valuable insights into their competitors' offers and pricing strategies. By using machine-learning models to search for similar items on competitive online platforms, sellers can easily compare prices and offers to optimise their own marketing strategy. This can help sellers attract new customers and increase sales by providing better value propositions and more appealing designs.

Furthermore, the ability to quickly adapt to changing market trends and customer preferences is critical for e-commerce sellers to remain competitive. With our approach, sellers can easily adjust their marketing strategy to capitalise on new opportunities and entice new customers. This can lead to increased customer loyalty and brand recognition, helping sellers to establish themselves as leaders in their respective markets.

Thus, our proposed method has the potential to significantly enhance the e-commerce experience for both consumers and sellers, making it easier and more efficient to find and sell items online.

In our following works, we plan to explore other algorithms to identify similar items to study the influence of their results on the quality of performing the last step of our pipeline, searching items on e-commerce platforms.

Acknowledgements

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FINANCIAL LITERACY OF CUSTOMERS OF THE SELECTED SLOVAK BANK AS A BASIS FOR MANAGERIAL DECISION-MAKING

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Abstract

Research purpose. The main goal of the article is to determine the current level of financial literacy among clients of the selected bank in Slovakia. This finding will be compared with the average level in the country. In the survey, we focused on determining their financial literacy level. Currently, a lot of attention is paid to the issue of financial literacy. In connection with financial literacy, a lot is said about education. Therefore, in the paper, we focused on finding out the relationship between financial literacy and the level of education as such. We also compared the financial literacy of the survey sample with the overall financial literacy in Slovakia.

Design / Methodology / Approach. For the purposes of this article, an anonymous online questionnaire survey focused on the financial literacy of customers of the selected bank was conducted. By analysing theoretical knowledge and existing surveys, we established hypotheses, which we subsequently verified statistically. When analysing theoretical knowledge and surveys in the Slovak Republic, we found that there is a large number of surveys focused on financial literacy. The output and support of each of them are primarily focused on increasing financial literacy through education. We, therefore, assumed, given that financial literacy has been in the curriculum of primary and secondary schools for several years, that financial literacy is related to the availability of goods. We also assumed that financial literacy in the Slovak Republic is increasing. To verify the hypothesis, we used two statistical methods - the Chi-Square test and the Mean Congruence Test. The reason for choosing customers of a specific bank for the purposes of our survey was the number of respondents' answers. We managed to collect the most answers for the bank mentioned.

Findings. Through the selected statistical method, we found that in our survey, the number of correct answers is not affected by the level of education. It was also interesting to find that the level of financial literacy of the selected region in 2022 is not higher than the overall level of financial literacy of the Slovak Republic determined on the basis of a survey from 2012.

Originality / Value / Practical implications. The proposals and recommendations that emerged from the survey relate to increasing the financial literacy of customers of the selected bank. We focused our recommendations on education and conducting surveys, both for customers and for the bank's management. The bank can use these recommendations as a basis for managerial decisions. It is necessary to increase the financial literacy of customers. It is also necessary to support the field of marketing, especially communication with customers. It is only up to the management of the bank to decide which customers it will have and how it will retain or expand them.

Keywords: Financial literacy; Customer; Management; Managerial decision-making.

JEL codes: G53; M29

Introduction

People naturally tend to fulfil their desires and demands while having only a limited amount of financial capital. The financial decision-making challenges cannot be matched by those faced by previous generations (Beranova et al., 2020). The financial environment, together with its digitisation, has become more demanding and unpredictable, which results in an increase in significant financial problems that people have to face (Dare et al., 2020). People with a low level of financial literacy, without basic financial knowledge and skills, do not know how to make sound financial decisions or manage crisis financial situations. While previous generations used to buy goods and services almost exclusively in the form of cash payments with the cash they had, over the past decade, various financial products and services have become widespread in society. Today, it is possible to use products such as credit cards, consumer loans, or mortgage loans. Products, as well as insurance and investment services, have also gained importance. Nowadays, people are afraid to put money into investment funds or securities (Stankeviciene & Petroniene, 2019). Empirical studies show that limited participation in the securities market is caused by a lower level of financial literacy (Caplinska & Ohotina, 2019). Individuals who have entered the financial markets are increasingly active due to the wide range of financial goods and services offered at this location (Ozkale & Erdogan, 2020). This fact makes it more important today than at any time in the past to understand how to use these products effectively and, above all, responsibly.

For a proper understanding of financial literacy, it is necessary to know what the concept of financial literacy is, what affects it, and what other literacy skills it is related to. It is necessary to know basic financial concepts, which are essential for acquiring a level of financial literacy and for use in practice. The main goal of the contribution is to find out the current state of financial literacy in the selected region of the Slovak Republic. We focused on bank clients, as the rational use of funds depends on their financial literacy, which can be a starting criterion for banks and client assessment. For this reason, we consider the focus of our research to be necessary.

Literature Review

There are many definitions in various professional literature or discussions on the concept of financial literacy. They all have the same essence: the ability to navigate one's own money and manage it properly so that people are not surprised by an unexpected economic situation (Filippini et al.,2021). Financial literacy refers to knowledge of financial products such as the differences between a share and a bond, as well as financial terms, such as inflation and interest rates (Hastings et al., 2013).

Gedvilaite et al. (2022) define financial literacy as the ability to use knowledge, skills, and experience to effectively manage one's financial resources to ensure lifelong financial security for oneself. The authors Pearson & Korankye (2022) explain the issue as a necessary process that constantly acquires abilities, knowledge, and skills that enable people to function economically independently, both in their families and in society. Basic principles should apply that everyone should understand as a whole, such as a correct understanding of the essence of money, constant control of money, the disposition to earn and save money, properly invest money, the ability to build assets, and its sufficient protection against various risks (Skagerlund et al., 2018). According to Bongini et al. (2018), financial literacy is the set of knowledge, skills, and value attitudes of a citizen necessary to financially secure himself and his family in today's society and actively participate in the market for financial products or services. According to Kawamura et al. (2021), financial literacy is a whole that consists of three parts, which are monetary literacy, price literacy, and budget literacy:

- financial literacy - the ability to properly handle cash and non-cash funds and transactions related to them, such as managing current bank accounts and using payment instruments;
- price literacy - understanding inflation and the tax system;
- budget literacy - the ability to manage a personal, family budget.

Constant monitoring of one's own income and expenses in the budget provides the ability to manage various unwanted situations or establish a family plan for the future. We have savings if income exceeds

expenses (Unruh et al., 2016). If expenses exceed income, a budget deficit arises, meaning households or individuals are in debt (Ho & Lee, 2020). When managing personal finances, an individual is influenced by skills and abilities such as:

- reading literacy - the ability to understand text that is found in various forms that are obtained through communication and information technologies;
- information literacy - the ability to correctly perceive, understand, and evaluate information based on the truth of the information, its purposefulness, and its reliability;
- legal literacy - the legal skills and knowledge required to enforce one's rights and obligations (Folke et al., 2021; Litvinova, 2018).

Based on the above knowledge, we can state that several authors agree on financial literacy.

Many people do not realise the value of money, which is often used for unnecessary purposes. Nowadays, we are affected by various types of aggressive advertisements, which tend to influence even a financially literate person. The essence of promotion is to create a desire to own a given good or service, which leads to a purchase. Often, many buyers do not have enough money, but their desire to own the advertised product is much greater than the fact that they lack money. Companies have an answer to the problem of lack of money, which is a short-term consumer loan. If this option is not available, another option is a non-purpose consumer loan from financial institutions, among which we can include commercial banks. If a commercial bank refuses to provide a loan due to the client's poor credit rating, a situation arises where most people consider whether the given product is necessary at all. If this has not happened, the last option is a loan from a non-bank institution, which will provide a loan even if the client has a bad credit rating. Many of these loans have high interest rates and fees that cause a default or the loss of assets. In addition to the negative impact on households, indebtedness also has consequences for the country itself, namely the likelihood of financial crises, which deepen their consequences and reduce the economy's growth potential (Fabova, 2017). It is essential to be financially educated because "bad financial decisions can push households closer to the poverty line" (Jerrim et al., 2022). Financial education was not considered a key subject in the development of individuals, which could disrupt their ability to find the optimal solution, especially in economic activities (Abad-Segura & Gonzalez-Zamar, 2019). It is necessary to make efforts through education and gain experience because financial literacy cannot be inherited or simply acquired (Al-Bahrani et al., 2018). People should acquire financial literacy from childhood, especially from their parents, because the main source of information for developing financial knowledge is their parents (Lucic et al., 2020). If the parents' financial literacy is low, there is a high probability that their offspring will have similar tendencies. Various educational institutions, especially schools, help the youth change these habits (Nemeth et al., 2022). Financial literacy is essential for young people as they face various financial decisions that can have important consequences throughout their lives (Lusardi, 2015; Sari & Fatimah, 2017). Improving financial literacy among adults is problematic because it is difficult to influence them in the usual ways.

Over the past decades, various foreign and domestic organisations have conducted surveys on the level of financial literacy. We consider the PISA 2018 survey, under the auspices of the OECD organisation, and the second HFCS survey of the third wave from 2017, dealt with by the NBS and the Statistical Office of the Slovak Republic, to be the most significant. PISA is a three-year survey of the international assessment of 15-year-old students from all over the world that was launched by the Organization for Economic Cooperation and Development (OECD) in 2000. According to the PISA 2018 survey, Slovakia's overall result was a score of 481 points, which statistically indicates that it is below the average level of the OECD countries. The average OECD score is 505 points. Comparable performance to Slovakia is achieved by Italy, which was ranked one rung lower with a point score of 476 points. Overall, the worst in the survey is Indonesia, with 388 points, and the best is Estonia, with 547 points. The results of this research are an important starting point for understanding the formation of financial literacy. Financial literacy begins to form in people already at school age. Since 2010, the Household Finance and Consumption Survey project has collected data on household income, consumption, and wealth (tangible and financial assets, financial liabilities) at three-year intervals (Kucserova & Strachotova, 2019). The intervals were divided into three waves: the first in 2010, the second in 2014, and the third in 2017. This project is managed by the European Central Bank. Based on the HFCS

project, the results of the third wave, which was implemented in 2017 with the help of the National Bank of Slovakia and the Statistical Office of the Slovak Republic, are summarised.

Based on the results of the third wave of the HFCS 2017, it was concluded that the dependence between education and financial literacy was confirmed (Kucserova & Strachotova, 2019). When answering the questions, it was found that the higher the level of education, the higher the number of correct answers in the survey. However, the overall result of the HFCS survey pointed out that the level of financial literacy in the Slovak Republic has slightly deteriorated compared to the second wave. Based on the analysis of official theoretical surveys, we decided to carry out research in the subject area, which would reflect current aspects of the given issue.

Research Methodology

A research method is a way of conducting research. It depends on a certain selection and organisation of research activities, while this learning method is planned and suitable for multiple uses. For the purposes of this contribution, an anonymous online survey was conducted that focused on the financial literacy of the selected region. We chose residents who live in the Trencin region in the territory of the Slovak Republic and subsequently focused on the clients of the bank with the most significant representation of answers from respondents. Research in this region has not yet been carried out.

The goal of the survey was to obtain knowledge from the clients of the selected bank in the field of finance, with the help of which we will determine their financial literacy level. In recent times, emphasis has been placed on education in the field of financial literacy. From that title, we assumed that the education achieved would have an impact on the respondent's financial literacy. From the bank's point of view, it is crucial that its clients are financially literate and that the products offered by the bank are in line with the survey results. At the beginning of the questionnaire, we tried to familiarise the respondents with the survey. The survey was aimed at residents of the Trencin region, whose minimum age limit is 15 years. We chose the age structure for the reason that a 15-year-old student can be a client of the bank, use applications on a mobile phone, and thus shape their financial literacy. The composition of the survey consisted of 15 questions, where the first 5 questions focused on basic information regarding the respondents (gender, age, district of the Trencin region, respondent's bank). The remaining 10 questions were used to assess the financial literacy of the practice (APRC, interest rate, payment cards, loans, insurance, etc.). The total time for completing the questionnaire was approximately 10 minutes. The survey regarding financial literacy was carried out from November 2022 to January 2023. A total of 529 respondents took part in the survey. Of these, clients of Slovenska Sporitelna had the most significant representation. Since we received the largest number of responses from clients of this bank, we prioritised evaluating these responses.

For the purposes of the contribution, we analysed the answers of 305 respondents as clients of Slovenska Sporitelna. We tried to ask the selected questions in such a way that they did not create a feeling of intrusion into the private lives of the respondents; for this reason, the questions for the respondent were designed from real-life examples from various situations. Based on the obtained theoretical knowledge from various existing surveys, we established hypotheses in which we assumed that financial literacy depends on the level of education achieved. In the second hypothesis, we optimistically assumed that the selected region would have higher financial literacy than the Slovak Republic as a whole. We used two methods of calculation to verify the hypotheses. When analysing the dependence between the level of education and the number of correct answers, we used the X2-test of independence of categorical variables. The second method of calculation, which served us to determine the level of financial literacy in the Trencin region, was the test of the agreement of the mean value with a known constant.

Hypothesis H1 was created based on the assumption that education in the field of financial literacy is necessary. This issue has been discussed for several years. Given that we considered official surveys from 2000–2012 as the basis, we assumed that the higher the level of education, the higher the respondents' financial literacy. We assume that the introduction of financial literacy in primary and secondary schools is already showing results. Also, banks are currently providing support for developing financial literacy among the population in the Slovak Republic. Hypothesis H2 arose because the level of financial literacy of the Slovak population was based on the data from the official survey of the Focus

agency from 2012. In this survey, the financial literacy of the Slovak population was determined to be 62.5%. Concerning financial education, we hypothesised that the current results would show a higher level of financial literacy. In order to achieve the set goals, it was necessary to use two calculation methods. When analysing the dependence between the level of education and the number of correct answers, we used the X2-test of independence of categorical variables. The second method of calculation, which served us to determine the level of financial literacy in the Trencin region, was the test of the agreement of the mean value with a known constant. The X2-test of independence of categorical variables is used if, through n elements of the sample set, we observe two qualitative features, A and B, which acquire more features, and the range of the sample set is more than 20. In our case, the qualitative features are the number of correct answers and the level of education achieved.

We subsequently verified the hypotheses established by us based on surveys carried out in the past using statistical methods. For the purposes of this survey, we defined the following hypotheses:

H1: The number of correctly answered questions depends on the level of education achieved (the higher the education, the more correct answers)

H2: The level of financial literacy in the Trencin Region is higher than the average level of financial literacy in the Slovak Republic, i.e., more than 62.50%

Research Results

Based on a questionnaire survey conducted in a selected region of the Slovak Republic, we found the following results:

- 13 respondents answered all questions correctly. Six respondents with a secondary school education with a high school diploma and three respondents with a first degree of university education achieved a 100% success rate. One with the second level of university education and a secondary school with a teaching certificate. Of the respondents with the highest level of primary education, there was not a single one who answered all the questions correctly.
- The level of financial literacy in our survey does not depend on the level of education of the respondents, even though the best success rate was among those with a second-level university education and above (59.39%). Respondents who achieved the highest level of secondary education with a high school diploma were better off with their results than those with a first-level university education. In our survey, the respondents who obtained a high school diploma obtained 58.20%, which is 1% lower than the respondents' 2nd level of higher education. Respondents who have achieved a first-degree university education (43.6%) had a lower level than those who have a basic education (45%). Respondents whose education is secondary school with a teaching certificate fared the worst. Their level of financial literacy is 40.17%;
- men had more correct answers than women, while the success rate for men was 60.91% and for women, 44.41%;
- in terms of age, the respondents who are in the age range of 15 to 24 years, whose level represents 59.66%, did the best; on the contrary, the worst were people over 55 years of age, whose success rate is 40.42%;
- all districts of the Trencin region had a success rate above 40%; only the district of Banovce nad Bebravou had 38.18%; The level was just above 40% in the districts of Povazska Bystrica (40.50%), Partizanske (41.96%), and Prievidza (44%). The district of Nove Mesto nad Vahom has the best financial literacy level, representing 70.43%, followed by the district of Trencin with 66.09%. Myjava district was also above our survey's average, reaching 50.59%. The districts of Ilava and Puchov, which had a 50% success rate, remained just below the level.
- Up to 65.20 per cent of respondents cannot distinguish which interest rate is more advantageous for them with a term account,

- When choosing a loan, 51.50% of the respondents decide on the basis of references from acquaintances and according to the required amount of money, while only 1/3 of the respondents would choose the annual percentage rate of costs.
- Less than half, i.e., 48.20%, of the respondents know that obtaining a loan is more difficult with delayed loan payments. We can also attribute this fact to the personal experiences of the respondents. In the issue of insurance, the results were the most satisfactory. 68.40% know that the insurance company can withdraw from the contract in case of concealment of facts, which represents the majority of respondents, and less than half (49.50%) know what is represented by the sum insured of the property,
- Question number 15, which was about investing in shares, was answered by most respondents, whose age is in the range of 15-34 years.

