LogForum

> Scientific Journal of Logistics <

2023, 19 (3), 395-409

http://doi.org/10.17270/J.LOG.2023.859

http://www.logforum.net p-ISSN 1895-2038 e-ISSN 1734-459X

ORIGINAL PAPER

EXPLORING THE TREND OF THE RESEARCH ON LOGISTICS 4.0

Zrinka Lacković Vincek, Iva Gregurec, Vladimir Kovšca

Department of Economics, Faculty of Organization and Informatics, University of Zagreb, Varaždin, **Croatia**

ABSTRACT. Background: As a result of the Industry 4.0 revolution, the Logistics 4.0 concept emerged, changed the already adopted solutions in traditional logistics, and introduced new enabling technologies. As Logistics 4.0 is a relatively new term and considering the emerging literature on these topics, the goal of this study is to identify the main research areas, understand the current state of development, and recommend potential future directions.
Methods: A bibliometric analysis of 181 scientific publications available in the Web of Science core collection database, dealing with the Logistics 4.0 research area and published between 2013 and early 2023 was performed. The analysis was carried out using VOSviewer software. Several bibliometric parameters were analyzed, such as year of publication, paper type, research area, distribution of articles by countries, language of publications, keyword and citation analysis, and most productive authors and organizations.
Results: The results of the study show that in the period from 2013 until early 2023 there were 181 publications produced on Logistics 4.0, published mostly in English, by a total of 200 authors from 41 different countries. Additionally, it was revealed that the main research areas in the field of Logistics 4.0 include supply chain visibility and transparency, IoT applications, big data analytics, AI and ML algorithms, robotics and automation technologies, blockchain technologies, and sustainability in logistics. These research areas represent key focus areas in the context of advancing logistics operations and optimizing supply chain management.
Conclusions: The results reinforce the main trends of the topic and provide an indication for future research. To the best of the authors' knowledge, this study is one of few attempts to investigate Logistics 4.0 research using a bibliometric analysis based on articles published in the past decade.

Keywords: Logistics 4.0, Industry 4.0, bibliometric analysis, VOSviewer

INTRODUCTION

Industry 4.0, also known as the fourth industrial revolution, begins to spread from 2011 in Germany, and logistics is only one small segment that has undergone numerous changes under its influence [Atzeni et al., 2021]. Under that influence, logistics has become a competitive driver for online stores and retailers around the world, where people and companies buy, produce, manage, sell, and deliver their products worldwide [Tang & Veelenturf, 2019]. The Logistics 4.0 concept describes the adoption of technologies and concepts of Industry 4.0 in the field of logistics [Lagorio et al., 2020], and the key technologies that drive Logistics 4.0 are cyber-physical systems (CPS), the Internet of Things (IoT), Big Data analytics, blockchain, and cloud computing [Angreani et al., 2020].

Amr, Ezzat, and Kassem [2019] defined the term Logistics 4.0 as: 'a strategic technological direction that integrates different types of technologies to increase both the efficiency and effectiveness of the supply chain, shifting the focus of organizations to value chains, maximizing the value delivered to the customers as well as customers by raising the levels of competitiveness. This is achieved by increasing the levels of transparency and decentralization among different parties through digitalization'. However, there is still no consensus on the definition and characteristics of the term Logistics 4.0 and digital technologies in logistics activities, which is why authors often confuse these two terms.

Some benefits of Logistics 4.0 are the implementation of self-regulating processes that

Citation: *Vincek Z. L., Gregurec I., Kovšca V., 2023. Exploring the trend of the research on Logistics 4.0. LogForum 19 (3), 395-409,* http://doi.org/10.17270/J.LOG.2023.859
Received: 20.06.2023, Accepted: 22.07.2023, on-line: 01.10.2023

improve supply chain transparency and achieve flexibility, process automation, decentralized decision-making, increased productivity, and cost reduction [Oleśków-Szłapka & Stachowiak, 2019]. On the other hand, the costs of implementation are very high because companies should first identify their key organizational processes and evaluate their technological needs to determine in which technology and when they should invest [Kodym et al., 2020]. Another challenge implies the collaboration of all stakeholders, which could lead to significant cost reduction [Chabot et al., 2018].

Figure 1 shows different business sectors that commonly use some technologies related to Logistics 4.0., according to the three main activities of logistics: inventory and warehouses, transportation and distribution, and supply chain.

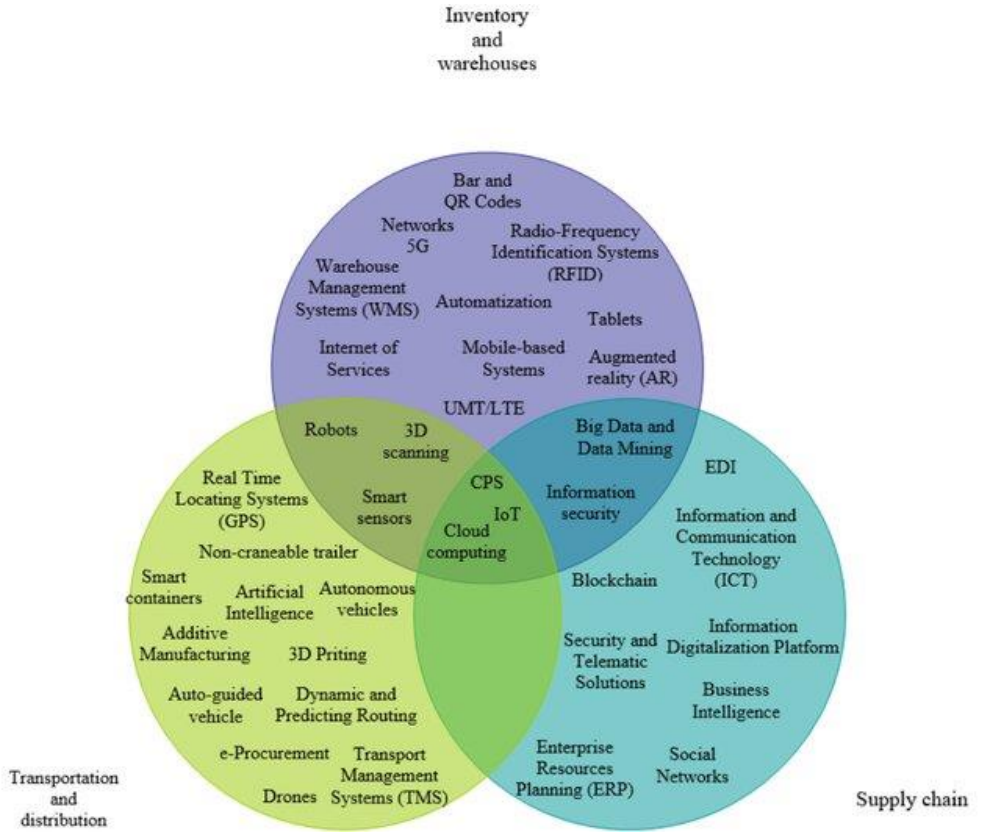

Fig. 1. Logistics 4.0 technologies grouped in the field of application
Source: Malagón-Suárez and Orjuela-Castro [2022]