Initially, we hypothesised that education and the number of correct answers are not dependent (H0). Our alternative hypothesis is that education and the number of correct answers are dependent (H1). We decided that the level of significance (α), also known as the deviation we are willing to accept, will be 0.05. After establishing the hypotheses and levels of significance, the real frequencies were determined. We obtained these frequencies by finding out how many respondents with the same level of education answered the individual questions correctly. This category does not include questions regarding basic data about the respondent. We present the detected frequencies in Table 1.

Table 1. Contingency table of real frequencies (Source: Own processing)

Education	The number of correct answers to individual questions										
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	∑
Basic	11	7	8	8	18	7	10	12	12	6	**99**
Secondary with a certificate	21	22	27	16	31	21	26	20	33	24	**241**
Secondary with a high school diploma	61	31	53	62	65	62	66	58	74	50	**582**
University 1st degree	31	25	35	32	41	26	28	26	42	37	**323**
University 2nd degree	30	21	24	30	32	29	32	35	36	22	**291**
∑	**154**	**106**	**147**	**148**	**187**	**145**	**162**	**151**	**197**	**139**	**1536**

In the contingency table, we can see that there were a total of 1,536 correct answers, but with 100% of the questions answered correctly, the total value would have to be 3,050. Thus, 50.36% of the total answers are correct. From the perspective of these results, we abstracted 49.64% of incorrect answers, so the error rate was higher. The analysis presented us with actual values, but to determine the dependence of our qualitative variables, it is also necessary to know the theoretical or expected frequencies. The condition must be met that the theoretical abundance value obtained should be equal to or greater than 5 or that 80% of these values meet the condition. The following table shows a table of theoretical values.

Table 2. Contingency table of theoretical or expected frequencies (Source: Own processing)

Education	The number of correct answers to individual questions										
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	∑
Basic	9,93	6,83	9,47	9,54	12,05	9,35	10,44	9,73	12,70	8,96	**99**
Secondary with a certificate	24,16	16,63	23,06	23,22	29,34	22,75	25,42	23,69	30,91	21,81	**241**
Secondary with a high	58,35	40,16	55,70	56,08	70,86	54,94	61,38	57,21	74,64	52,67	**582**

school diploma											
University 1st degree	32,38	22,29	30,91	31,12	39,32	30,49	34,07	31,75	41,43	29,23	**323**
University 2nd degree	29,18	20,08	27,85	28,04	35,43	27,47	30,69	28,61	37,32	26,33	**291**

We obtained the test criterion through the difference between real and theoretical abundance.

Table 3. Test criterion value (Source: Own processing)

Education	The number of correct answers to individual questions										
	6	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**	∑
Basic	0,12	0,00	0,23	0,25	2,93	0,59	0,02	0,53	0,04	0,98	**5,68**
Secondary with a certificate	0,41	1,73	0,67	2,25	0,09	0,13	0,01	0,58	0,14	0,22	**6,24**
Secondary with a high school diploma	0,12	2,09	0,13	0,63	0,48	0,91	0,35	0,01	0,01	0,14	**4,86**
University 1st degree	0,06	0,33	0,54	0,02	0,07	0,66	1,08	1,04	0,01	2,07	**5,88**
University 2nd degree	0,02	0,04	0,53	0,14	0,33	0,09	0,06	1,43	0,05	0,71	**3,40**
∑	**0,73**	**4,20**	**2,10**	**3,28**	**3,92**	**2,38**	**1,52**	**3,59**	**0,24**	**4,11**	**26,06**

The value of the test criterion is 26.06. We used the test criterion for the inequality of the critical domain. The critical field pointed out that the inequality does not hold, so we did not reject our null hypothesis. In the event that the null hypothesis is rejected and the result is that there is a dependence between the qualitative features, the intensity measure would determine how strong the dependence is between them. Through the X2-test of independence of categorical variables, we found that in our survey, the number of correct answers was not affected by the level of educational attainment.

To compare the level, we used the Mean Value Conformity Test method with a known constant. We chose this type of test because we know the constant with which we compare our unknown value and determine whether the level of financial literacy in the Trencin region is identical, higher, or lower. The calculation of the test was done in absolute values. Our constant is the level of the Slovak Republic, which represents 62.50%, i.e., 0.625, which also means the null hypothesis, which claims that the level of financial literacy of the Trencin Region and the Slovak Republic is identical (H0). As mentioned above, the average level of financial literacy of Slovaks was shown by a survey conducted in 2012 by the Focus agency, which was 62.50%. We approved the chosen source because a more up-to-date status could not be obtained from available sources that we would consider relevant to the needs of this post. An alternative two-sided hypothesis is that the level of financial literacy in the Slovak Republic and the Trencin Region is not identical (H1). In confirming the two-sided alternative, it is essential to find out through the one-sided alternative whether the level of financial literacy is higher or lower. Our one-sided alternative is that the level of financial literacy in the Trencin region is lower compared to the level in the Slovak Republic. The necessity for the calculation of the test criterion is the sample characteristics, which are the arithmetic mean, the sample standard deviation and the sample variance. The test criterion and critical range can be calculated according to the following relationships:

$$T = \frac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}} \tag{1}$$

where:

T test criterion

$\bar{x}$ average value

μ_0 mean value of a statistical set

s standard deviation of a statistical set

n the size of the statistics set

$$T = \frac{\bar{x} - \mu_0}{\frac{s}{\sqrt{n}}} = \frac{0{,}5036 - 0{,}6250}{\frac{0{,}2339}{\sqrt{305}}} = -9{,}0659$$

Verification of the hypothesis: whether the level of the Trencin region is the same as the average level of Slovakia:

$$|T| \geq z_{\alpha}(n-1)$$

$$9{,}0659 \geq z_{0{,}05}(305-1)$$

$$9{,}0659 \geq 1{,}9678$$

Verification of the hypothesis: whether the level of the Trencin region is lower than the average level of Slovakia:

$$T < 2z_{\alpha}(n-1)$$

$$-9{,}0659 < 2z_{0{,}05}(305-1)$$

$$-9{,}0659 < -1{,}6499$$

Through the test criterion and the critical area of rejection, we found that the levels of financial literacy in the Trencin region and the Slovak Republic are not identical. Our survey shows that the level of the Trencin region is 50.36%, which points to the fact that it is 12.14% lower than the SR average.

Discussion

Based on our survey results, which were aimed at residents of the Trencin region of the selected bank, we obtained information about the current state of financial literacy. Based on the survey results, we decided to make suggestions and recommendations for increasing financial literacy. We would suggest improving financial literacy among people in productive and post-productive ages due to the lack of knowledge on the issue pointed out by the survey. We would recommend educational courses through which orientation in the field of finance is obtained, which is related to practice. Another option is podcasts, which are available for free on music and streaming services such as Spotify and YouTube. An example is the Index podcast from the SME Daily, the BMT (Business Money Talks) podcasts, and many others, which easily try to explain the importance of financial literacy and other economic information currently happening in the country and the world. It would be appropriate if the bank entered this process of financial literacy education through qualified employees who communicate with clients. She could create her own podcasts with well-known personalities or influencers who would lead people to financial literacy and thus to the use of their services and products. Currently, there are still many schools in the Slovak Republic that do not teach financial literacy, which is why they should include it in their curricula. Here, it is up to the bank to consider whether it will create space for the education of students already at the elementary and secondary school levels. The issue of financial literacy should be constantly pointed out through more extensive surveys. Banks can also actively participate in this process and conduct a financial literacy survey in person or through an application. They can use apps, social networks, and trusted mass media to promote survey results for the same reason mentioned above when conducting surveys. For the others who do not use the previous option, they have a radio, a daily newspaper, or a TV at their disposal. In this way, they could make the obtained results available to clients and use them to support the improvement of their clients' financial literacy. From our point of view, it is a means by which the bank can differentiate itself from its competition. Products presented in this way would, on the one hand, increase clients' financial literacy and, from our point of view, would be more accepted than an aggressive promotion of products and services. From the point of view of the bank's clients, it is crucial to have their income and expenses under control. For increasing individual or

household budgets, it is important to consider income and expenses influenced by insufficient financial knowledge and aggressive promotions of products and services. Therefore, the appropriate way is to regulate income and expenses, which will lead to an increase in the budget. When communicating with the management of the selected bank, we found out that they recommend that clients keep their spending on consumer goods, housing, transportation, and education under control.

Expenditures on consumer goods can be divided into short-term and long-term. We can include food in the short-term and appliances and equipment in the long-term expenditures.

The most significant portion of the family budget is spent on food. With this item, it is possible to save a considerable amount of money, which can be used for other purposes. Some households believe that "what is expensive is good quality," but this assumption has been debunked numerous times. When comparing the composition of goods, it is easy to find out which of the goods is beneficial for health (more BIO, etc.). After obtaining information about individual goods, it can be said that even cheap goods can have the required quality. Households should be interested in unit prices of goods by weight. With the exception of changes in the quality of the goods, the weight also changes. When comparing two products of the same quality, we should look at the unit price per weight. The price per unit weight, because the actual price can be deduced from it, i.e., one can pay more for the same quality product, even if optically we think we have saved.

Following the promotional brochures of retail chains provides an overview of stock goods that can supply the household for several days. Another solution is the ability to resist the goods presented by sellers' manipulative techniques to lead the customer to buy. Among these manipulators, we include posters with blackboards in eye-catching colours with inscriptions such as 3+1, 50% off, Black Friday, or post-season sales. This will make the customer realise that the product is worth it and will make him want to buy, leading him to the realisation itself. There is a homogeneous procedure for another means of manipulation: the offer of coupons for discounts on goods.

Constant changes in market trends and modern technologies define the nature of durable goods. Every year, similar goods compared to the previous ones, with an innovative or new function, are launched on the market. The innovation evokes in people the desire to own the product, although the selling price is extremely high and the original product fulfils its role flawlessly. In households, mobile phones are a typical example.

After the wear and tear of appliances that are a necessary part of every household, the choice should be made based on utility, lifespan, and price. A certain part of the population chooses appliances for various reasons. Among these benefits, we can include gifts. A typical example is dishwashers, where sellers offer a free monthly supply of capsules as a gift or free winter tires when buying a car. In most cases, individual benefits are included in the price of the goods or are conditioned by various factors.

Housing expenses include mortgage repayments, rent, and household expenses (gas, water, and electricity). These are all costs that will increase significantly due to the current inflation rate. It is for this reason that people in the Slovak Republic must be financially literate.

As for a mortgage loan, most households will agree to one provided by a commercial bank with which they have an open bank account. A suitable variant is the analysis of individual offers from competing banks. Households should focus on the annual percentage rate of costs (RPMN), which represents the total annual cost of the loan, the amount of the monthly payment, and the maturity period. They should know that the longer the loan is repaid or the lower the instalment in a given period, the longer the repayment period and the higher the repayment of the loan. To analyse individual offers, it is advisable to visit commercial banks in person, use an external consultant, or use websites that contain loan calculators. In the calculator, the client enters the amount of money he wants to borrow, the number of years of repayment, and the monthly payment amount. Before ratifying the credit agreement between the creditor and the debtor, that is, the commercial bank and the client, there is an important part, namely literacy, thanks to which it is guaranteed to eliminate fees from unwanted services. Expenses for transport, but above all for a car, a standard of everyday life. Many households use a car daily, whether for short or long distances. The price of fuel, fees, repairs, and services for cars is increasing, which also increases household expenses. A step towards reducing transportation expenses is that cars will only be

used in cases of necessity or for long distances. This type of transport use behaviour also contributes to higher environmental protection. Education expenses are integral to acquiring knowledge, not only in the financial field. Even if education is included in expenses, it represents an investment for households to achieve a better financial situation. If there is a lack of funds used to improve the quality of knowledge, we recommend increasing this item.

Conclusions

Nowadays, we have a lot of financial products and services available to us, which each of us uses, but not everyone understands them. Many people think they have sufficient information in the area of financial literacy, but the opposite is often true. The article contains the results of selected surveys conducted in the Slovak Republic in the past and the results of a survey conducted by us focused on the financial literacy of the clients of the selected bank. Using survey data and statistical calculations, we determined the state of financial literacy among these clients. The resulting level of financial literacy reached 50.36%. A statistical calculation was also carried out through the X2-test of independence of categorical variables, which pointed out the fact that the number of correct answers in the conducted survey does not depend on the education obtained, even though respondents who achieved the second level of university education and above had the best results. The proposals and recommendations that emerged from the survey relate to improving the financial literacy of the clients of the selected bank so that, on the one hand, the financial literacy of the clients increases and, on the other hand, there is effective communication between the bank and its clients. In conclusion, we would like to add that financial literacy is the ability of individuals to make well-considered financial decisions and thus have their financial situation firmly in their hands. We believe that this is also the goal of every bank and that the results of the bank's survey inspire the improvement of the financial literacy of its clients.

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ELECTRIC VEHICLES FROM AN ECONOMIC POINT OF VIEW

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Abstract

Research purpose. In recent years, the importance of moving from a linear economy to a circular economy in every area and sector of the economy has been discussed more than ever before. This includes discussions on a net zero energy system as the basis for a fully decarbonised electricity sector. The increase in demand for electricity and the push for net zero emissions are leading to a focus on using electric vehicles to meet the EU's sustainability targets. The European transport sector is responsible for a significant part of the European Union's total greenhouse gas emissions. The main aim is to evaluate the impacts of the automotive industry from an economic point of view because the increase in sales of electric cars can lead, among other things, to the mitigation of environmental problems.

Design / Methodology / Approach. Electric cars and biofuel cars are the two most discussed solutions in the transport sector. As EVs are sustainable to the extent that their energy sources are sustainable, the main aim of this research paper is to investigate the impacts of the chosen electric vehicle types from an economic point of view, especially the sales of electric vehicles in the time period of 2010-2021. Battery electric vehicles and plug-in hybrid vehicles' sales situation will be analysed in Europe and globally. The assumptions and hypotheses were set and verified through regression and correlation analysis.

Findings. The research results have confirmed our assumptions that the number of vehicles sold in Europe and worldwide is increasing with time. During the time period under consideration, electric car sales increased worldwide. 6,600,000 battery electric vehicles and plug-in hybrid vehicles were supplied in total in 2021, representing a 45% increase from the previous year. The most significant growth in car sales in Slovakia was in 2021, but only one-tenth of one per cent were electric vehicles.

Originality / Value / Practical implications. A gradual shift of the main interest from automakers to electric vehicles is seen. At the same time, there are other questions connected to electric vehicles that need to be addressed and analysed, such as their high price, charging options and infrastructure and, nowadays, the electricity price.

Keywords: Electric vehicles; Circular economy; Sustainable economics

JEL codes: Q42; Q50; L94

Introduction

The present economic model is the linear economy, in which natural resources are taken, processed, used and disposed of (Johannsen et al., 2022). This model is, however, totally unsustainable (Tan et al., 2022); therefore world came up with the idea of a circular economy that is durable, green and sustainable (Sulich & Soloducho-Pelc, 2022). Environmental regulation and environmental awareness drive the

circular economy (Neves & Marques, 2022), which is a challenging model getting a lot of critiques from one side (Corvellec et al., 2022), offering many opportunities on the other side (Marsh et al., 2022). The idea of transitioning from a linear approach is not new. Society started to make efforts to prevent environmental problems stemming from a linear model of the economy by the 1960s and 1970s by discussing the necessity of recycling, the protection of wilderness, and issues connected with air and water pollution (Mulvaney et al., 2021). The circular economy model is considered an excellent tool for reaching sustainable development goals, according to Rodriguez-Anton et al. (2022). The aim of the Paris Agreement from 2015 to keep global warming to no more than 1.5°C requires greenhouse gas emissions to reach net zero by 2050 (Bataille et al., 2018). The circular economy concept looks for new ways of providing everything society needs. It revolves around deploying rather than consuming materials, using them more than once, and redesigning them to make them as efficient as possible – both economically and environmentally (Ashby, 2016). This transition is also dependent on the use of more efficient products, enabling smart homes and hybrid plug-in electric vehicle technologies, according to Abdallah and El-Shennawy (2013). Climate changes significantly affect the electric sector, electricity demand, supply, and infrastructure (Jaglom et al., 2014). As a result of global warming, the annual cost of electricity production will increase by 14% by 2050 (Gerlak et al., 2018). The fact that society depends highly on fossil fuels is one of the greatest problems nowadays, since this leads to significant environmental issues, there is a need to find an alternative to fossil fuel that will be environmentally friendly, sustainable as well as efficient. Fuel cell technologies represent one of the most promising alternatives to fight these problems (Wilberforce et al., 2016).