For the purpose of writing this article, desk research was conducted to collect secondary data. Analysis of secondary data and scientific papers on Logistics 4.0 indicates a large gap between developed and developing countries, which have greater barriers in the adoption of Logistics 4.0 concepts due to the low level of application of technology in their supply chains. In their study, Facchini et al. [2020] proposed a maturity model for Logistics 4.0 based on Industry 4.0 implementation in logistics processes, so that companies would be in a better position to plan the next steps towards the fourth industrial revolution. Werner-Lewandowska and Kosacka-Olejnik [2019] investigated the level of Logistics 4.0 tools in the Polish service industry on a sample of 2000 enterprises.

Moreover, the desk research conducted by the authors recognizes the lack of studies focused on the bibliometric analysis of Logistics 4.0, as well as the implementation aspects of Logistics 4.0. Most publications analyze the technological aspects of Logistics 4.0 and how useful they are for the adoption of Logistics 4.0 [Khan et al., 2022]. For example, a study by Markov and Vitliemov [2020] analyzed the implementation of blockchain technologies in logistics and supply chains in the context of the automotive industry. A study by Atzeni et al. [2021] presented the results of a bibliometric analysis of

64 scientific articles whose focus is on collaborative robots ('cobots') applied to logistics systems. Bigliardi et al. [2021] conducted a bibliometric analysis on Industry 4.0 in the logistics field, based on 131 articles gathered from the Scopus database, published from 2013 to early 2020. Another recent study by Rejeb et al. [2020] analyzed and reports the 807 journal articles on the the Internet of Things indexed in the Scopus database. Another systematic literature review by Malagón-Suárez and Orjuela-Castro [2023] investigated the challenges and trends in the implementation of Logistics 4.0, based on articles published from 2015 to 2021 in the Scopus, Science Direct, Taylor and Francis and Google Scholar databases.

Due to the lack of a bibliometric analysis of publications of Logistics 4.0, the aim of this article is to provide a quantitative analysis of the academic literature on Logistics 4.0 performed on 181 scientific articles. To be more precise, the analysis takes into account the following main parameters: document type, year of publication, keywords, research area, most active countries, organization, authors (and co-authors), as well as citations. This study is unique because most previous systematic and bibliometric reviews were carried out on data retrieved from the Scopus database, and for the purpose of writing this paper the Web of Science core collection database was selected, as it is one of the most widely used databases.

The organization of the study is as follows. The first section will explain the objectives and background of the study. The second section will outline the research methodology used in this study, including the scope, source, and data collection for the analysis. The third section will include detailed and exhaustive descriptive statistics, focusing on publication output, citation analysis, distribution of documents by countries, and analysis of the most active organizations and authors. The next section will present the results and findings of the bibliometric analysis carried out on the sample of the articles reviewed, with the focus being on the frequency of keywords, co-authorship analysis, and citation metrics. Finally, the fifth section concludes the article by summarizing the significant findings and recommendations for future research.

RESEARCH METHODOLOGY

The global literature on Logistics 4.0 published between 2013 and 2023 was scanned in the WOS core collection database. The WOS was chosen because it is considered the most selective database [Singh et al., 2021], thus it is assumed that the WOS records are the highest-quality research articles, and, on the other hand, based on desk research. This type of research on Logistics 4.0 had not been performed until then, so the contribution of this article is evident. The search term applied to identify the closest matching publication included "Logistics 4.0", which was used as the keyword in the title or abstract. The information for the documents that met the threshold included the year of publication, language, journal, title, author, affiliation, keywords, document type, and citation count, all of which was exported into the CVS format. The date of retrieval was 15 May 2023. To analyze co-authorship, co-occurrence, citation, bibliographic coupling, co-citation, and themes, VOSviewer software (version 1.6.10) was used. VOSviewer is a free software tool for constructing and visualizing bibliometric networks [www.vosviewer.com].

Bibliometric analysis using a quantitative linguistic technique consisting of statistical and mathematical methods applied to sets of bibliometric references in the academic literature allows for a rigorous examination of all aspects related to publications on a particular topic [Saglietto, 2021]. It helps to determine the most influential authors, their affiliations, the keywords they use, and how academic studies are related. It consists of general descriptive statistics, such as the identification of the main authors, countries, publishing journals, or organizations [Wu & Wu, 2017]; and more sophisticated methods such as document co-citation analysis, which is among the most commonly used bibliometric techniques [Fahimnia et al., 2015; Appio et al., 2016]. The result of the study co-citation analysis is in the form of a map that consists of a set of circles representing cited documents, and a set of links representing the co-occurrence of circles in the reference list of papers upon which the map is based. Documents are co-cited if they appear together in the reference list of the publication, that is, Documents A and B are co-cited if they

are both cited by a Document C [Hjørland, 2013; Ardito et al., 2019].

In order to produce the database that was the goal of this article, data on Logistics 4.0 published between 2013 and 2023 from the Web of Science collection database was sourced. The search terms applied to identify the closest matching publication included "Logistics 4.0" as the keyword in the title or abstract.

DESCRIPTIVE STATISTICS

In this section, some general descriptive statistics are made on the sample of documents reviewed, in terms of document type, year of publication, geographical distribution of the articles, research area, and most influential authors and organizations.

This first analysis will examine published documents, depending on their document types, which refer to the type of document based on the originality of the documents such as journal articles, conference proceedings, book chapters, editorial materials, etc. [Sweileh et al., 2017].

Between 2012 and early 2023, a total of 181 publications on the topic of Logistics 4.0 were identified in the WOS core collection database. These publications included 88 original research articles, 81 proceeding articles, 11 review articles, 1 book chapter and editorial material, and 12 other forms of publication (Figure 2).

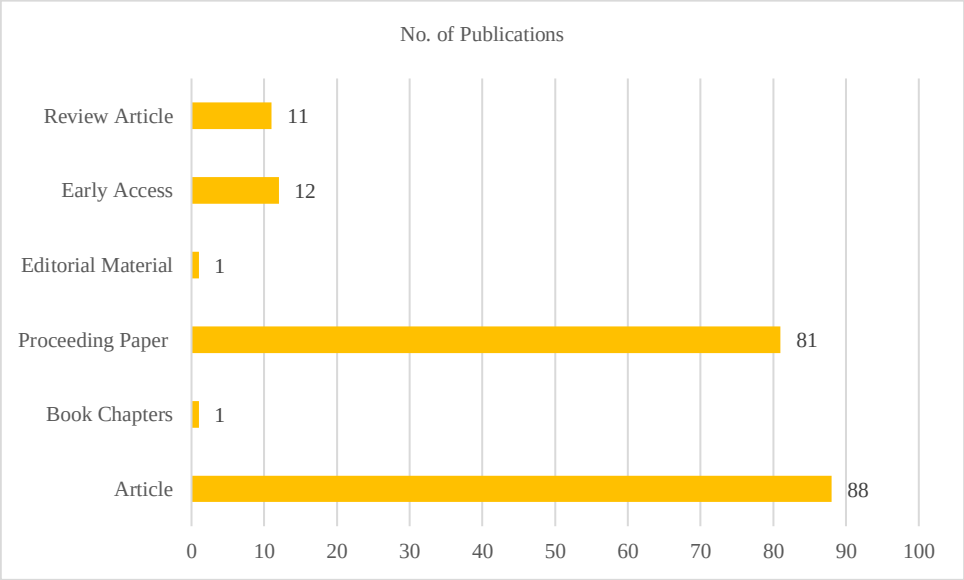

Fig. 2. Document type
Source: authors' own work.

The published documents from the data set were also analyzed based on the number of documents published per year. According to Ahmi and Mohd Nasir [2019], the examination of documents based on the year of publication helps the researcher observe the pattern and popularity of the research subject over time. Kruckhans and Meier [2013] published the first publications on Logistics 4.0. Since then, the numbers have increased year by year, and the highest number of publications on Logistics 4.0 was in 2022 (see Figure 3). More than 80% of the studies have been published in the last five years. For 2023, only the first five months are included in the time span of the analysis, and in this period a total of 13 papers were recorded, which is why it is reasonable to expect a significant increase by the end of the year. Logistics 4.0 can be concluded to be a relatively young but very popular research field. This trend indicates the increasing importance of Logistics 4.0 not only in practice, but also in science and suggests that the application of Logistics 4.0 has become more popular in recent years. [Bigliardi et al., 2021].

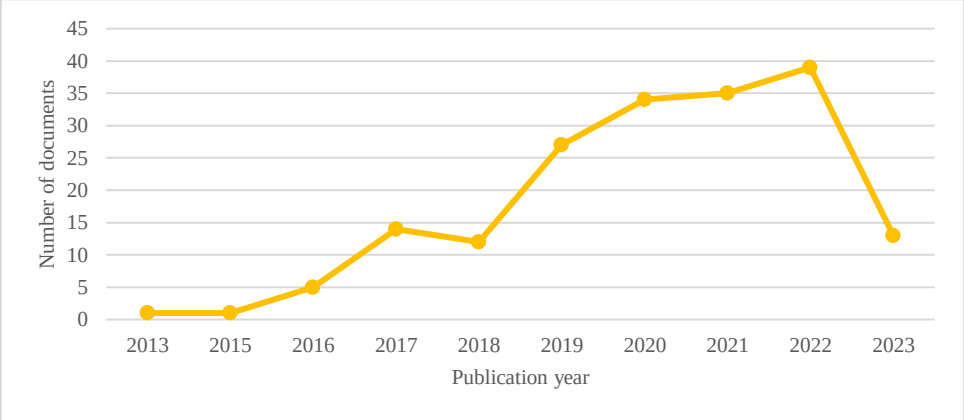

Fig.3. Publication by year
Source: authors' own work.

Almost all of the publications (178, 98.34%) were written in English and only three of them were published in German.

This section categorizes the publications based on the research area, as summarized in Figure 4. Considering that Logistics 4.0 is more focused on studies related to engineering and management, it is evident that both subject areas represent 42% (76 articles) and 24% (44 articles) of the total publications, respectively. Other contributing research areas include computer science, technology science, environmental science, materials science, transportation, chemistry, and physics.

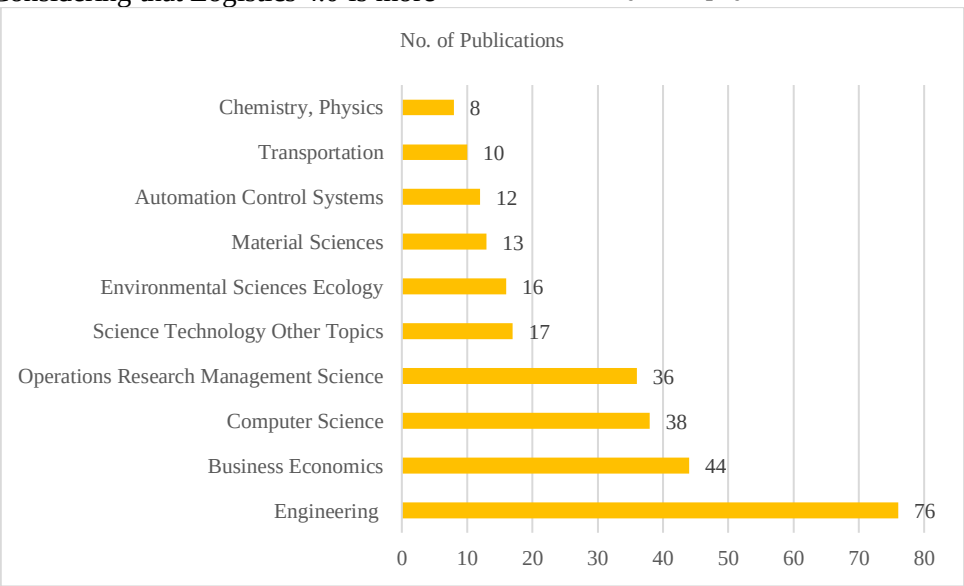

Fig. 4. Research area
Source: authors' own work.