The main objective is, therefore, to evaluate the impact of the automotive industry from an economic point of view since an increase in the sale of electric cars (battery electric vehicles and plug-in hybrid vehicles), which are considered to be a more environmentally friendly alternative compared to petrol and diesel cars, could lead, among other things, to the solution of some environmental problems. Plananska (2020) agrees and adds that many governments also introduced measures to promote electric vehicle sales (mainly regulation, financial incentives, and information-based interventions) designed to motivate electric vehicle purchases by raising awareness about electric vehicles and their environmental benefits.

Literature review

Li et al. (2019) divides all electric vehicles into three classes depending on the purpose. The first class is the Urban electric vehicles with a maximum speed of up to 100 km/h, the second is highway electric vehicles with maximum speed over 100 km/h, and the third is sports electric cars with a maximum speed of over 200 km/h. According to Wilberforce et al. (2017), electric cars cost around 2 cents per mile which is a great difference compared to conventional petrol-powered cars that cost 12 cents per mile. Also, electric cars are able to operate within 4–8 miles per kWh of energy with zero emission of greenhouse gases. Fuel cells produce zero-emissions power by using hydrogen as a fuel to generate electrical energy through a chemical reaction (Baroutaji et al., 2015). Kundu and Dutta (2016) name some advantages of hydrogen fuel cells over battery systems: instant recharging via replacement or a refilled fuel cartridge, independence from electricity, longer cell lifetime, or higher energy conversion (chemical to electrical) efficiency. Even more than a decade ago, fuel cells were considered as appropriate as portable power systems due to their durability and low cost (Cacciola et al., 2001). From a fuel cell, through a chemical reaction with oxygen, hydrogen as the energy carrier can be converted into electricity (Khan & Iqbal, 2009). Plug-in electric vehicles have been seen since the beginning of their development as part of the solution to reduce road transport emissions of CO_2 (Meinshausen et al., 2009). The result of the study from 2010 showed that in the situation in which the entire 2009 passenger car fleet would be replaced by an equal share of three battery electric vehicles available in that year, and then CO2 emissions would be reduced by 51 – 91% in European countries (Inderwildi et al., 2010). Graham-Rowe et al. (2012) named three broad types of plug-in electric vehicles: (i) battery-electric vehicles, (ii) plug-in hybrid electric vehicles that developed from hybrid electric vehicles, and (iii) range-extended electric vehicles. The complete list of hybrid and electric vehicles also includes hybrid electric vehicles and vehicles powered by hydrogen fuel cell technologies. The study from 2019 shows that even though electric and plug-in hybrid car prices have decreased since 2010, it is crucial to give attention to

non-cost market barriers for these vehicles, such as recharging infrastructure (Weiss et al., 2019). Electric and plug-in hybrid cars are becoming financially more attractive to consumers and economically more efficient in mitigating the negative impacts of road transport, according to Degraeuwe et al. (2016).

Also, the share of respondents considering purchasing a hybrid or electric vehicle in the near future across the European Union in the study from 2019 increased from 32% in 2014 to almost 38% in 2018 (Christidis & Focas, 2019). Although the rapid progress of the world economy and technology has advanced human civilisation, it has also caused tremendous damage to the global ecological environment (Tu, 2002). Electric power as a currently viable energy solution can solve the country's dependence on petroleum resources to some extent (Liu, 2008). One of the important causes of environmental pollution is the large increase in car ownership and use (Hao et al. 2016). According to International Energy Agency (IEA) statistics, there are currently approximately 1 billion vehicles in the world, consuming about 60 million barrels of oil per day (about 70% of total oil production); private vehicles consume an average of about 36 million barrels of oil per day, emitting 14 million tons of carbon dioxide (Sang & Bekhet, 2015). Therefore, one of the solutions to environmental problems is to replace traditional vehicles with new energy vehicles (IEA, 2017). From an energy perspective, having more energy sources for vehicles will improve the reliability and balance of energy consumption. In conjunction with the smart development of electric vehicles, transport conditions and road use will be significantly improved (Eltayeb et al., 2010). Ellingsen et al., however, have clearly stated that considering the whole life cycle of vehicles (production, use and scrappage), pure electric vehicles can reduce GHG emissions by around 30% compared to combustion engine vehicles in the current European electricity generation mix. Given the pressures of resource reduction and environmental change, electric vehicles will become a significant trend in the development of the future automotive industry. Therefore, developing low-carbon, energy-efficient, intelligent electric vehicles is imperative to reduce environmental impact (Tu, 2002).

Research Methodology

The main aim is to evaluate the impacts of the automotive industry from an economic point of view. The objects of research are two types of electric vehicles, namely:

- battery electric vehicles in Europe and the world (BEV),
- plug-in hybrid vehicles in Europe and the world (PHEV).

The primary data were collected from publicly available databases (International Energy Agency) and subsequently processed and evaluated in Microsoft Excel.

In the context of the research part of this paper, we have set research assumptions, which we have verified through regression and correlation analysis:

1. The number of battery electric vehicles sold in Europe increases with increasing time;
2. The number of plug-in hybrid vehicles sold in Europe increases with increasing time;
3. The number of battery electric vehicles sold in the world increases with increasing time;
4. The number of plug-in hybrid vehicles sold worldwide increases with increasing time.

We have chosen the hypotheses based on previous assumptions that as the time period increases, the number of electric cars sold increases because people in the world and Europe are more and more interested in buying electric cars, on the basis of which we believe that people are more and more concerned about the environment, as electric cars are generally considered to be more environmentally friendly. It is obvious that additional variables, such as average income or vehicle pricing, should have been considered to assess the overall economic condition and the readiness for the widespread use of electric automobiles. However, here we focus mainly on the development of the number of electric vehicles and the prediction for the future. Later research and the project, of which this paper is also a part, will address other economic points and consumer needs to boost electric vehicle sales.

We considered the time period of 2010-2021 as the independent variable and the sales of battery electric vehicles and plug-in hybrid vehicles in Europe and worldwide as the dependent variable. The null and alternative hypotheses were set as follows:

- H0: the time period does not affect the number of battery electric vehicles sold in Europe
- H1: time period affects the number of battery electric vehicles sold in Europe

- H0: the time period does not affect the number of plug-in hybrid vehicles sold in Europe
- H1: time period affects the number of plug-in hybrid vehicles sold in Europe

- H0: time period does not affect the number of battery electric vehicles sold worldwide
- H1: time period affects the number of battery electric vehicles sold worldwide

- H0: time period does not affect the number of plug-in hybrid vehicles sold in the world
- H1: time period affects the number of plug-in hybrid vehicles sold in the world

After applying all the regression models, the polynomial function proved to be the most appropriate in terms of the coefficient of determination for describing the relationship between the observed variables.

$$y_j' = b_0 + b_1 * x_j + b_2 * x_j^2 \quad (1)$$

Where:

- b_0 – intercept,
- b_1 – regression coefficient,
- y_j' – j-th value of the dependent variable,
- x_j – j-th value of the independent variable.

The Durbin-Watson statistic is a test statistic to detect autocorrelation in the residuals from a regression analysis.

$$d = \sum_{t=2}^{T}(e_t - e_{t-1})^2 / \sum_{t=1}^{T} e_t^2$$

Where:

- T – The total number of observations
- e_t: – The tth residual from the regression model

This test uses the following hypotheses:

- $H0_{DW}$: there is no correlation among the residuals.
- $H1_{DW}$: the residuals are autocorrelated.

The Durban-Watson statistic will always assume a value between 0 and 4. A value of DW = 2 indicates that there is no autocorrelation. When the value is below 2, it indicates a positive autocorrelation and a value higher than 2 indicates a negative serial correlation. To test for positive autocorrelation at significance level α (alpha), the test statistic DW is compared to lower and upper critical values:

- If DW < Lower critical value: There is statistical evidence that the data is positively autocorrelated
- If DW > Upper critical value: There is no statistical evidence that the data is positively correlated.
- If DW is in between the lower and upper critical values: The test is inconclusive.

Research results

World and European vehicles sales situation

The following figure (Fig. 1.) shows the number of sales of selected vehicle types worldwide and in Europe during the period under review (2010-2021).

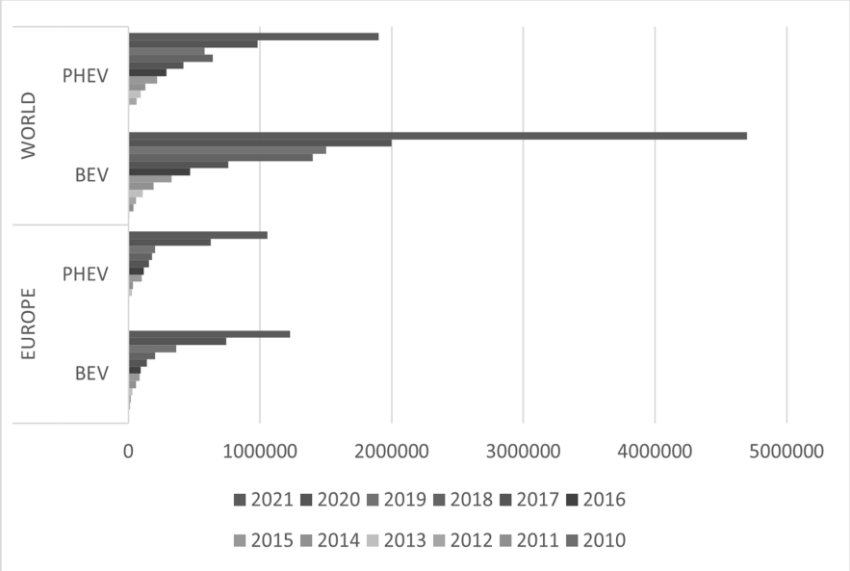

Fig. 1. Number of sales of selected vehicles types in the world and in Europe (Source: own processing)

The global battery electric vehicles and plug-in hybrid vehicles market developed at an increasing pace during the period under review, with battery electric vehicles and plug-in hybrid vehicles sales in Europe following this trend. The growing consumer interest in battery electric vehicles and plug-in hybrid vehicles is due, among other reasons, to the increase in average CO2 emissions and the rise in fuel prices.

Share of global sales of electric and hybrid vehicles

The following table (Table 1) provides an overview of the percentage of global sales of battery electric vehicles, plug-in hybrid vehicles, and both in Europe.

Table 1. Share of global sales of electric and hybrid vehicles (Source: own processing)

SHARE (%)	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	Average
BEV	28.78	27.43	31.94	29.78	31.29	26.43	19.68	18.29	14.43	24.17	37.07	26.14	**26.29**
PHEV	11.05	4.88	15.34	28.23	26.35	45.44	40.27	37.15	28.11	35.24	63.68	55.66	**32.62**
BEV + PHEV	27.92	23.25	23.50	29.07	29.28	34.04	27.54	25.00	18.72	27.26	45.82	34.64	**28.84**

Based on our calculated data for the period under review (2010-2021), we found that European sales account for an average of 26.29% of global Electric vehicles (battery electric vehicles) sales, and thus, more than a quarter of global battery electric vehicles sales are in Europe. If we look more closely at plug-in hybrid vehicles (plug-in hybrid vehicles), we can see from the table above that sale of these vehicles have a larger share (32.62%) of total sales, so we can conclude that customers prefer to buy plug-in hybrid vehicles over battery electric vehicles. In the last reporting year, 2021, the highest sales value was recorded in Germany for both battery electric vehicles and plug-in hybrid vehicles (360,000 - battery electric vehicles; 330,000 - plug-in hybrid vehicles). In contrast, Greece accounted for the smallest share of battery electric vehicles and plug-in hybrid vehicles sales within Europe (2,200 - battery electric vehicles; 4,800- plug-in hybrid vehicles). Despite a significant increase in EV sales in recent years, battery and hybrid electric cars account for only 1.5% of all vehicles in Europe.

Table 2. Share of powertrain types of vehicles in Slovakia in 2021 (Source: own processing)

	Battery electric vehicles	Plug-in hybrid vehicles
Slovakia	0.1	0.1
EU (average)	0.8	0.7

According to the available data in 2021, petrol vehicles dominate in terms of the powertrain used, with a percentage share of 50%, followed by diesel vehicles with a percentage share of 40%. The share of electric vehicles (battery electric vehicles) is 0.1%, plug-in hybrid vehicles (plug-in hybrid vehicles) 0.1%, and the remaining 3.3% is accounted for by hybrid and gas vehicles in Slovakia. Slovakia is below the EU average for battery electric vehicles and plug-in hybrid vehicles sales.

Regression-correlation analysis

In the following pictures (see Figure 2-5), values are situated around the trending line. The convex shape shows that the years 2010-2021 increase are also increasing sales of battery electric vehicles and plug-in hybrid vehicles in Europe and the world. According to mentioned figures, we could state that there is significant dependence between variables that a polynomial function can describe. Even though the analysis focuses solely on determining the dependence between time period and the number of battery electric vehicles and plug-in hybrid vehicles sold in Europe and the world, the number of sold vehicles can be affected by the number of additional determinants that are not included in our analysis (for example customer preference, prices of vehicle, etc.). After applying all regression models, the polynomial function appears from the point of view of the coefficient of determination as the most fitting for a description of dependence between observed variables.

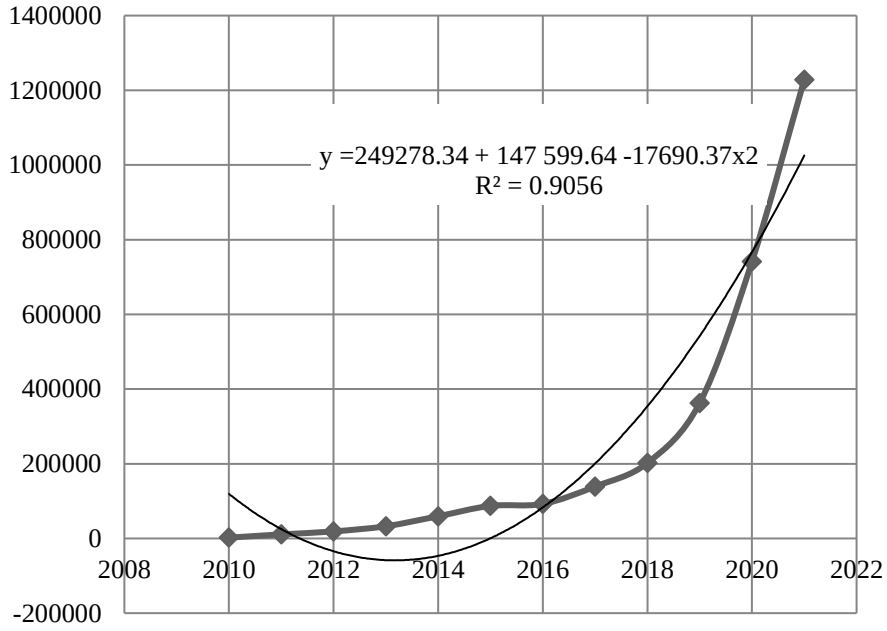

Fig. 2. Europe – Battery electric vehicles - sales (Source: own processing)

The quality of the chosen polynomial model is tested using regression and correlation analysis results that consist of three parts, each having a different role. The first part is made of correlation analysis by which we can test the strength of dependency between variables. Multiple R, multiple correlation coefficient has a value of 0,977868818 that shows the strong dependency between time period and the number of sold battery electric vehicles, since the closer the number is to 1, the stronger the dependency. R Square, coefficient of determination informs us that chosen regression function (polynomial)

describes and explains around 96% variability of battery electric vehicles sold. The remaining part means unexplained variability, the influence of random or other factors. A higher percentage means a better description of the dependence by the regression model. The polynomial model we chose shows the highest percentage of explained variability among all regression models. Adjusted R square is the adjusted coefficient of determination, taking the number of estimated parameters and measurements into account, and its value is close to the coefficient of determination value. The value of Standard Error should be as small as possible. The last evidence that correlation analysis offers is Observations, so the number of measurements. Analysis of dependence between the time period and sales of battery electric vehicles was realised during a time period of 12 years. The task of the second part of the testing is to verify the fitness of the chosen model using the null hypothesis, according to which the chosen model is not suitable. The alternative hypothesis states otherwise. For the evaluation of hypotheses F test, the comparison of the value of Significance F with the level of significance alpha is used. We test with a significance level of 0.05, and if the value of Significance F is lower than alpha, we reject the null hypothesis. In our case is Significance F (4.03E-08) < alpha (0.05), according to which we can reject the null hypothesis and accept the alternative hypothesis, which means the suitability of the regression model. The last part of the output is regression analysis which observes the relationship between variables. Based on that, we are able to formulate a regression function: y=249278.34 + 147 599.64 - 17690.37x squared. In this part, we test hypotheses too. Hypotheses are related not only to the whole model but also to locating constant and regression coefficients. The null hypothesis states that the coefficient is statistically insignificant, and the alternative hypothesis states the opposite. To choose the hypothesis, we use P-value and compare it with the level of significance alpha 0.05, as before. We can see that the P-value of the Intercept is greater than the alpha, which means that locating the constant is statistically insignificant. The P-value for the regression coefficient time period (x) is lower than the level of significance alpha that shows us the significance of this coefficient. Its value of 147 599,64 means that if the time period rises by one unit, which means one year, we can expect an increase in the sale of battery electric vehicles by 147 599,64 pieces on average.