In general, a total of 41 identified countries were involved in Logistics 4.0. The most active countries with a minimum of three publications on Logistics 4.0 are listed in Figure 5. Poland contributes the largest number of publications (27) representing 17.09% of the total publications on Logistics 4.0, followed by Germany and Italy (23, 4.96%), India (12, 2.59%), and the Czech Republic (10, 2.16%). Based on the results shown in Figure 5, it can be concluded that European countries have taken the lead in research into Logistics 4.0 compared to the rest of the world. Due to the fact that industry 4.0 started to develop in Germany in 2011 and that Germany, together with Italy and China, one of the world's productive powers, the fourth industrial revolution is still being studied more in these countries than in others.

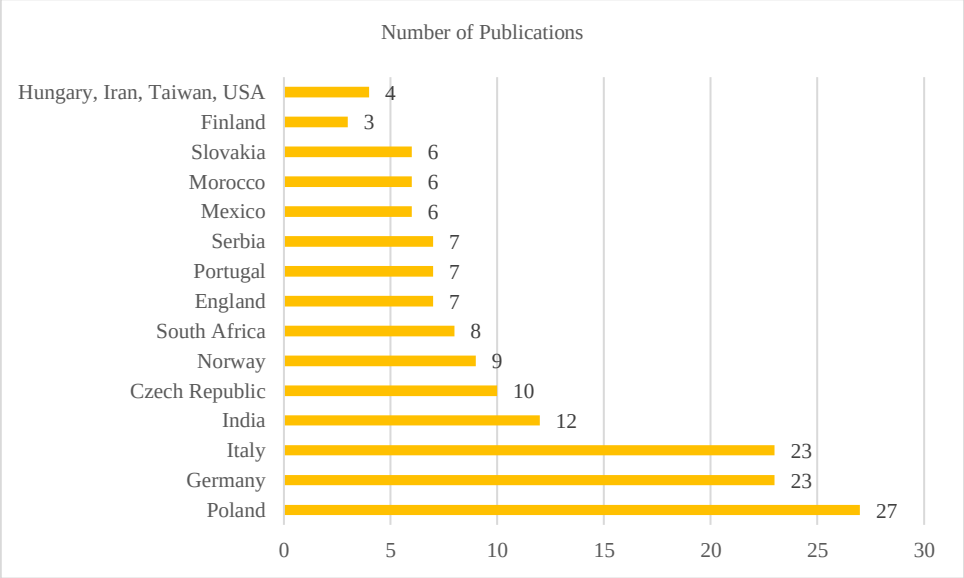

Fig. 5. Most active countries with a minimum of three publications
Source: authors' own work.

Table 1 presents the most active academic institutions contributing most to Logistics 4.0 research with a minimum of five publications. It is revealed that 200 institutions have published related papers, and eight of them have more than five publications. Poznan University of Technology in Poland has the highest number of publications on Logistics 4.0 (9, 4.97%). The University of Johannesburg (7, 3.87%) is the second highest, followed by the Norwegian University of Science Technology, the University of Bergamo and the University of West Bohemia Pilsen (6, 3.31%).

Table 1. Most active institutions with a minimum of five publications

Organization	No. of publications	Percentage (%)
Poznan University of Technology	9	4.97
University of Johannesburg	7	3.87
Norwegian University of Science Technology NTNU	6	3.31
University of Bergamo	6	3.31
University of West Bohemia Pilsen	6	3.31
Indian Institute of Technology IIT Delhi	5	2.76
Indian Institute of Technology System IIT System	5	2.76
University of Belgrade	5	2.76

Source: authors' own work.

A total of 234 authors have participated in publications on Logistics 4.0. Table 2 lists the most active authors, but to be more effective, the table is limited to the authors who have published at least three articles in the field of Logistics 4.0. Of 234 authors, only ten authors have published more than two papers in this field. Among them, C. Cimini from the University of Bergamo, A. Lagorio, also from the University of Bergamo, and Michal Zoubek from the Czech Technical University Prague have six papers, which mostly focus on smart manufacturing and logistics. In addition to these authors, J. Oleskow-Szlapka, H. Yu, G. P. Agnusdei, J. O. Strandhagen, M. Šimon, S. El Hamdi, and F. Pirola have published more than two publications on Logistics 4.0.

Table 2. The most active authors with more than two publications

Author name	No. of publications
Cimini, Chiara	6
Lagorio, Alexandra	6
Zoubek, Michal	6
Oleskow-Szlapka, Joanna	4
Yu, Hao	3
Agnusdei, Giulio Paolo	3
Strandhagen, Jan Ola	3
Šimon, Michal	3
El Hamdi, Sarah	3
Pirola, Fabiana	3

Source: authors' own work.

BIBLIOMETRIC ANALYSIS

This section describes the bibliometric analysis of co-occurrence of author keywords, co-authorship of authors, co-authorship of countries, and citation metrics. In the case of co-occurrence of author keywords, the total link strength (TLS) points to the number of publications in which any two terms appear together, and in the case of co-authorship analysis, TLS shows the number of co-authored publications with two researchers [Van Eck & Waltman, 2018].

An analysis of the author's keywords for the articles included in the review and that occurred more than twice in the WOS core collection database generated a list of 37 with a total of 242 keywords. Based on this analysis, nine clusters with different colors were obtained, as shown in Figure 6. A circle represents a keyword, and the size of the circle is proportional to the co-occurrence frequency of the keyword. The distance between two circles in the figure is determined by the density, and the larger the density, the closer the distance between two circles [Rejeb et al., 2020]. The first cluster, which is colored red, is related to digital transformation, digitalization, internal logistics, logistics 4.0, logistics performance, manufacturing, maturity, and warehouse. The second cluster, which is colored green, includes the keywords of artificial intelligence, automotive, big data, internet of things (IoT), and machine learning.