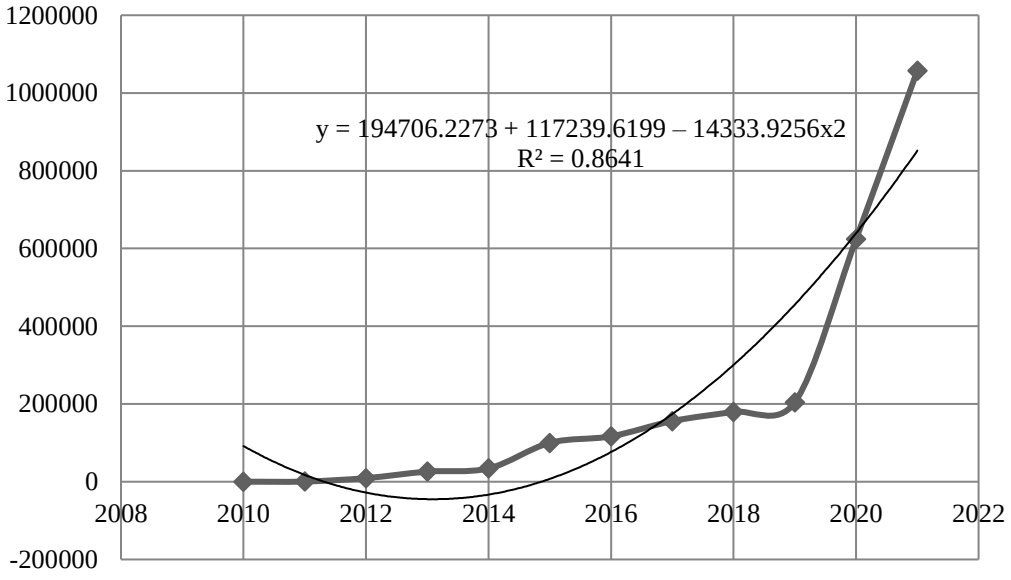

Fig. 3. Europe – Plug-in hybrid vehicles – sales (Source: own processing)

Multiple R, so the correlation coefficient in our correlation analysis has a value of 0.9296; according to that, we can state there is high dependence between variables. Next is the coefficient of determination, which stands for 86%, while the remaining 14% stands for undescribed variability. Based on the regression analysis, we can formulate a regression function which takes the following form: $y = 194706.2273 + 117239.6199 - 14333.9256x^2$. To verify the assumption "The number of plug-in hybrid vehicles sold in Europe increases with increasing time", we use the P-value and compare it with a

significance level of alpha = 0.05. In this case, the intercept constant is statistically insignificant because its P-value is more significant than alpha. Its value of 194706.2273 indicates that with an increase in the time period by one unit (year), the sales of plug-in hybrid vehicles in Europe will increase by 194704.2273 vehicles.

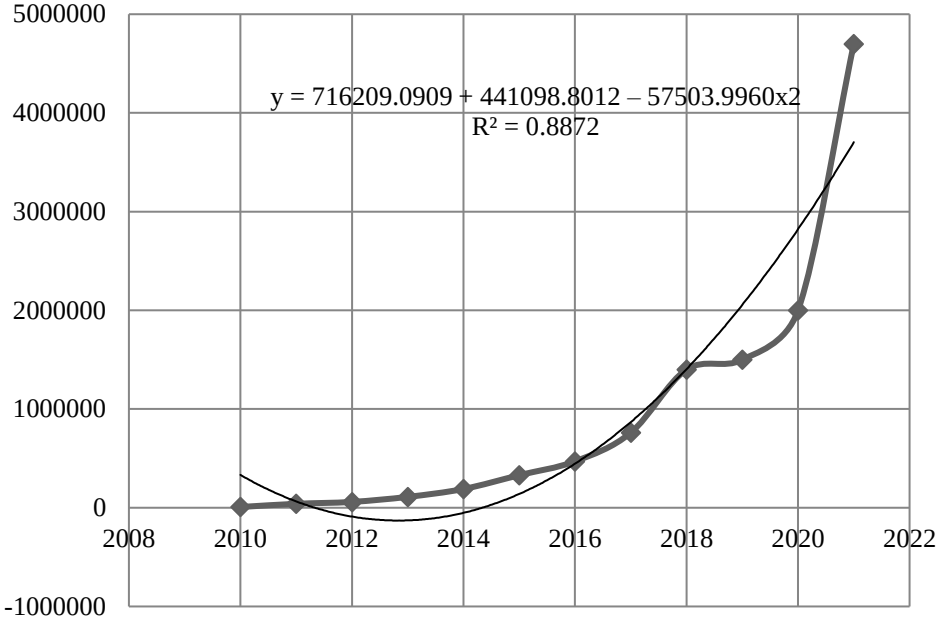

Fig. 4. World – Battery electric vehicles – sales (Source: own processing)

We have analysed the battery electric vehicles and plug-in hybrid vehicles sales situation not only within Europe but also globally, based on available data, and have come to the following conclusions. The results are very similar, as European sales of battery electric vehicles contribute to a large share of total global battery electric vehicle sales. Also, in this section, we have followed all the mentioned outputs of the regression and correlation analysis and thus:

- the polynomial regression function explains 89% of the variability of battery electric vehicles sold in the world,
- the multiple correlation coefficient takes the value of 0.9419, which also indicates a very high dependence between the variables studied,
- based on Significance F, which is lower than alpha, we reject the null hypothesis, i.e. that the number of battery electric vehicles sold in the world increases as the time period increases,
- the regression function is of the form $y = 716209.0909 + 441098.8012 - 57503.9960x^2$,
- the p-value at the locus constant is greater than alpha, and hence the locus constant is statistically insignificant.

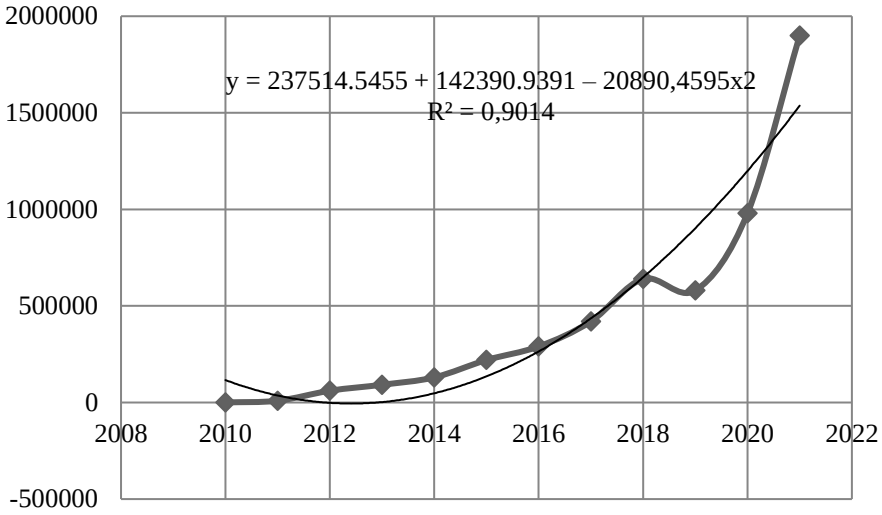

Fig. 4. World – Plug-in hybrid vehicles - sales (Source: own processing)

The last regression analysis was performed on global plug-in hybrid vehicle sales, where the assumption we examined that the number of plug-in hybrid vehicles sold worldwide increases with time was again confirmed. Based on the regression analysis output, we constructed a polynomial regression function: $y = 237514.5455 + 142390.9391 - 20890.4595x^2$.

Regression-correlation analysis – Durbin – Watson test

Based on the results of the Durbin-Watson test, we can conclude that it indicates positive autocorrelation in all of our chosen statistical models. Subsequently, comparing the lowest and highest critical values, we found that the tests are non-transitive because the Durbin- Watson test value is between the lowest and highest critical value in all four cases (WORLD BEV 1.70; WORLD PHEV 1.44; EUROPE BEV 0.78; EUROPE PHEV 0.99). Since our test statistics do not lay outside of this range, we do not have sufficient evidence to reject the null hypothesis of the Durbin-Watson test - there is no correlation among the residuals.

Conclusion and Discussion

Global sales of electric vehicles were up during the period under review. In 2021, a total of 6,600,000 battery electric vehicles + plug-in hybrid vehicles were delivered, representing an increase of +45% compared to 2020. Consumer attitudes, perceptions, and political actions directly impact the acceptance of new and/or evolving technology. In order to understand the hurdles to entrance and consumer mass adoption of electric vehicles, numerous studies have been done and examined the effects of political and economic support decisions (Emanovic et al., 2022; Ling et al., 2021). The European market contributed 26.29% of global sales for battery electric vehicles and 32.62% for plug-in hybrid vehicles. According to the electric vehicle market, which is one of the leading global advocates for the use and adoption of electric vehicles, the market is constantly growing at the level of the European Union (through the standard policies adopted), with an increase in the number of newly registered electric vehicles over the past five years. Figures, however, are comparatively small when compared to the total number of vehicles registered in the European Union, necessitating more substantial and more direct action in order to identify (and put into effect) the necessary steps to increase the share of electric vehicles in the market for vehicles while also getting rid of the old and polluting ones (Mariasiu et al., 2023). Slovakia saw the most significant increase in cars sold in 2021. It is clear that Slovakia steadily holds the rapid growth of its infrastructural country's electromobility coefficient, which is far above the V4 average (Skrabulakova et al., 2021), but electric cars still account only for one-tenth of one per cent. In 2021, Slovakia sold more electric vehicles than rechargeable (plug-in) hybrids.

Regarding the spread of electric cars, we are still well below the average in Europe. Skrabulakova et al.

(2021) also agree and discovered that Slovakia is well behind the European Union leaders in terms of electromobility preparation. However, it is still at a fairly good stage, and the electromobility infrastructure in the Slovak Republic had grown rapidly during the previous five years, with a 334 times increase in the country's electromobility coefficient. The article's main aim was to examine the situation with electric vehicles from an economic point of view and to confirm or refute the assumption that there is a dependence between the time period and the number of cars sold. This could, among other things, result in the resolution of some environmental issues. By examining the relationship between the time period and the number of cars sold in Europe and worldwide, we rejected the null hypotheses and confirmed the stated assumptions that as the time period increases, the number of electric cars sold increases using regression-correlation analysis which supports our belief that people are becoming more and more concerned about the environment. Zhang and Fujimori (2020) point out also that switching to clean energy sources for electricity production is necessary for vehicle electrification to help mitigate climate change. They also state that electric vehicles can lower mitigation costs, suggesting that transportation policies favour the economy. Based on the findings, Ling et al. (2021) recommend that authorities continue or increase providing direct monetary incentives to purchase electric vehicles.

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INVESTIGATION OF CSR ACTIVITIES CONNECTED TO COVID-19 IN CZECH AND SLOVAK BUSINESSES

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Abstract

Research Purpose. The COVID-19 pandemic was very demanding for business entities which have to introduce new managerial tools and approaches to protect the health of employees and maintained continuity in the company's activities. Most countries worldwide have implemented policies and guidelines that protect employees from potential risks related to the Covid-19 pandemic. The study aims at identifying if any difference exists (and what these differences are) between Czech and Slovak companies in the emphasis they pay to the corporate social responsibility (abbreviated: CSR) activities connected with the COVID-19 pandemic.

Design / Methodology / Approach. A questionnaire composed of Likert scale statements, whose reliability was tested with Cronbach's Alpha (0.797), was sent to daughter companies (subsidies) of foreign multinationals (pioneers in CSR activities in SK), who were selected based on stratified randomisation. We obtained data from 360 Czech and Slovak companies (180 from CZ and 180 from SK). We tested whether the differences were statistically significant using a non-parametric test, namely the Mann-Whitney U test.

Findings. We identified a statistically significant difference between Czech and Slovak companies only for one factor - extra employee benefits, which include, for example, the possibility to test at the workplace or take voluntary quarantine with income compensation, etc. Other CSR activities connected with the COVID-19 pandemic were realised with the same emphasis in both countries. We observe that most of the companies use these practices. However, assisting the communities and society is somewhat neglected by the majority of them. In this regard, we argue that it is important to support communities more as the money spent for it may come back in the form of purchases by consumers.

Originality / Value / Practical implications. In the same vein as previous works, we studied the differences between SK and CZ, two countries which shared for a long time the same history and culture. The originality here is the investigation of CSR practices connected to COVID-19 in the two countries. Findings have theoretical and practical implications. Theoretical as they contribute to expanding the literature on CSR and practical as we present to what degree the organisations and their managements from the sample put emphasis on CSR activities adopted to fight and limit the spread of the COVID-19 pandemic.

Keywords: Corporate social responsibility; CZ; Slovak Republic; COVID-19; Differences; Protective equipment; Social distance.

JEL Codes: M14; A13; H59

Introduction

Responsible conducts in business are mainstream practices around the world. They constitute what is known as Corporate Social Responsibility (CSR). To witness the attention that nowadays is given to CSR, the EU will require, starting from 2024, that all companies listed in the stock exchange market (but micro-enterprises) produce reports on CSR activities. Concerned with treating internal and external stakeholders in a way that is ethical and responsible (Hopkins, 2016; Singh & Misra, 2021), it aims at satisfying all stakeholders. Although some controversial results are found in the literature between corporate financial performance and CSR (Tang et al., 2012), opting for sound CSR practices is

beneficial and necessary for the firm to build its reputation among the public; firms would be able to maintain employee commitment and morale, potentially contributing to encouraging a positive attitude towards work (Singh & Misra, 2021). Not taking care of them can have implications for productivity, efficiency and commitment in the long term (González-De-la-Rosa et al., 2023). Moreover, a perceived unsafe work environment can be harmful to employees' physical and psychological wellbeing and negatively influence perceptions of workplace psychosocial climate (Subramony et al., 2022).

With the spread of the COVID-19 pandemic around the world, companies had to adopt special practices, grouped under CSR, aimed at safeguarding employees' health. CSR can reduce the negative consequences of the pandemic (Baatwah et al., 2022, cited in Schwartz & Kay, 2023) and represent the only way to survive and be open. In addition, families of workers who are believed to have contracted fatal cases of COVID-19 on the job may sue the companies of their late family members for a lack of preventive measures (Carroll, 2021).

Considering the above, fighting the pandemic in the workplace appears more than a simple moral obligation. With a focus on daughter companies of foreign multinationals, which first introduced CSR in the Czech Republic (CZ) and the Slovak Republic (SK) - closely tied by their shared history and often benchmarked from diverse perspectives - the end of this study is to identify if differences exist between companies based in two countries in the emphasis given to CSR practices linked to COVID-19 pandemic. We postulate that no difference can be found because of the importance of fighting the pandemic for businesses. Formally:

Hypothesis 1: No difference exists between companies based in CK and SK territories for CSR practices.

From the analysis, it emerges that with the exception of extra benefits such as testing for COVID at the workplace and starting a voluntary quarantine with income compensation, the two countries do not differ in the specific CSR practices investigated here.

After a brief literature review on CSR and related COVID-19 prevention conducts, we present the methodology used in detail and the hypotheses formulated. Then, the focus is on the results and the discussion based on these results. The last paragraph presents the main conclusions and limitations.

Literature Review

CSR practices are widely employed in enterprises based in Europe, thanks to the awareness of stakeholders and directives enacted by the EU.

Sometimes, as for crises, the commitment of companies to CSR practices becomes an actual test. For example, during the 2008 financial crisis, CSR was clearly impacted, and linked activities were reduced (Bansal et al., 2015; Jacob, 2012). With COVID-19, challenges inevitably emerged, and companies were tested in respecting ethical business conduct and CSR. Still, due to the importance of the pandemic, certain practices are necessary and essential for the survival of a company, such as the need to act fast, an economic responsibility of CSR emerged during the pandemic (Carroll, 2021). Other activities constitute measures to fight COVID consequences and limit its impact at the business level.

Following the first guidelines for the workplaces of WHO (n.d.), the European Commission and others indicated recommendations for its member countries and the companies in their territories. As governments eased restrictions, work on-site was possible again (even in companies not producing essential goods, e.g., service and tourism), but it demanded respect for basic rules. Measures like green passes, obligatory vaccination and tests to enter the premises of the workplace were more or less tight (depending on the governments' decisions). In any case, the impossibility of establishing when the pandemic will ultimately end, living and working under a 'new normal' and other unknown threats necessitate learning the best practices on how to deal with and address them with superior scientific certainty (Cirrincione et al., 2022; Kosieradzka et al., 2022).

An epidemic as an emergency prompts spontaneous responses in organisations, some of which are novelties, innovations. As the risk of infection increases, the measures become tighter. The risk may vary depending on the individuals the company deals with. Cirrincione et al. (2022) identify what

companies did to prevent and protect their workers and premises from the pandemic in cases of low (limited interaction with the public), medium (interaction with the public) and high (health sector) risk. Besides, as the risk increases, recommendations and rules become more formal and binding (Cirrincione et al., 2022). Taylor et al. (2021) suggest building systematic measures to minimise failures in behaviour by redesigning the workplace as necessary. In addition, according to Kosieradzka et al. (2022), managers may compare the measures adopted by their company to those in companies of a similar type within their industry. Thus, organisations can make use of the best practices.

Low-risk practices are common to a diverse group of companies. Below we briefly analyse some of the most common measures.

Disinfection and cleanliness of premises

These practices have become more and more frequent. Environmental measures like the usage of specific chemicals and of ventilation systems, which periodically perform air exchange) contribute to containing the spread of the pandemic and safeguard employees' health. Specific chemicals are employed to eliminate traces of the virus on surfaces of the premises. The frequency of sanitisation changes depending on the risk level, i.e., direct contact with the public (for example, the customers) for touching potentially infected objects (gloves, clothing, waste, goods at the shops) (Cirrincione et al., 2022). Particular attention was paid to, e.g. shared spaces, like bathrooms, changing rooms, and canteens (Cirrincione et al., 2022).

Providing employees with protective equipment

Employees had personal protection that limited the spread of COVID-19 outside the organisation. Examples are gloves, masks, protective visors and isolation gowns. The latter are very advanced protections used in high-risk workplaces by, e.g., nurses in hospitals. Masks are recommended for single-use and properly worn to get the highest protection. Sometimes, masks and gloves are sterilised and reused due to a lack of supply, as happened in the first wave of the pandemic. Particular attention should be paid to removing the equipment once used as the risk that the virus is on them is high, which is highlighted by national healthcare governmental agencies. The primary mode of transmission of COVID-19 is through respiratory droplets and surface contact (Yadav et al., 2020), so care should be taken.

There are different types of masks, with varying defence levels. Medical (or surgical) masks are mainly a filter for large particles in the air when the wearer breathes in, and for droplets and sprays (Das et al., 2021). Similar to them are cloth masks. For more details, refer to Anjum & Islam (2021) and Li et al. (2021). Following Mar-Cupido et al. (2022), we observe that masks like N95 and NK95 are more appropriate to limit infection. Likewise, FFP2 and FFP3 masks have high protection too.

Gloves can be of nitrile, polyurethane, neoprene and more. If, on the one hand, they guarantee protection, they can be, at the same time, a vehicle for the virus to spread. This can happen if they are not correctly removed (for instance, touching the face). Yadav et al. (2020) argue that for the general population, handwashing is a more convenient and safe practice during the pandemic. Alternatively, employees can limit the spread of the virus by sanitising their hands with products containing a percentage of alcohol (62-71%) that can eliminate traces of the virus or carefully washing them with soap and water at regular intervals (Ministero della Salute, 2021).

Moreover, WHO (2020a) recommends doing it in case of other "events". Relevant for the workplace are: coughing or sneezing after using the toilet and before eating (e.g., lunchtime). Washing hands is a way of preventing the virus from spreading among the staff.

Elimination of social contacts in the workplace

Social contact had to be minimised to have lower chances of getting infected. Several measures were taken, including home office where possible (e.g., service sector) and, whereby, not working hours in shifts as possible. Obviously, the aim was to reduce the number of people working at the same time. In a study conducted in the USA, home office was negatively felt by workers who showed lower satisfaction at home than at the office (with lighting, spatial, and IT environments) (Umishio et al., 2021). It was not rare that employees – especially the old ones - felt lost with technology. As a result,

companies trained them to use software like Microsoft Teams. As the infections caused by COVID-19 decreased, many firms welcomed back workers to their premises, and for those who wished, they allowed them to continue home office.

Increased prevention costs

It is not rare that costs linked to business-related activities are reimbursed by the employer. Examples are business trips and business supplies. Similar and related to these costs are those that employees had to consider in order to continue working in adverse conditions caused by COVID-19. Testing, protective face masks, gloves, temperature check and reimbursement of nutritional supplements are several of the costs incurred to face the pandemic. The employer covers the related costs and expenses for their staff. Furthermore, costs increased to boost the safety of the premises.

Assistance to the public and the local community

In the literature, it is acknowledged that helping communities and assisting the public (that include potential consumers) can be beneficial for the companies, as assisting them is likely to have an economic return for the former. As research showed, CSR has an impact on consumer attitudes regarding "purchase intentions, consumer–company identification, loyalty, and satisfaction" (Öberseder et al., 2013). In this aspect, important traditional CSR measures are the opportunities these businesses generate for the communities. More specifically, a firm can create new jobs (with the promise and intention to maintain them), providing fair wages and sourcing raw materials from the local community. This can improve the community, as the population see their wealth improve and as a result, have a more significant amount of money to spend in the companies that created such opportunities.

In addition to the traditional CSR practices that target the communities where the companies do their business, firms can, and some opted to include specific measures for the pandemic. Examples are sponsorship, participation in testing and trials, research for vaccines and promotion of best practices to limit the contagious virus.

Extra employee benefits

As highlighted above, COVID-19 challenged to keep employees' morale and motivation high. Benefits – noncash and cash compensations - voluntarily provided are known as discretionary. They are believed to improve individual performance and attraction and retention of employees (e.g. Werner et al., 2016).

The same could be applied in relation to the implications of the pandemic. Thus, we can consider those benefits as extra and include: the possibility to perform anti-covid tests at the workplace, take voluntary quarantine in case, e.g., of symptoms and at the same time being compensated with income, etc.

Research Methodology

Due to a lack of data regarding the number of subsidiaries of multinational companies in monitored countries, it was not possible to calculate the sample representativeness. Thus, the selection of daughter companies was made through stratified randomisation. The same sample size from both countries was used (180 Slovak and 180 Czech companies). The data acquisition was conducted in the winter of 2021-2022 as part of a more comprehensive study aiming at various aspects of corporate social responsibility. In this paper, only the part concerning COVID-19 activities was included. The analysis was realised in the form of a questionnaire. We used selected questions from broader research about CSR: thus, only relevant outcomes are displayed. They were constructed as a Likert scale with five possible answers: 1. Nothing out of the ordinary; 2. The minimum above the normal framework; 3. Weak emphasis beyond the usual framework; 4. Strong emphasis beyond the usual framework; 5. Very strong emphasis beyond the usual framework.

Questions concerned companies' emphasis on six types of activities connected to the COVID-19 pandemic that they realise beyond the scope of law and requirements of policymakers. For the purpose of this study, questions were encoded into variables:

- **P1**. Disinfection and cleanliness of premises

- **P2**. Equipping employees with protective equipment
- **P3**. Elimination of social contacts in the workplace (Home Office, shifts, changes in schedules)
- **P4**. Increased prevention costs (testing at the employer's expense, reimbursement of nutritional supplements, etc.)
- **P5**. Assistance to the public and the local community (sponsorship, participation in testing, vaccine research, etc.).
- **P6**. Extra employee benefits (possibility to test at the workplace, take voluntary quarantine with income compensation, etc.)

In order to find statistically significant differences between Slovak and Czech companies, statistical tests were realised using IBM SPSS Software. The reliability statistics confirmed a Cronbach's Alpha value of 0.797 which indicates that our model is suitable for statistical analysis and data displaying. Also, as Cronbach's Alpha, if Item Deleted varies from 0.743 to 0.818, it is justified to keep individual items in the model.

Later, the Durbin-Watson test resulted in no autocorrelation between variables, and the Shapiro-Wilk test confirmed non-normal data distribution: the use of the non-parametric test for further testing is justified. We thus used the Mann-Whitney U test to test the following hypothesis:

- **H0**: there is no statistically significant difference between Czech and Slovak companies in the emphasis they put on CSR activities connected with the COVID-19 pandemic (P1-P7).
- **H1**: there is a statistically significant difference between Czech and Slovak companies in the emphasis they put on CSR activities connected with the COVID-19 pandemic (P1-P7).

Results and Discussion

The analysis gave some important results, revealing many similarities between CZ and Slovak Republic for business CSR activities linked to the COVID-19 pandemic. Indeed, with the exception of P6, no statistical difference can be found between the two countries (Table 1). Therefore, we do not reject H0 in P1, P2, P3, P4, P5 and P7; we do reject it in P6.

Table 1. Test Statistics (Source: own elaboration based on own data)

a. Grouping Variable: Country	**Mann-Whitney U**	**Wilcoxon W**	**Z**	**Asymp. Sig. (2-tailed)**
P1 Disinfection and cleanliness of premises	15180.000	31470.000	-1.123	0.262
P2 Equipping employees with protective equipment	14544.500	30834.500	-1.811	0.070
P3 Elimination of social contacts in the workplace	14572.500	30862.500	-1.710	0.087
P4 Increased prevention costs	15744.000	32034.000	-0.481	0.631
P5 Assistance to the public and the local community	15927.000	32217.000	-0.284	0.777
P6 Extra employee benefits (possibility to test at the workplace. take voluntary quarantine with income compensation. etc.)]	14236.500	30526.500	-2.042	***0.041***
P7 Other	15467.500	31757.500	-0.777	0.437

Let us analyse in greater detail the answers to each question. Table 2 illustrates the answers for each of the questions, P1-P7.

P1. According to the questionnaire, one third of companies gave at least a strong emphasis beyond the usual framework for disinfection and cleanliness of premises. Of them, the majority puts a solid emphasis beyond the usual framework (160, divided as follows: 84 answers for the Slovak Republic and 76 for CZCZ). We observe that the disinfection of premises is a very important preventive action of monitored companies against COVID-19. Pradhan et al. (2020) identify this activity as an activity which requires critical attention.

P2. Among the firms in the sample, most gave at least a strong emphasis equipped employees with equipment against covid (82% of the sample). To highlight, a slight difference, with 89 out of 180 companies in SK answering with very strong emphasis, while 78 (the majority in CZCZ) put strong emphasis. Equipping employees against the infection would include various tools. However, it can be considered a basic activity for all businesses. Of course, for healthcare workers is of the highest importance (Sayburn, 2020) and for other workers disposed to the public, including first contact administrates (WHO, 2020b).

A strong emphasis is put on limiting social contact in the workplace. 62,5% of the firms say that at least a strong emphasis equipped employees with protection to face the pandemic. While most Czech companies (69) have put a strong emphasis, Slovak-based companies have a very strong one. We can conclude that face masks were key pieces of equipment against disease spreading. Despite confirmed justification of their use (Chua et al., 2020; Liao et al., 2021), there are still some disadvantages connected with their use and waste management (Silva et al., 2021).

P4. As for the previous, great attention is given to decreasing the threats of the virus. For this particular question, prevention costs have substantially increased for the majority of the companies in the sample (strong emphasis on it). Czech ones (67) are more concerned with the increment of prevention cost than Slovak ones, which answered: "strong emphasis" (59). The concern of prevention costs was already highlighted (Kao et al., 2021; Zhou et al., 2022). Moreover, Richards et al. (2022) underlined prevention costs as a considerable economic burden.

P5. Oppositely to the analysed questions so far, assistance to the community and the public is rare. This outcome is quite alarming, considering that marginalised communities relied on this support (Sevelius et al., 2020). The more the demanded effort, the lower the number of companies that emphasise this particular aspect of CSR. In this regard, we believe companies should have increased the assistance to communities. Indeed, for the choice of products and companies, consumers evaluate them in terms of CSR: negative CSR associations are more impactful and have more damaging effects than positive ones (Öberseder et al., 2013).

P6. According to the questionnaire results, employees seem to enjoy more extra benefits in CZ than in SK. As many as 101 companies in CZ (more than 50% of the total 180, i.e., 56.1%) put at least a strong emphasis beyond the usual framework. In contrast, in SK, less than half do that (80 over 180). In percentage terms: 44.4%. P6. This is a critical aspect to evaluate for the analysis due to the statistically significant difference between the two countries. With a p-value = 0.041, the Mann-Whitney U test is significant, which means that extra employee benefits like testing at the workplace, taking voluntary quarantine with income compensation, etc., differ. These had an incredibly positive impact on employees (Howe et al., 2021) and their mental health (Kirwin & Ettinger, 2022)

P7. This question is generic because the aim was to include anything not previously mentioned. For this reason, what can be "Other" for one company cannot be the same for another.

Table 2. Results of the questionnaire (Source: own elaboration based on own data)

		1. Nothing out of the ordinary	2. The minimum above the normal framework	3. Weak emphasis beyond the usual framework	4. Strong emphasis beyond the usual framework	5. Very strong emphasis beyond the usual framework	Total
P1							
Country	1 SK	2	5	17	72	84	180
	2 CZ	4	6	22	72	76	180
Total		6	11	39	144	160	360
P2							
Country	1 SK	3	6	22	60	89	180
	2 CZ	6	8	19	78	69	180
Total		9	14	41	138	158	360
P3							
Country	1 SK	12	24	44	47	53	180
	2 CZ	12	14	29	69	56	180
Total		24	38	73	116	109	360
P4							
Country	1 SK	15	11	47	59	48	180
	2 CZ	17	7	41	67	48	180
Total		32	18	88	126	96	360
P5							
Country	1 SK	47	48	33	33	19	180
	2 CZ	54	26	52	24	24	180
Total		101	74	85	57	43	360
P6							
Country	1 SK	22	32	46	49	31	180
	2 CZ	17	28	34	58	43	180
Total		39	60	80	107	74	360
P7							
Country	1 SK	72	20	51	25	12	180
	2 CZ	74	15	39	32	20	180
Total		146	35	90	57	32	360

As it is possible to see from the data, almost 40% of the analysed companies (146) do not do anything out of the ordinary that can be labelled as "other". These organisations are split 72 in SK and 74 in CZ. Moreover, only 32 out of 360 (of which 20 from CZ) put a very strong emphasis on practices beyond the framework. Conducted research does not include open questions regarding the specification of "other

activities". However, as the most effective "other activity" in the pandemic era, proactive social (group) therapy was identified (Finnerty et al., 2021).