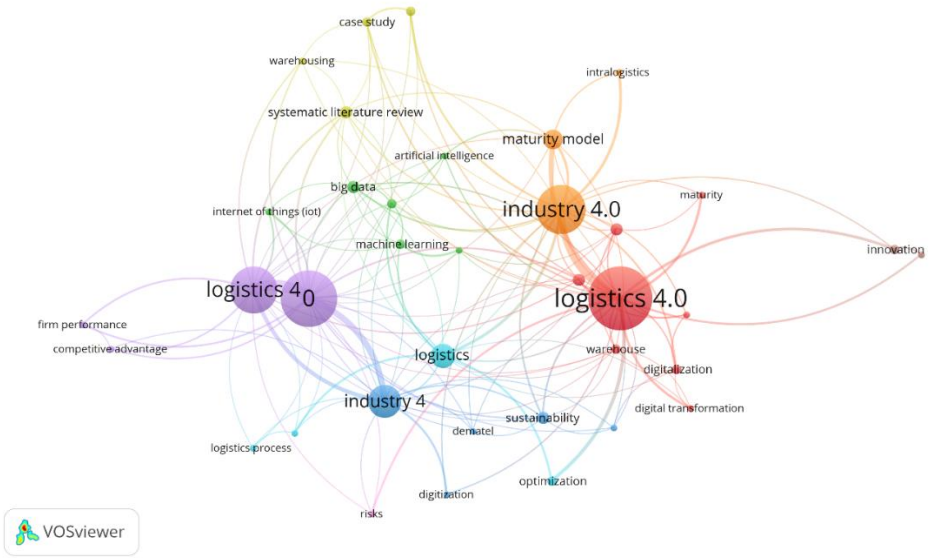

Fig. 2: Network visualization map of author keywords
Source: authors' own work.

The keywords that appeared most after exclusion of the core keywords related to a search query were industry 4.0, logistics, maturity model, and those related to the main technologies that are transforming industrial production, such as big data, manufacturing, internal logistics, warehouse, digitalization, innovation, internet of things, machine learning, etc. (see Table 3).

Table 3. The most frequently used keywords

Author Keywords	Total	Percentage (%)
logistics 4.0	29	11.98
industry 4.0	21	4.53
logistics 4	20	4.31
industry 4	13	2.80
logistics	9	1.94
maturity model	7	1.51
big data, manufacturing, sustainability, systematic literature review, internal logistics	4	0.86
warehouse, case study, digitalization, human factors, innovation, internet of things, machine learning, optimization	3	0.65

Source: authors' own work.

Figure 7 shows the network visualization map of influential authors that have more than five citations by performing a co-authorship analysis using the fractional counting method using VOSviewer. The color, circle size, font size, and thickness of connecting lines indicate the strength of the relationship amongst the authors. Connected authors, indicated by the same color, are commonly grouped together. The diagram shows that J. Oleskow-Szlapka co-authored with F. Facchini, L. Ranieri and A. Urbinati. (colored green). Moreover, M. Adamczak has collaborated with P. Cyplik, L. Hadas and A. Stachowiak (colored red), as well as R. Domanski with G. Pawlowski and H. Wojciechowski (colored blue).

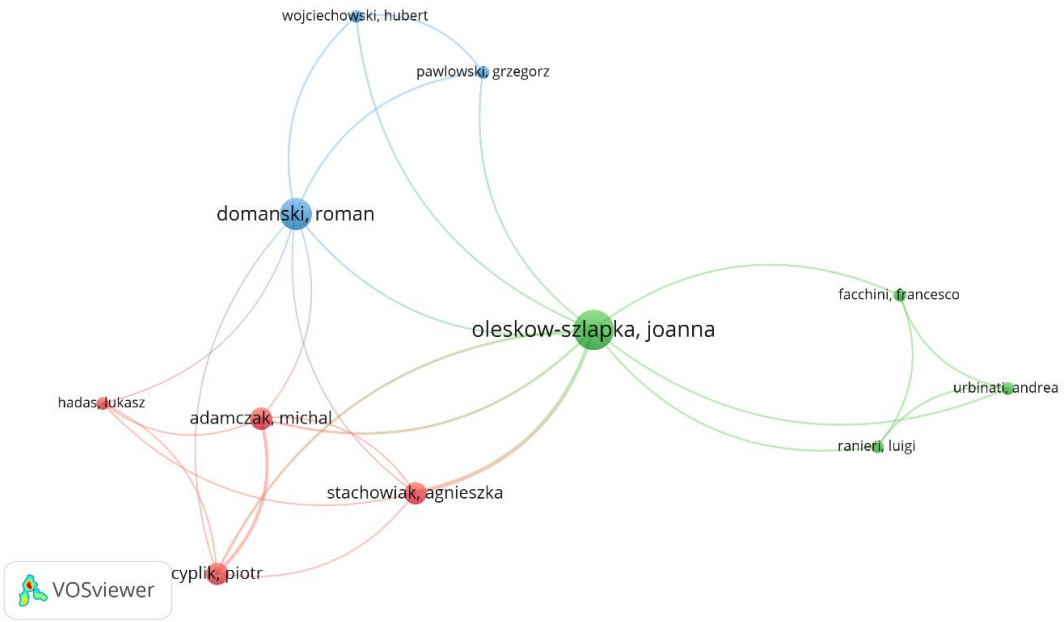

Fig. 7: Network visualization map of the co-authorship based on authors that have a minimum of five numbers of citations (fractional counting)
Source: authors' own work.

Further analysis shows the network visualization map of the authors according to the countries with which they are affiliated (Figure 8). This analysis considered only countries with more than two articles and more than five citations. Different colors represent a different clusters, and the size of the circles represents the number of publications. The thickness of the lines represents the strength of the country. As shown in Figure 8, the main partners for Poland are Italy and Serbia (colored red). Germany collaborates closely with Brazil (colored blue), while Austria works closely with Thailand and the United States of America (colored green).