The answers in P1, P2, P3 and P4 highlight the awareness of companies to implement measures that can minimise the spread of the virus; it results in advantages for the company itself and the employees. Having sound measures can guarantee the minimisation of COVID-19 infections, companies' survival and that employees feel safe in their workplaces. Not only safety keeps high morale among employees, but also it reduces possible damage to the firm's reputation (Kabir et al., 2018). Consumers that realise a company does not do much to safeguard employees' health would stop purchasing from them (Dimitrios et al., 2020). For example, this lowers the chances that employees get isolated (for quarantine), and so complications for division and coordination of labour between those individuals or teams that got infected and must spend a period alone (Carnevale & Hatak, 2020). In addition, having implemented protective measures allow the continuity of the business and its operations (Bailey & Breslin, 2021).

Conclusion

CSR practices are now important for all companies. They help to build up a positive reputation and create an environment in which employees feel motivated and whereby morale and commitment are high. With COVID-19, the need to have additional CSR practices has become essential. In this paper, we briefly discussed some of the fundamental measures, basic ones (including cleaning and sanitation of premises, elimination of social contacts and the provision of protective equipment) and more "sophisticated ones" (e.g., extra benefits, assistance to the public). Opting for these practices is to take advantage of the company implementing them and to employees working for it. They indeed allow ongoing business operations during restrictions and limit the risk of infection. This also can be seen from external stakeholders, particularly customers, who would reward the company for complying with CSR practices connected to COVID-19.

As the questionnaire revealed, between Czech and Slovak businesses, not many differences exist for what regards the selected responsible activities linked to COVID-19. It emerged that only one activity group out of seven is statistically different. Therefore, H1 was verified only in P6. The number of companies that guarantee extra benefits than the usual framework is higher in CZ (at least a strong emphasis is indicated by many companies). The assistance to the public and the local community is low in the sample. Increasing the emphasis on that can give a clear positive image to the organisation and, as mentioned, be rewarded by the community.

The study has an obvious limitation. The restricted sample cannot be representative of all daughter companies, which makes generalisation difficult, yet it reveals the necessity for companies to largely make use of responsible activities. This may explain why companies based in CZ and SK do not differ so much in CSR practices linked to COVID-19. The reason could not only be limited to the long-lasting common history of the two countries: the pandemic cannot be neglected, but it should be attentively fought to minimise its impact on everyday business. Further studies can verify whether more differences emerge in companies based in other countries (perhaps with a distant culture).

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DIGITAL BARRIERS IN DIGITAL TRANSITION AND DIGITAL TRANSFORMATION: LITERATURE REVIEW

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Abstract

Research purpose. The research aimed to identify digital barriers in the digital transition and digital transformation in businesses and industries under the umbrella of human resource management. The topicality of the research relates to the need to identify digital barriers impeding digital transition and transformation that can be addressed through the prism of human resource management policies or that can be related to human resource management.

Design / Methodology / Approach. The research method was the analysis of the keywords and keyword concordances, conducted on the sample of the created corpus of 50 recently published scientific papers, which were analysed using the text analysis instruments *AntConc* and *Voyant Tools*.

Findings. Two digital barrier types were postulated - individual and organisational barriers, which were further spread across five digital barrier areas - human resource, technological, management, business development, and financial ones that were able to accommodate the following barriers: general human resource, staff resistance, psychological, staff digital competences, decision-makers digital competences, internal information exchange, external information exchange, data processing, technical, IT complexity, poor usability, cybersecurity, general management, business structure, business 4.0, industry 4.0, creativity, and costs.

Originality / Value / Practical implications. The created structure of digital barriers provides human resource departments with a global picture of barriers that should be reviewed within their competence areas to ensure the recruitment of specialists capable of conducting specified digital operations and the continuous development of digital competencies of the entire labour force of the organisation. The suggested digital barrier structure can also be used to develop the organisational strategy for the digital transition and digital transformation.

Keywords: Digital barriers; Transformation; Human resources.

JEL codes: M50; M53; M54.

Introduction

Digital transformation of business activities is currently underway at governmental, industrial, business, and personal levels to achieve Business 4.0 and Industry 4.0 outcomes aimed at boosting economic sustainability inclusive of financial, business development, environmental, societal, and human capital aspects. While Business 4.0 concepts pertain to entrepreneurial endeavours employing technological tools of Industry 4.0 to address socio-economic development, Industry 4.0 focuses more on innovations in technologies (Sergi et al., 2022) because Industry 4.0 is the essence of the fourth industrial revolution that creates cyber-physical spaces (David et al., 2022). Therefore, Industry 4.0 innovations are based on artificial intelligence, cloud computing, advanced robotics, the Internet of Things, etc., that are used to create digital ecosystems (Marcon et al., 2022), and their implementation into business activities is the key priority of Business 4.0, which is why digital competences of staff are prioritised (Sergi et al., 2022). Otherwise, the application of Industry 4.0 solutions might be impeded.

Industry 4.0 is part of the network consisting of a circular economy, competitiveness and stakeholders that aims to increase business sustainability while ensuring client satisfaction (Hallioui et al., 2022). The circular economy also emphasises using digital technologies through business circular models that are expected to expand competitiveness opportunities (Wasserbaur et al., 2022). The use of such technologies under circular economy models also requires a higher level of digital competencies of staff, which cannot be ignored because circular business models in Business 4.0 transform not only some aspects of business activities of organisations – they holistically change business operations which is why the expectations of more advanced digital competences of staff apply not only to specific operations but generally to the entire network of operations of an organisation, including communication, record-keeping, data analysis, etc. Thus, digital competencies should also be approached from a holistic perspective. The reason is that they cover both soft-skill and hard-skill aspects, ensuring work progress in the digital environment (Cimini et al., 2021).

Although the fourth industrial revolution began prior to the COVID-19 pandemic, it was this health crisis that necessitated a more rapid transition to Industry 4.0 solutions and their application to current business models; in other words, it facilitated the transition to Business 4.0 and circular economy operations, including those of smart circular economy. However, a rapid transition requires rapid development of necessary digital competencies of staff, which might be problematic due to various factors, such as time constraints of learning, financial, management and technological gaps, etc. A lack of financial resources might also impede a rapid transition to invest in acquiring new technologies and restructuring business processes, etc. Such factors create barriers in the transition to Business 4.0 and circular economy operations, which impede the digital transformation of organisations.

To be able to lower the negative impact of digitalisation barriers, it is essential to identify them first. This research aimed to identify digital barriers impeding digital transition and digital transformation in organisations concerning human resource management. Digital barriers could be defined in different ways. For example, digital barriers might refer to issues related to the inaccessibility of digital learning materials, issues with digital equipment, and lack of awareness of the constituents of digital barriers (Sanderson et al., 2022). In this research, digital barriers are defined as obstacles related to the creation, access and use of resources in both offline and online digital spaces. The aim was attained through the analysis of scientific sources by application of the keyword frequency and concordance research methods. The outcomes of this research can be used by senior management teams and the managers of business development, human resources, and technological resources in handling overt and possibly covert digital transition and digital transformation barriers in their operations. The fact is, not all digital transition and digital transformation attempts are successful. For example, in 2019, less than 10% of enterprises in China, which is the second largest digital economy in the world, demonstrated positive outcomes of digital transformation, possibly due to the digitalisation paradox, which reveals that investment in digital transformation does not produce the increase in revenues (Guo et al., 2023). This paradox might be attributed to digital transformation and transition barriers, and unless they are identified and overcome, the digitalisation paradox might continue to negatively impact the number of revenues, thus hindering organisational operations' digitalisation.

Literature review

Digital transformation is one of the priorities of the European Union because it facilitates the implementation of green policies, for example, by decreasing greenhouse gas emissions, and prepares citizens for activities in digital spaces, thus, fostering the development of digital competencies across all citizen groups (European Commission, 2022). According to the European Parliament policies, digital transformation opens new opportunities for businesses, helps to reach climate neutrality objectives by 2050, and encourages the development of people's digital competencies, including those pertinent to the workplace (European Parliament, 2023). According to the European Digital Decade Policy Programme 2030, business digital transformation has the potential to benefit more than 90% of small and middle-size businesses and facilitate their transition to basic digital intensity (European Commission, 2022), which ensures the sustainability of such businesses in the competitive marketplace.

Digital transformation is triggered by technological tools (Niu et al., 2023), the impact of which cannot be ignored due to the capacity of such tools to facilitate sustainability and competitiveness at industrial levels, including small and medium-sized enterprises (Chatzistamoulou, 2023), and even micro-enterprises (Niu et al., 2023). The outcomes of digital organisational transformation create new products and services that customers prefer. This puts pressure on all organisations to shift to digital transition and digital transformation to ensure organisational survival in the market with innovative digital market entrants, such as *Amazon.com* (Verhoef et al., 2021).

In the study on the transition to a smart circular economy, which thrives on digital technologies, and constitutes Industry 4.0, Trevisan et al. (2021) identified 45 barriers grouped into eight dimensions: knowledge management, financial, process management and governance, technological, product and material, reverse logistic infrastructure, social conduct, as well as policy and regulatory barriers (Trevisan et al., 2023). The key knowledge management barriers included the lack of knowledge of technologies, environmental issues and economic gains, and competent labour (Trevisan et al., 2023). The financial dimension covered the barriers of the lack of funds and investment into digital technologies and the high costs of new technologies (Trevisan et al., 2023). The barriers to process management and governance incorporated the lack of management support, innovation capacity, integration of cross-departmental operations, the strategy of risk aversion, and longitudinal planning (Trevisan et al., 2023). The technological barriers covered the lack of IT tools, models, infrastructure, protocols, and cybersecurity tools and difficulty conducting data analysis and data integration (Trevisan et al., 2023). As for the product and material barriers, they included the poor quality of materials, low added value, and slow pace of product development (Trevisan et al., 2023). The problems with waste disposal and the selective collection of materials formed obstacles to the reverse logistics infrastructure (Trevisan et al., 2023). The social behaviour barriers covered the concerns over data sharing and employment policies, as well as client behaviour, public interest safeguarding, and change resistance issues (Trevisan et al., 2023). Finally, the policy and regulatory barriers included the lack of governmental support, high taxation and excessive bureaucratic structures, high costs of imported goods and non-challenging environmental targets (Trevisan et al., 2023). Overall, barriers were identified in the areas of management, technologies, funding, human resources, and public policies.

Although there are various types of barriers hindering the transition and creation of digital transformation, those related to the digital competencies of staff might be among the key obstacles. Having conducted the analysis of scientific sources, Gong & Ribiere (2021) concluded that digital transformation rests on the innovative deployment of advanced digital technologies for the purposes of creation and support of a value network for various stakeholders aimed at developing and sustaining organisational identity, which entails a global organisational change in activities, structure, as well as approaches and attitudes. Clearly, such transformation is hardly possible even if available funds and technologies are not supported by staff digital competencies that would ensure the maintenance of current digital operations and create new activities in the digital space.

However, what is digital competence? Digital competence is the capacity to deploy digital technologies by using digital tools to assess problems critically, offer problem-solutions (Süße et al., 2018), conduct daily operations, and create products and services. In one study, Norveel et al. (2022) found that bank employees had a relatively low level of basic digital competencies. This suggests that the digital competencies of staff should be a concern of organisations. In fact, many enterprises claim insufficient digital competencies of staff and view this factor as an impediment in the implementation of Industry 4.0 objectives, which is a barrier in the transition to the digital transformation of Industry 4.0 (Steinlechner et al., 2021), Business 4.0 and circular economy. Therefore, the European Commission emphasises the importance of creating a digital education ecosystem and the development of citizens' digital competencies (European Commission, 2023).

So, who should be responsible for developing proper staff digital competencies at an organisation? It is partly the responsibility of the senior management team, should support the development of digital competencies of staff (Wang et al., 2023) because staff might be incompetent to utilise the latest technologies, which might create unnecessary psychological barriers. The human resource department is also partly accountable for a proper level of digital skills of staff because, on the one hand, the human resource managers should introduce a proper recruiting strategy to ensure the acquisition of required

digital skills by the organisation. However, on the other hand, they should provide regular testing and training of digital competencies staff due to the rapid and complex development of digital technologies.

Considering the importance of staff digital competencies for ensuring the digital transition and digital transformation, the focus of this research was on the identification of digital barriers in the digital transition and digital transformation in businesses and industries under the umbrella of human resource management.

Research Methodology

The research methodology followed the PRISMA principles of systematic literature review (PRISMA, 2023), which according to Page et al. (2021), was designed to provide consistency in reporting and define the minimum requirements for review reporting.

The research method was text analysis, for which a research paper corpus was created. Fifty papers were selected for the analysis. This number of papers was justified by the aim of the research – to identify digital transition and transformation barriers concerning human resources management rather than to explore the constructs of these concepts and develop lexical networks between and within these concepts (see Table 1). The papers were obtained from the platform *ScienceDirect,* positioned by its creator *Elsevier* as a leading platform of more than 2,650 scientific peer-reviewed journals providing full access to papers (Elsevier, 2023a). *Scopus* is another product of *Elsevier*, but it is an abstract and citation database (Elsevier, 2023b), which is why it was not used in this research. The *Google Scholar* platform was not used because it provides access to peer-reviewed papers and non-reviewed papers. The selected papers were published throughout 2017 - 2023 and were selected if their titles included the following keywords related to this research: (1) digitisation and transition / transformation; (2) digital transition; (3) digitisation/digitalisation and its impact / development; (4) challenges / problems / barriers and digital / digitisation (transition); (5) digitalisation / barriers / transition and human resource management. The overall context of these keywords in the title pertains to business, management, economy, industries, sectors, workplace, and human resource management. The range of the keyword contexts did not focus solely on human resource management or workplace in the companies due to the limited number of papers available on such topics.

Table 1. Papers used in the analysis (Source: authors created)

No.	Authors	Paper title
1	Abbate et al. (2023)	The digital and sustainable transition of the agri-food sector
2	Ancillo et al. (2023)	The impact of research and development on entrepreneurship, innovation, digitisation, and digital transformation
3	Andersen et al. (2021)	On digitalisation and sustainability transitions
4	Annosi et al. (2021)	Digitalisation within food supply chains to prevent food waste. Drivers, barriers, and collaboration practices
5	Bansal et al. (2023)	A study of human resource digital transformation (HRDT): A phenomenon of innovation capability led by digital and individual factors
6	Baptista et al. (2020)	Digital work and organisational transformation: Emergent digital/human work configurations in modern organisations
7	Baumle et al. (2023)	The contribution of knowledge intermediation to sustainability transitions and digitalisation: Qualitative insights into four German regions
8	Bui & Le (2023)	Digital capability and creative capability to boost firm performance and formulate differentiated CSR-based strategy
9	Busch et al. (2018)	Opportunities and challenges of digitised discretionary practices: A public service worker perspective
10	Caputo et al. (2023)	Building T-shaped professionals for mastering digital transformation

11	Cerchione et al. (2023)	Blockchain's coming to hospital to digitalise healthcare services: Designing a distributed electronic health record ecosystem.
12	Chen & Thio (2021)	Exploring the drivers and barriers to uptake for digital contact tracing
13	Chen et al. (2023)	Enabling the twin transitions: Digital technologies support environmental sustainability through lean principles.
14	Chirumalla et al. (2023)	Moving from servitisation to digital servitisation: Identifying the required dynamic capabilities and related microfoundations to facilitate the transition.
15	Cirillo et al. (2023)	The adoption of digital technologies: Investment, skills, work organisation
16	Cisarova (2023)	We were innovators, but we gave up: the muted digital transition of local newspapers.
17	Dabbous et al. (2023)	The impact of digitalisation on entrepreneurial activity and sustainable competitiveness: A panel data analysis
18	Dabic et al. (2023)	Future of digital work: Challenges for sustainable human resources management
19	Dalenogare et al. (2023)	Building digital servitisation ecosystems: An analysis of inter-firm collaboration types and social exchange mechanisms among actors
20	Favoretto et al. (2022)	From servitisation to digital servitisation: How digitalisation transforms companies' transition towards services
21	Feliciano-Cestero et al. (2023)	Is digital transformation threatened? A systematic literature review of the factors influencing firms' digital transformation and internationalisation
22	Ferreira et al. (2022)	The interactions of entrepreneurial attitudes, abilities, and aspirations in the (twin) environmental and digital transitions? A dynamic panel data approach
23	Giua et al. (2022)	Smart farming technologies adoption: Which factors play a role in the digital transition?
24	Golab-Andrzejak (2023)	AI-powered digital transformation: Tools, benefits, and challenges for marketers – Case study of LPP
25	Guo et al. (2023)	Does digital transformation improve the firm's performance? From the perspective of digitalisation paradox and managerial myopia
26	Hewitt et al. (2020)	Participatory development of digital support tools for local-scale energy transitions: Lessons from two European case studies
27	Hojnik et al. (2023)	Challenges of demographic changes and digitalisation on eco-innovation and the circular economy: Qualitative insights from companies.
28	Holopainen et al. (2022)	Managing the strategic readiness of industrial companies for digital operations
29	Liu et al. (2023)	How do family firms respond strategically to the digital transformation trend: Disclosing symbolic cues or making substantive changes?
30	Makitie et al. (2023)	Digital innovation's contribution to sustainability transitions.
31	Meske et al. (2020)	Bridging formal barriers in digital work environments – Investigating technology-enabled interactions across organisational hierarchies
32	Nwaila et al. (2022)	The minerals industry in the era of digital transition: An energy-efficient and environmentally conscious approach.
33	Okorie et al. (2023)	Digital transformation and the circular economy: Creating a competitive advantage from the transition towards Net Zero Manufacturing
34	Polakova-Kersten et al. (2023)	Digital transformation in high-reliability organisations: A longitudinal study of the micro-foundations of failure.
35	Pellegrini et al. (2020)	Digital transition and waste management in architecture, engineering, construction, and operations industry
36	Quaranta et al. (2023)	Digitalisation and real-time control to mitigate environmental impacts along rivers: Focus on artificial barriers, hydropower systems and European priorities
37	Qian et al. (2023)	Digitalisation of logistics for transition to a resource-efficient and circular economy

38	Ramachandran et al. (2023)	Barriers and facilitators to the adoption of digital health interventions for COPD management: A scoping review
39	Saarikko et al. (2020)	Digital transformation: Five recommendations for the digitally conscious firm
40	Selimovic et al. (2021)	Digital workplace transformation in the financial service sector: Investigating the relationship between employees' expectations and intentions
41	Setkute & Dibb (2022)	"Old boys' club": Barriers to digital marketing in small B2B firms
42	Sergi et al. (2022)	Creative abilities and digital competencies to transitioning to Business 4.0
43	Shen et al. (2022)	Digital transition and green growth in Chinese agriculture
44	Tavani et al. (2022)	Smartphone assisted fieldwork: Towards the digital transition of geoscience fieldwork using LiDAR-equipped iPhones
45	Teixeira et al. (2022)	Demystifying the digital transition of re-manufacturing: A systematic review of literature
46	Trevisan et al. (2023)	Barriers to employing digital technologies for a circular economy: A multi-level perspective
47	Vuchkovski et al. (2023)	A look at the future of work: The digital transformation of teams from conventional to virtual
48	Wilson & Mergel (2022)	Overcoming barriers to digital government: mapping the strategies of digital champions.
49	Zhang et al. (2017)	From numerical model to computational intelligence: The digital transition of urban energy system
50	Zhong & Ren (2023)	Independent and joint effects of CSR and CSI on the effectiveness of digital transformation for transition economy firms

Seventy-eight per cent of all papers were published in 2022 – 2023, which indicates a growing interest of the scientific community in the topic.

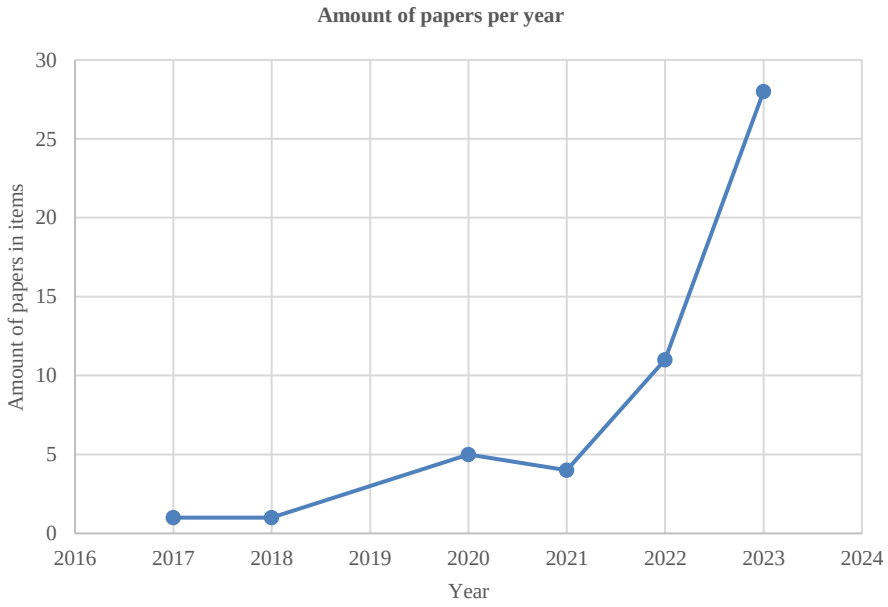

Fig. 1. Number of papers per year (Source: authors created)

The papers were published in 29 journals (see Fig. 1).

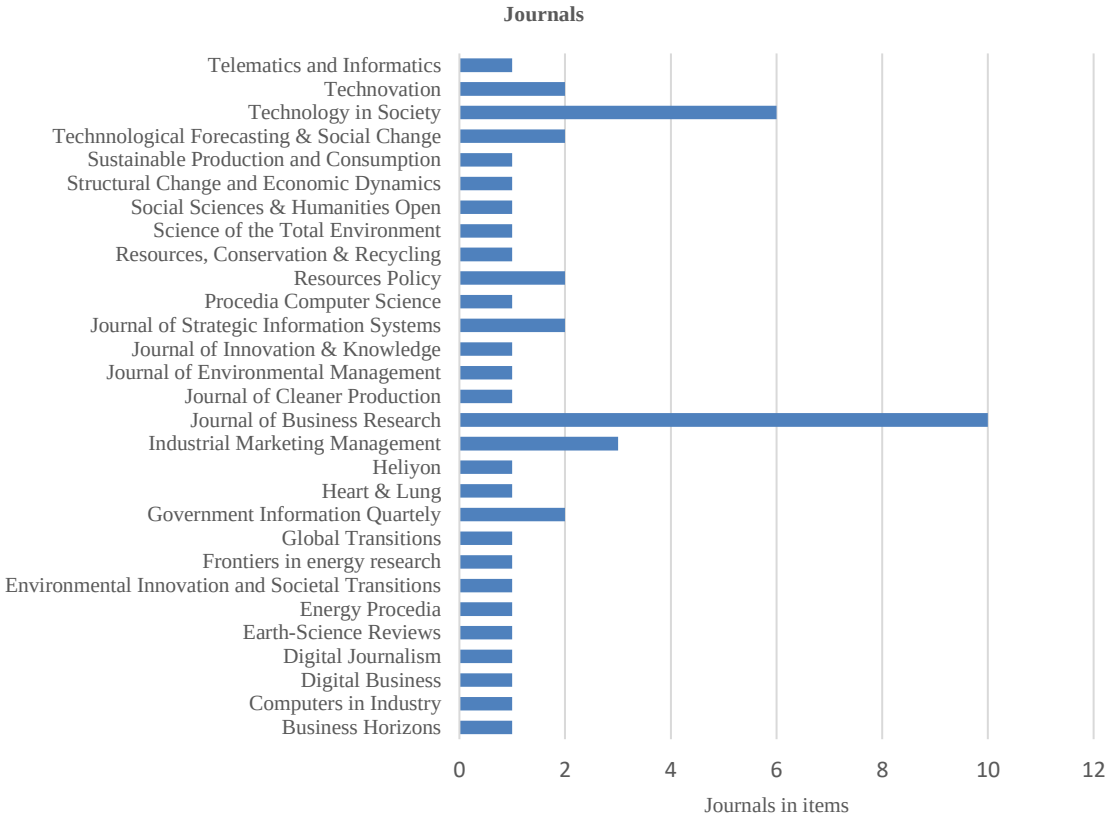

Fig.2. Journals of the selected papers (Source: authors created)

Although nine journals were not found in the Scopus database, retrieved from the section *Scopus Source List* (Scopus, 2023), they were included in the analysis because they were provided by *Science Direct*, which indicated that the journals were indexed with *Scopus*, one such case being the journal *Procedia Computer Science* (ScienceDirect, 2023). Furthermore, according to the *Scimago Journal & Country Rank*, most of these journals are in Scopus Q1, which points to a high quality of selected papers (see Fig. 3)

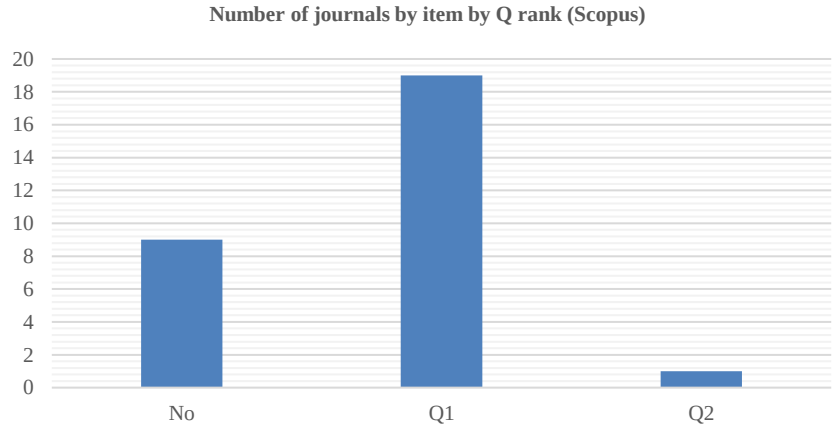

Fig.3. Number of journals per quartile (Source: authors created)

All papers were analysed together because the research aimed to identify barriers related to the digital transition and digital transformation in pertinence to human resource management that is mentioned in scientific literature overall.

Word frequency analysis was run on the open-access text analysis platform *Voyant Tools*, while the word concordance analysis was performed in the text analysis program *AntConc*. Both *Voyant Tools* and *AntConc* are used to create text corpora, determine word frequency based on the word occurrence in the created corpus, and explore the lexical contexts of selected words, referred to as word concordances (Laurence Anthony's Website, n.d.; Voyant Tools, n.d.). However, the visualisation capacity of these instruments differs, which is why they both were used for more effective visualisation of research results.

Research results

To identify digital barriers in digital transition and transformation concerning human resource management, 50 selected papers were loaded onto the *Voyant Tools* and *AntConc* platforms to create one unified text corpus. The resulting corpus included 731,236 words (see Fig. 4).

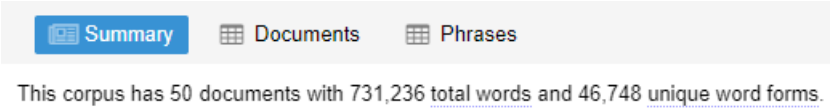

Fig. 4. Corpus created on the platform *Voyant Tools* (Source: authors created)

The keywords were combined into ten lexical tokens. They constituted 0,005% of the entire corpus, and their raw frequency is provided in Fig.5.

Terms

	Term	Count	Trend
1	"digital* transformation"	1324	
2	digitalization*	765	
3	barrier*	614	
4	challenge*	587	
5	"digital* transition"	232	
6	problem*	215	
7	digitization*	135	
8	"human resource*"	103	
9	"human capital*"	91	
10	"human resource management*"	60	

Fig. 5. Frequency of the keywords in the created corpus on *Voyant Tools* (Source: authors created)

The relative frequency of the selected concepts within documents, ranging from 0.000 to 0.016, is provided in Fig. 6.

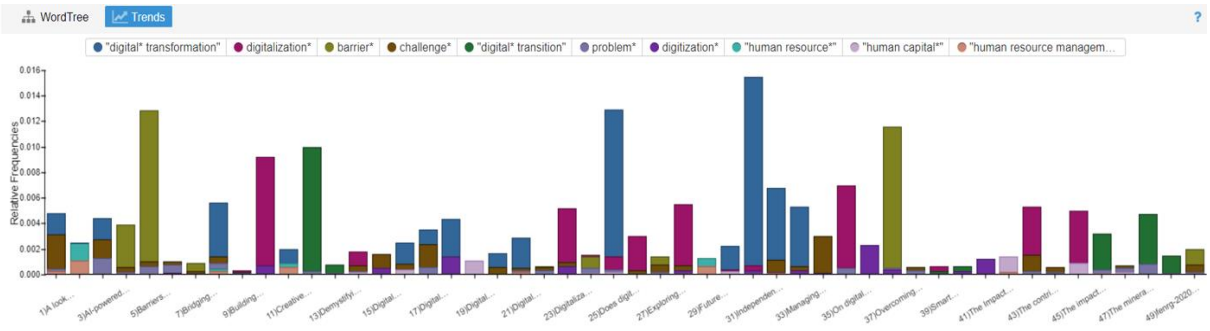

Fig. 6. Relative frequency of the keywords in the created corpus on *Voyant Tools* (Source: authors created)

Within the text analysis theory, the importance of a word in the text is transmitted through its frequency, which is why more crucial concepts are expected to be more frequently used than less important words (Han et al., 2017). This suggests that the selected keywords (see Fig. 5) are not of high importance in the created corpus, which might explain why there is a lack of barrier types in the created corpus.

The concept of the digital transition was mentioned 5,7 times less frequently than the notion of the digital transformation, despite the concept of transition taking up 60% of all the papers that contained the lexical item "transition" or "transformation" in the title. This means that the concept of the digital transition is less frequently addressed than that of digital transformation.

The concepts of difficulty conveyed through the words of barriers, challenges and problems were researched in concordance, an example of which is provided in Fig. 7.

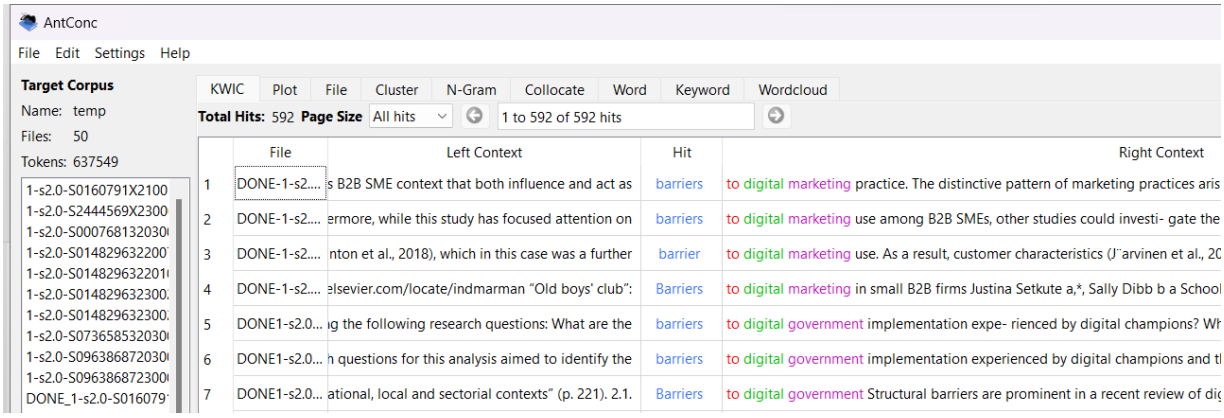

Fig. 7. Concordance sample for *barriers* created in the program *AntConc* (Source: authors created)

The concepts of *barriers*, *challenges*, and *problems* in relation to management, business, entrepreneurship, transition, and transformation in the context of digitisation and digitalisation were identified in 47 out of 50 papers. The analysis resulted in the identification of the following categories: (1) barrier domains: digital and general barriers; (2) barrier types: individual, organisational, individual / organisational, and market-related; (3) barrier specification (see Table 2). Individual barriers referred to the personal competencies of people, while organisational barriers refered to the capacities of organisations. The barrier type *individual / organisational* combined both personal and organisational characteristics.