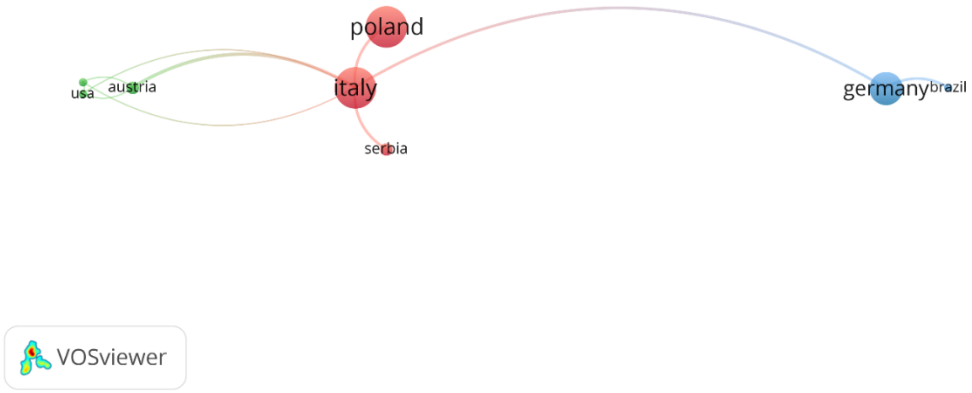

Fig. 8: Network visualization map of the co-authorship based on countries that have a minimum of two numbers of articles and five numbers of citations (fractional counting)
Source: authors' own work.

The following citation metrics show the impact of publications on Logistics 4.0. There are 181 published documents with a total of 3483 citations reported in 10 years (2013-2023) of Logistics 4.0 publications (Table 4). Additionally, there are an average of 387 citations per year and 19,24 citations per document, with a Hirsch *h*-index of 24.

Table 4. Citation metrics

Metrics	Data
Publication years	2013-2023
Citation years	10
Documents	181
Citations	3483
Citations per year	387
Citations per document	19.24
Hirsch h-index	24

Source: authors' own work.

The top ten articles most cited (based on the number of times the document was cited) in the field of Logistics 4.0 were listed in descending order of the number of citations received in Table 5. The document entitled "Industry 4.0 and the current status as well as future prospects on logistics" by Hofmann and Rusch received

the highest number of citations among all the papers (749 citations or an average of 107 citations per year). The second most cited article is "Industry 4.0 implications in logistics: an overview" by Barreto, Amaral and Pereira with a total number of 280 citations or an average of 40.00 citations per year. Both articles were published in 2017. Understandably, as the peer review process requires time, for more recent publications, it is difficult to achieve a high citation rate, but it is reasonable to expect an increase of citations for papers recently published.

Table 5. The top ten most cited articles in the field of Logistics 4.0

Authors	Title	Source	Cites	Cites per year
Hofmann, E. & Rusch, M.	Industry 4.0 and the current state, as well as future prospects on logistics	Computer Science, Interdisciplinary Applications	749	107
Barreto, L., Amaral, A. & Pereira, T.	Industry 4.0 implications in logistics: an overview	Manufacturing Engineering Society International Conference 2017 (MESIC 2017)	280	40.00
Winkelhaus, S. & Grosse, E.H.	Logistics 4.0: a systematic review towards a new logistics system	International Journal of Production Research	226	45.2
Witkowski, K.	Internet of Things, Big Data, Industry 4.0-Innovative Solutions in Logistics and Supply Chains Management	7TH International Conference on Engineering, Project, and Production Management	195	27.86
Tang, C.S. & Veelenturf, L.P.	The strategic role of logistics in the industry 4.0 era	Transportation Research Part E-Logistics and Transportation Review	184	36.80
Strandhagen, J.O., Vallandingham, L.R., Fragapane, G., Strandhagen, J.W., Stangeland, A.B.H. & Sharma, N.	Logistics 4.0 and emerging sustainable business models	Advances in Manufacturing	125	17.86
Strandhagen, J.W., Alfnes, E., Strandhagen, J.O. & Vallandingham, L.R.	The fit of Industry 4.0 applications in manufacturing logistics: a multiple case study	Advances in Manufacturing	87	12.43
Bag, S., Yadav, G., Wood, L.C., Dhamija, P. & Joshi, S.	Industry 4.0 and the circular economy: Resource melioration in logistics	Resources Policy	81	20.25
Meudt, T., Metternich, J. & Abele, E.	Value stream mapping 4.0: Holistic examination of value stream and information logistics in production	CIRP Annals-Manufacturing Technology	81	11.57
Lin, C.C. & Yang, J.W.	Cost-Efficient Deployment of Fog Computing Systems at Logistics Centers in Industry 4.0	IEEE Transactions on Industrial Informatics	76	12.67

Source: authors' elaboration work.

DISCUSSION

The concept of Logistics 4.0 includes the integration of digital technologies and advanced data analytics in logistics processes to enhance operational efficiency.

As demonstrated by the analysis of keywords that appeared most in the previous chapter, the main research areas related to Logistics 4.0 include supply chain visibility and transparency, application of the Internet of Things (IoT), big data analytics, artificial intelligence and machine learning, robotics and automation, block chain technology, and sustainability.

The use of RFID technology, IoT sensors, and cloud computing platforms facilitates data collection and analysis for better visibility of the supply chain. IoT applications have transformed logistics operations by enabling seamless connectivity and real-time data exchange between physical objects and digital systems. Research in this area explores the challenges of data security, interoperability, and scalability associated with implementation of IoT in logistics [Ahmed et al., 2021]. Big data analytics in Logistics 4.0 involves the extraction, processing, and interpretation of vast datasets to gain actionable insights [Garg et al., 2021]. Research in this area focuses on developing advanced analytics and techniques, such as data mining, machine learning algorithms, and predictive modeling, to improve demand forecasting, supply chain optimization, risk management, and overall customer experience. Research on artificial intelligence (AI) and machine learning (ML) explores the use of AI-powered algorithms and ML techniques to automate logistics operations, optimize transportation routes, streamline warehouse operations, and improve demand forecasting accuracy [Younis et al., 2022; Kersten et al., 2019].

Research in the area of robotics and automation technologies focusses on the development and deployment of autonomous vehicles, drones, robotic process automation, and automated guided vehicles to handle material, order fulfilment, and inventory management [Agrawal et al., 2020; Kern, 2021]. In recent years, there has been a growing number of studies investigating the use of blockchain in supply chains, highlighting its significant potential to revolutionize various aspects of supply chain functions. This includes enhancing supply chain provenance, reengineering business processes, and bolstering security measures [Raja Santhi & Muthuswamy, 2022; Dutta et al, 2020].