Table 2. Barriers per papers (Source: authors created)

Papers		Authors created		
Authors	**Lexical context of *barriers, challenges and problems***	**Barrier specification**	**Barrier domains**	**Barrier type**
Vuchkovski et al. (2023)	Lack of technology knowledge among (older) employees	Staff lack of digital knowledge	Digital	Individual / organisational
	Lack of face-to-face communication, decreasing motivation, lower sense of teamwork, work tasks in virtual teams	Psychological	Digital	Individual / organisational
	Barriers to creative work	Creativity	Digital	Organisational
Bansal et al. (2023)	Competition in the market increasing and work in the virtual environment is going to increase, so, organisations should ensure their competitiveness in such environment	Technical and structural	Digital	Organisational
Golab-Andrzejak (2023)	Lack of investment in artificial intelligence	Financial	Digital	Organisational
Ramachandran et al. (2023)	Barriers in the adoption of digital health interventions	Clients' lack of digital knowledge	Digital	Individual
	Barriers in the adoption of digital health interventions from the hospital perspective include the staff lack of digital knowledge	Staff lack of digital knowledge	Digital	Individual / organisational
	Barriers in the adoption of digital health interventions from the hospital perspective include the increased workload	Management	Digital	Organisational
	Barriers in the adoption of digital health interventions from the hospital perspective include the lack of funding	Financial	Digital	Organisational
	Barriers in the adoption of digital health interventions from the hospital perspective include the lack of dedicated and trained staff	Human resource	Digital	Organisational
Cerchione et al. (2023)	Barriers in information access across various organisations, e.g. healthcare system	External information exchange	Digital	Organisational
Meske et al. (2020)	Barriers in information exchange among different levels of employees across an organisation	Internal cross-level information exchange	Digital	Organisational
Caputo et al. (2023)	Employee rejection of digital transformation	Staff resistance	Digital	Organisational
Sergi et al. (2022)	Business 4.0 creates market-entry barriers	Business 4.0	Digital	Organisational
Teixeira et al. (2022)	Industry 4.0 and re-manufacturing problems associated with re-manufacturing systems	Industry 4.0	Digital	Organisational
Polakova-Kersten et al. (2023)	Complexity of IT	IT complexity	Digital	Organisational
Chen & Thio (2021)	Poor usability of DCT creates barriers for users	Poor usability	Digital	Organisational
Setkute & Dibb (2022)	Lack of knowledge regarding digital marketing related to the generational gap	Decision-makers' lack of knowledge	Digital	Organisational
Favoretto et al. (2022)	Data-related issues, such as poor data standardisation and data integration in servitisation	Data-related	Digital	Organisational
	Lack of funds to invest in digitalisation	Financial	Digital	Organisational

Abbate et al. (2023)	Obstacles in the implementation of I4.0 technologies	Technical	Digital	Organisational
Nwaila et al. (222)	Obstacles impeding the implementation of new technologies and data technologies	Technical	Digital	Organisational
	Obstacles impeding the implementation of data technologies	Data processing	Digital	Organisational
Dalenogare et al. (2023)	Security of digital operations and data	Cybersecurity	Digital	Organisational
	Insufficient digital competencies of staff	Staff digital competence	Digital	Organisational
Holopainen et al. (2022)	Lack of interest in customers to accept digital operations of companies	Client digital competences	Digital	Organisational
Bui & Le (2023)	Cultural and physical barriers in doing or expanding business on an international scale that a digital platform can help to lower.	Market-entry	General	Market-related
	Systemic barriers associated with the transition to the use of sustainable (renewable) energy sources	Systemic energy	General	Organisational
Makitie et al. (2023)	Circularity barriers that impede making connections between waste users and waste producers	Client identification	General	Organisational
Okorie et al. (2023)	Barriers in attaining zero-emission level	Green barrier	General	Organisational
Saarikko et al. (2020)	Barriers in finding reliable suppliers and contractors	Supplier general	General	Organisational
Shen et al. (2022)	Entering market barriers for small farms	Market-entry	General	Organisational
Selimovic et al. (2021)	Interpersonal relations of employees affect collaboration and productivity	Interpersonal employee	General	Organisational
Quaranta et al. (2023)	Physical and geographic barriers in construction	Landscape	General	Organisational
Trevisan et al. (2023)	Costs	Financial	General	Organisational
	Dimension barriers: technology, data protection, general management and structural	Organisational lack of knowledge	General	Organisational
	Product development			
	New investment in new ideas			
	Lack of proper infrastructure			
Qian et al. (2023)	Dependency of industries on resources	Resource dependency	General	Organisational
Annosi et al. (2021)	Difficulty entering global supply chain markets	Global market integration	General	Organisational
Wilson & Mergel (2022)	Lack of knowledge of how to manage and do business	Organisational lack of knowledge	General	Organisational
Pellegrini et al. (2020)	Lack of knowledge of how to manage waste	Organisational lack of knowledge	General	Organisational
Dabic et al. (2023)	Vulnerable workers face more barriers in finding employment	Employability of vulnerable groups	General	Market-related
Zhong & Ren (2023)	Weak organisational capabilities impeding the transition to digital transformations	Firm capacity	General	Organisational
Feliciano-Cestero et al. (2023)	Lower barriers for entering markets for competitors	Market competition	General	Organisational

Chirumalla et al. (2023)	Lack of understanding of how to deploy resources	Firm capacity	General	Organisational
	Customer, stakeholder and industry preferences	External	General	Organisational
Andersen et al. (2021)	New products	Market-entry	General	Organisational
Busch et al. (2018)	Technology-related problems to ensure discretionary practices	Discretionary	General	Organisational
Hewitt et al. (2020)	Social acceptance of society of wind turbines	Social acceptance	General	Market-related
	Legal barriers in companies	Legal	General	Organisational
Cirillo et al. (2023)	Cost barriers related to business capacity	Financial	General	Organisational
Baumle et al. (2023)	Management barriers related to balancing innovation and transition approaches	Management	General	Organisational
	Obstacles in knowledge transfer in the region	Organisational lack of knowledge	General	Market-related
Ferreira et al. (2022)	Market entry barriers	Market-entry	General	Organisational
Cisarova (2023)	Understanding barriers between newspapers and technological innovations	Lack of management knowledge	General	Organisational
Ancillo et al. (2023)	Pandemic, climate change and digitalisation	Environment	General	Market-related
Tavani et al. (2022)	Obtaining equipment for specific purposes	Acquisition of technology	General	Organisational
Baptista et al. (2020)	Workplace technologies for digital transformation to boost productivity	Acquisition of technology	General	Organisational
Chen et al. (2023)	Workplace technologies for digital transformation in manufacturing	Use of new technology	General	Organisational
Dabbous et al. (2023)	Measuring performance and competitiveness of the company	Data science	General	Organisational
Hojnik et al. (2023)	Deploying existing resources to meet growing demands of clients	Resource effectiveness	General	Organisational
Liu et al. (2023)	Managing transition to digital transformation, including shifts in strategy, and reducing risks	Digitalisation management	General	Organisational

Having the focus on digital barriers, the research then focused on summarising digital barriers in the program *Power BI* (see Fig.8).

Fig. 8. Digital barriers in the digital transition and digital transformation (Source: authors created)

Overall, 15 organisational, three individual / organisational and one individual barrier emerged (see Fig. 9).

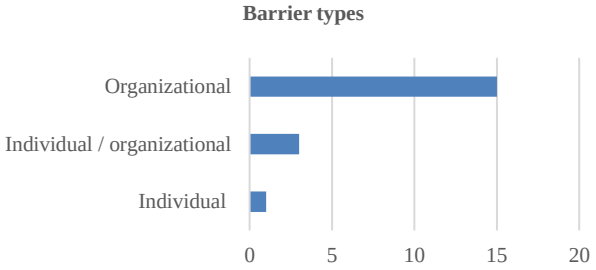

Fig. 9. Summary of barrier types (Source: authors created)

The analysis of barrier specifications identified barrier areas – technological, management, business development, human resources, and financial ones (see Fig. 10).

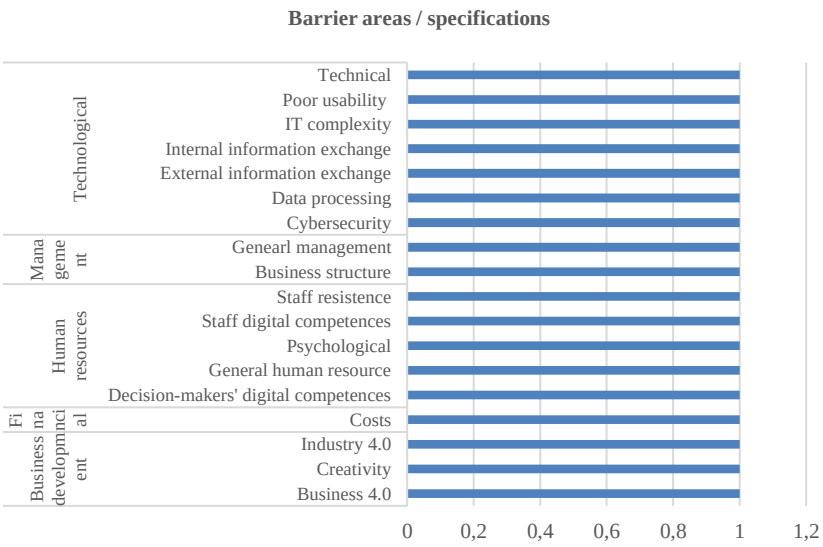

Fig. 10. Barrier areas / specifications (Source: authors created)

Overall, the analysis of scientific literature resulted in the creation of the internal digital barrier structure for an organisation, excluding external barriers, such as clients' digital competence level. External barriers were excluded because just one such barrier was identified in this research, which is an insufficient number to suggest a barrier structure. The resulting structure is provided in Fig. 11.

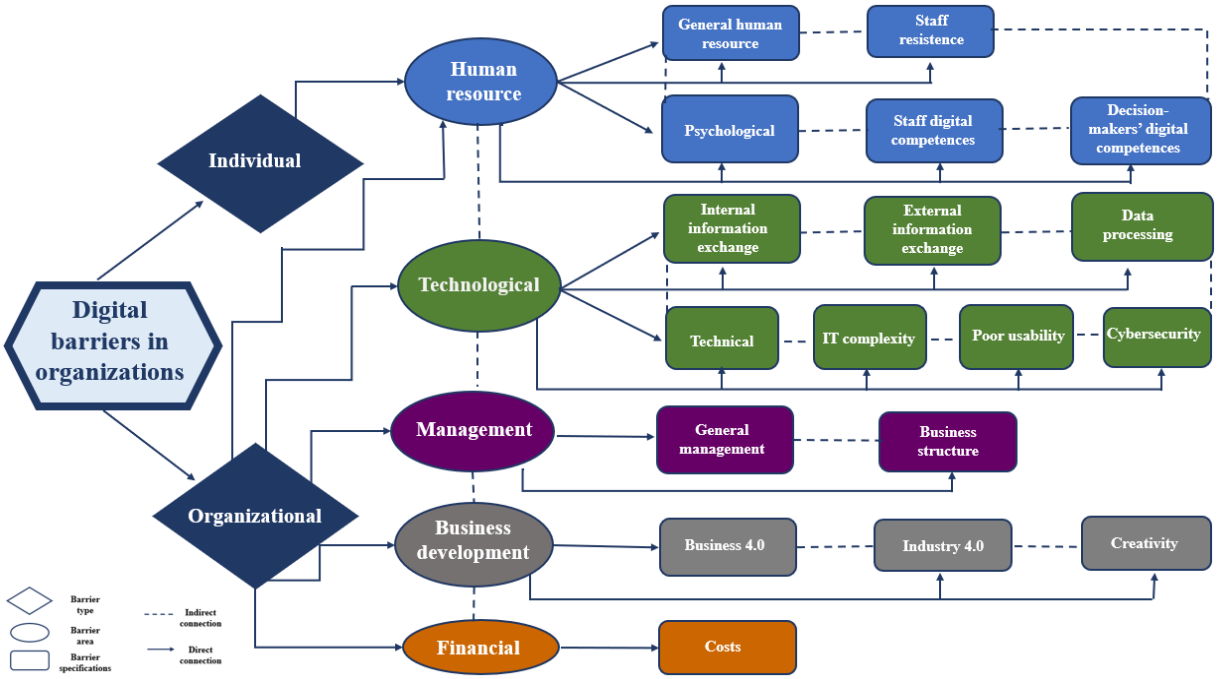

Fig. 11. Digital barrier structure in organisations (Source: authors created)

This structure combines two barrier types (individual and organisational ones) that are further divided across five barrier areas (human resource, technological, management, business development, and financial ones), each of which contains specific barriers (general human resource, staff resistance, psychological, staff digital competences, decision-makers' digital competences, internal information exchange, external information exchange, data processing, technical, IT complexity, poor usability, cybersecurity, general management, business structure, business 4.0, industry 4.0, creativity, and costs), referred to as barrier specifications in this research.

Conclusions

The consequences of the 4th industrial revolution include transitioning to Business 4.0 organisational models functioning in Industry 4.0 contexts. One of the strategic aims of such models and contexts is to increase organisations' productivity, efficiency, and competitiveness. This is expected to happen through the utilisation of innovative technologies of Industry 4.0 (Sergi et al., 2022). Whether modern technologies are welcomed or impeded at an organisation depends on various cross-structural and cross-capacity factors, for example, organisational capacity to invest into new technologies, digital competencies of staff and decision-makers related to the use of new digital technologies, etc. To facilitate the acceptance and deployment of such digital technologies, organisational leaders and staff should be aware of digital barriers. Challenges in digital transformations vary across different types of industries and organisations, such as enterprises that focus on end-consumers and those that are distanced from them, such as asset-intensive companies (Buck et al., 2023), which is why this study aimed to identify general digital organisational barriers, outlined in scientific research, which impede digital transition and digital transformation of various types of organisations under the umbrella of human resource management. To attain this aim, the paper analyses of the recent scientific literature

was conducted, the result of which was the proposal of a digital barrier structure that could be used as a starting point in the design of digital transition and digital transformation strategy or be integrated into a digital transition and digital transformation road map. Earlier, Buck et al. (2023) postulated the corporate need for the identification of digital challenges and digital skills of staff for the inclusion in digital transformation road maps encompassing strategy, recruitment, and business models.

The created digital barrier structure is a multi-layer hierarchical structure that categorises barrier specifications (barrier names) into barrier areas, ultimately divided into barrier types. Barrier areas cover various aspects of organisational activities: human resource, technological, financial, management and business development. While the senior management team can address all barriers through corporate policies at the business strategy and business model levels, ultimately, implementing such policies lies with the human resource department. However, partial responsibility for overcoming some digital barriers lies with individual staff members.

The created structure of digital barriers provides a global picture of barriers that should be considered within the human resource management perspective because the task of human resource departments is to ensure both the recruitment of professionals capable of conducting specific digital operations and the ongoing acquisition of digital competences of the entire labour force of the organisation. This means that human resource departments should be able to contribute to the development of digital transition and digital transformation strategies by informing the senior management team about possible digital barriers within their competence level. The suggested barrier structure can also be used to develop the organisational framework of digital barriers. Earlier, Cirillo et al. (2023) claimed that one of the challenges of integrating new technologies at the workplace related to their diversity makes it implausible to assign them to one common matrix in an organisation. Although this study does not help to create such a matrix, it proposes a structure across which technologies could be spread, ultimately allowing for consistently identifying converging and departing points of technology use.

As with any study, this one also has limitations. One of them relates to a relatively limited number of the analysed papers, which was justified by the task of the research – identification of currently known barriers in the digital transition and digital transformation in human resource management. In the future, the corpus of analysed papers should be expanded to verify the obtained results. Another research limitation pertains to the imbalanced number of publications per year - most papers were published in 2023. This limitation is attributed to the research task, which did not require the identification of a tendency but focused on identifying the most recent facts and opinions expressed in scientific literature. The imbalance of publications was increased by the gap between papers published in 2017 and 2018, which covered only two articles, and the rest of the publications, spanning from 2020 to 2023. The inclusion of 2017 and 2018 papers was justified by the contexts of their discussion – public service and urban energy sector, which contrasted with other selected publications. This imbalance should be addressed in the future by including a relatively even number of papers from a broader range of years. Yet another limitation of the study relates to the source of the analysed papers, which was restricted to only one platform – *ScienceDirec*t, owned by *Elsevier*. *Web of Science*, another well-respected source of scientific references, which is a product of *Clarivate*, was excluded from creating the paper corpus to avoid potential redundancy in results. Because the research task was restricted to identifying barriers, the information available on *ScienceDirect* was considered sufficient. W*eb of Science* should be used in future research to explore the components and interconnections of the identified network concepts. Overall, these methodological constraints were caused by the research task focusing on the surface identification of digital transition and transformation barriers in human resource management rather than exploring deeper structures and networks of conceptual relationships.

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