All of these areas hold great potential to transform logistics operations and create new opportunities for efficiency, agility and sustainability in the context of Logistics 4.0 concept, and therefore they represent critical domains for further research. Continued research in these areas will contribute to the improvement and implementation of innovative technologies and strategies within the logistics industry.

CONCLUSION

An analysis of Logistics 4.0 research reveals many insights and makes an important contribution to the literature, highlighting the fact that the number of scientific publications in the field of Logistics 4.0 is increasing rapidly. Based on the information provided here, it can be concluded that the objective of the article has been achieved. This study provides a detailed bibliometric analysis of the Logistics 4.0 research area based on 181 studies published between 2013 and early 2023 and indexed in the WOS core collection database.

The Logistics 4.0 study, based on documents collected from the WOS core database, was initiated by Kruckhans and Meier [2013] under the title ‘Industry 4.0 Fields of Action of the Digital Factory to Optimize Resource Efficiency in Production Processes’. Since then, the number of documents on Logistics 4.0 has increased rapidly, especially during the last two years, and the upward trend is likely to continue in the near future because the technology which is the basis of Logistics 4.0 has taken over the world.

More than 55% of the research papers were published as journal articles compared to other types of documents. More than 98% of the documents were published in English and

originated in 41 countries. In terms of national contributions, there is a high concentration of publications from European countries, such as Poland, Germany, and Italy, with the highest number of publications (73), followed by India (12). In terms of productivity, C. Cimini, A. Lagorio, and M. Zoubek were the most productive researchers. In terms of institutional contributions, the Poznan University of Technology is the most productive institution. Logistics 4.0 is primarily focused on the fields of engineering, business economics, and computer science.

Next, based on the visualization of the keyword frequency in Logistics 4.0, the most common keywords in the documents gathered turned out to be: Industry 4.0, maturity model, big data, manufacturing, sustainability, and internal logistics. Regarding the analysis of the WOS core database on Logistics 4.0, based on ten years of publications (2013-2023), the 181 publications have registered a total of 3483 citations. Overall, there are on average 387 citations per year and 19.24 citations per article.

Additionally, this article identifies the main research areas related to the Logistics 4.0 concept, and it is worth considering the following potential future directions related to Logistics 4.0: supply chain visibility and transparency, IoT applications, Big data analytics, AI and ML algorithms, robotics and automation technologies, blockchain technologies and sustainability in logistics. These research areas represent the key focal points in advancing Logistics 4.0 and transforming traditional supply chain management into a more efficient, transparent, and sustainable ecosystem.

The publications on Logistics 4.0 were retrieved from the Web of Science core collection database and the data were analyzed objectively and comprehensively, focusing on the bibliometric network analysis shown in VOSviewer. However, this study comes with certain limitations. The first limitation of this study is that only the Web of Science core collection database was used to select the previous literature. Although the Web of Science is considered a very comprehensive database, future studies should extend the context of this study and enhance its findings by including other scientific databases, such as the Scopus database, EBSCOhost, Google Scholar, Dimensions, or any other relevant database that highlights the major contributions to guide future researchers in this field and fill in any possible gaps. Future studies could also compare the results from different databases. Secondly, no search query is completely perfect and therefore false positive and negative results should be foreseen.

However, this study has gained a broader view of the current state of Logistics 4.0 research and will provide some direction for future research, as well as identification regarding the Logistics 4.0.

ACKNOWLEDGMENTS

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

REFERENCES

Agrawal, M., Eloot, K., Mancini, M., & Patel, A. (2020). Industry 4.0: Reimagining manufacturing operations after COVID-19. McKinsey & Company, 1-11.

Ahmed, S., Kalsoom, T., Ramzan, N., Pervez, Z., Azmat, M., Zeb, B., & Ur Rehman, M. (2021). Towards supply chain visibility using internet of things: A dyadic analysis review. Sensors, 21(12), 4158. https://www.doi.org/10.3390/s21124158

Ahmi, A., & Mohd Nasir, M.H., 2019, Examining the trend of the research on extensible business reporting language (XBRL): A bibliometric review. International Journal of innovation, creativity and Change, 5 (2), 1145-1167.

Amr, M. Ezzat, M., & Kassem, S., 2019, Logistics 4.0: Definition and historical background. In the 2019 Novel Intelligent and Leading Emerging Sciences Conference (NILES), 1, 46-49.

Angreani, L. S., Vijaya, A., & Wicaksono, H., 2020, Systematic literature review of industry 4.0 maturity model for manufacturing and logistics sectors. Procedia manufacturing, 52, 337-343. https://www.doi.org/10.1016/j.profmg.2020.11.056

Ardito, L., Scuotto, V., Del Giudice, M., & Petruzzelli, A.M., 2019, A bibliometric analysis of research on Big Data analytics for business and management. Management Decision, 57 (8), 1993-2009. https://www.doi.org/10.1108/MD-07-2018-0754

Appio, F. P., Martini, A., Massa, S. & Testa, S., 2016, Unveiling the intellectual origins of social media-based innovation: insights from a bibliometric approach. Scientometrics, 108, 355-388. https://www.doi.org/10.1007/s11192-016-1955-9

Atzeni, G., Vignali, G., Tebaldi, L., & Bottani, E., 2021, A bibliometric analysis on collaborative robots in Logistics 4.0 environments. Procedia Computer Science, 180, 686-695. https://www.doi.org/10.1016/j.procs.2021.01.291

Bigliardi, B., Casella, G., & Bottani, E., 2021, Industry 4.0 in the logistics field: A bibliometric analysis. IET Collaborative Intelligent Manufacturing, 3(1), 4-12. https://www.doi.org/10.1049/cim2.12015

Chabot, T., Bouchard, F., Legault-Michaud, A., Renaud, J., & Coelho, L.C, 2018, Service level, cost and environmental optimization of collaborative transportation. Transportation Research Part E: Logistics and Transportation Review, 110, 1-14.

Facchini, F., Oleskow-Szlapka, J., Ranieri, L., & Urbinati, A., 2020, A maturity model for Logistics 4.0: an empirical analysis and a roadmap for future research. Sustainability, 12 (1), 86. https://www.doi.org/10.3390/su12010086

Dutta, P., Choi, T. M., Somani, S., & Butala, R. (2020). Blockchain technology in supply chain operations: Applications, challenges and research opportunities. Transportation research part e: Logistics and transportation review, 142, 102067. https://www.doi.org/10.1016/j.tre.2020.102067

Fahimnia, B., Sarkis, J., & Davarzani, H, 2015, Green supply chain management: A review and bibliometric analysis. International Journal of Production Economics, 162, 101-114. https://www.doi.org/10.1016/j.ijpe.2015.01.003

Garg, R., Kiwelekar, A. W., Netak, L. D., & Ghodake, A. (2021). i-Pulse: A NLP based novel approach for employee engagement in logistics organization. International Journal of Information Management Data Insights, 1 (1), 100011. https://www.doi.org/10.1016/j.jjimei.2021.100011

Hjørland, B., 2013, Citation analysis: A social and dynamic approach to knowledge organization. Information Processing & Management, 49 (6), 1313-1325. https://www.doi.org/10.1016/j.ijpm.2013.07.001

Kern, J. (2021). The digital transformation of logistics: A review about technologies and their implementation status. The digital transformation of logistics: Demystifying impacts of the fourth industrial revolution, 361-403. https://www.doi.org/10.1002/9781119646495.ch25

Kersten, W., Blecker, T., & Ringle, C. M. (2019). Artificial intelligence and digital transformation in supply chain management: innovative approaches for supply chains. Berlin: epubli GmbH. https://www.doi.org/10.15480/882.2460

Khan, S., Singh, R., Haleem, A., Dsilva, J., & Ali, S.S., 2022, Exploration of critical success factors of logistics 4.0: a DEMATEL approach. Logistics, 6 (1), 13. https://www.doi.org/10.3390/logistics6010013

Kodym, O., Kubáč, L., & Kavka, L., 2020, Risks associated with Logistics 4.0 and their minimization using Blockchain. Open Engineering, 10 (1), 74-85. https://www.doi.org/10.1515/eng-2020-0017

Lagorio, A., Zenezini, G., Mangano, G., & Pinto, R., 2020, A systematic literature review of innovative technologies adopted in logistics management. International Journal of Logistics Research and Applications, 25(7), 1043-1066. https://www.doi.org/10.1080/13675567.2020.1850661

Malagón-Suárez, C.P., & Orjuela-Castro, J.A., 2023, Challenges and Trends in Logistics 4.0. Ingeniería, 28. https://www.doi.org/10.14483/23448393.18492

Markov, K. & Vitliemov, P., 2020, Logistics 4.0 and supply chain 4.0 in the automotive industry. In IOP conference series: Materials Science and Engineering. 878 (1), p. 012047). IOP Publishing. https://www.doi.org/10.1088/1757-899X/878/1/012047

Oleśków-Szłapka, J., & Stachowiak, A., 2019, The framework of logistics 4.0 maturity model. In Intelligent systems in production engineering and maintenance (pp. 771-781). Springer International Publishing.

Raja Santhi, A., & Muthuswamy, P. (2022). Influence of blockchain technology in manufacturing supply chain and logistics. Logistics, 6 (1), 15. https://www.doi.org/10.3390/logistics6010015

Rejeb, A., Simske, S., Rejeb, K., Treiblmaier, H., & Zailani, S., 2020, Internet of Things research in supply chain management and logistics: A bibliometric analysis. Internet of Things 12, 1-16. https://www.doi.org/10.1016/j.iot.2020.100318

Saglietto, L., 2021, Bibliometric analysis of sharing economy, logistics, and crowd logistics. International Journal of Crowd Science, 5 (1), 31-54. https://www.doi.org/10.1108/IJCS-07-2020-0014

Singh, V. K., Singh, P., Karmakar, M., Leta, J., and Mayr, P., 2021, The journal coverage of Web of Science, Scopus and Dimensions: A comparative analysis, Scientometrics, 126, 5113-5142. https://www.doi.org/10.1007/s11192-021-03948-5

Sweileh, W.M., Al-Jabi, S.W., AbuTaha, A.S., Zyoud, S.E.H., Anayah, F.M. and Sawalha, A.F., 2017, 'Bibliometric analysis of worldwide scientific literature in mobile-health: 2006–2016', BMC medical informatics and decision making, 17, 1-12. https://www.doi.org/10.1186/s12911-017-0476-7

Tang, C.S. & Veelenturf, L.P., 2019, The strategic role of logistics in the industry 4.0 era. Transportation Research Part E: Logistics and Transportation Review, 129, 1-11. https://www.doi.org/10.1016/j.tre.2019.06.004

Van Eck, N. J., & Waltman, L., 2018, VOSviewer Manual-Manual for VOSviewer Version 1.6.7. Universiteit Leiden, no. February, p. 51.

Werner-Lewandowska, K., & Kosacka-Olejnik, M., 2019, Logistics 4.0 maturity in service industry: Empirical research results. Procedia Manufacturing, 38, 1058-1065. https://www.doi.org/10.1016/j.promfg.2020.01.192

Wu, Y. C.J. & Wu, T., 2017, A decade of entrepreneurship education in the Asia Pacific for future directions in theory and practice. Management Decision, 55 (7), 1333-1350. https://www.doi.org/10.1108/MD-05-2017-0518

Younis, H., Sundarakani, B., & Alsharairi, M. (2022). Applications of artificial intelligence and machine learning within supply chains: systematic review and future research directions. Journal of Modelling in Management, 17(3), 916-940. https://www.doi.org/10.1108/JM2-12-2020-0322

Zrinka Lacković Vincek ORCID ID: https://orcid.org/0000-0002-8055-5481
Department of Economics,
Faculty of Organization and Informatics,
University of Zagreb, Varaždin, **Croatia**
e-mail: zlackovi@foi.unizg.hr

Iva Gregurec ORCID ID: https://orcid.org/0000-0002-2429-0335
Department of Economics,
Faculty of Organization and Informatics,
University of Zagreb, Varaždin, **Croatia**
e-mail: igregure@foi.unizg.hr

Vladimir Kovšca ORCID ID: https://orcid.org/0000-0001-7212-2558
Department of Economics,
Faculty of Organization and Informatics
University of Zagreb, Varaždin, **Croatia**
e-mail: vkovsca@foi.unizg.hr