OĞUZHAN
SOSYAL BİLİMLER DERGİSİ
Journal of Social Sciences

e-ISSN : 2687-5845	Cilt / Volume	Sayı / Issue	Yıl / Year	Ay / Month	Sayfa / Page
	4	2	2022	Aralık / December	175-192

Geliş Tarihi / Received : 04.07.2022 / 07.04.2022
Kabul Tarihi / Accepted : 01.08.2022 / 08.01.2022

Derleme Makalesi - Review Article

DOI: https://doi.org/10.55580/oguzhan.1140477

PAST, PRESENT AND FUTURE OF DIGITALIZATION OF LOGISTIC OPERATION: A BIBLIOMETRIC ANALYSIS

LOJİSTİK OPERASYONUN DİJİTALİZASYONUNUN GEÇMİŞİ, BUGÜNÜ VE GELECEĞİ: BİBLİYOMETRİK BİR ANALİZ

Kevser YILMAZ[a], Aşkın ÖZDAĞOĞLU[b]

ABSTRACT: This paper aims to analyze the digitalization-logistic operation-related literature from 1995 to 2021 using the bibliometric technique. This article analyses 266 papers from the Web of Science database and the database consisted of peer-reviewed journal articles, reviews, and early accesses articles. Moreover, Bibliometrix R-Package software is used to map the bibliographic material. The research revealed that: the number of publications steadily increased after 2017 and Engineering and Business and Economies are the most productive research areas. China, the USA and Germany are the most productive country based on the total publications and total citations. Indeed, when analyzing the academic collaborative relationships among countries, China is the center of international collaboration and mostly works with the UK and the USA. Furthermore, "Sustainability" is the most productive journal, "International Journal of Production Research" has the highest impact factor and "Annals of Operations Research" has the highest total citation. Besides, Jinan University is the most productive institution and Ivanov D. is one of the most academically influential author in the research area. According to keyword analysis, "logistics", "management" and "performance" keywords are frequently used by authors.

Keywords: ***Digitalization, Logistic, Operation, Bibliographic Analysis, Collaborative Relationship.***

ÖZ: Bu makale, bibliyometrik teknik kullanarak 1995'ten 2021'e kadar olan dijitalleşme-lojistik operasyonla ilgili literatürü analiz etmeyi amaçlamaktadır. Bu makale Web of Science veritabanından 266 makaleyi analiz etmektedir ve veritabanı hakemli dergi makaleleri, incelemeler ve erken erişim makalelerinden oluşmaktadır. Bunun yanı sıra, bibliyografik materyali haritalamak için Bibliometrix R-Package yazılımı kullanılmaktadır. Araştırma şunu ortaya koymuştur: 2017'den sonra yayın sayısı istikrarlı bir şekilde artmış ve Mühendislik, İşletme ve Ekonomi en verimli araştırma alanlarıdır. Toplam yayın ve toplam atıf bazında Çin, ABD ve Almanya en üretken ülkelerdir. Nitekim, ülkeler arasındaki akademik işbirliği ilişkileri analiz edildiğinde, Çin uluslararası işbirliğinin merkezidir ve çoğunlukla Birleşik Krallık ve ABD ile çalışmaktadır. Ayrıca dergiler arasında "Sustainability" en verimli dergi, "International Journal of Production Research" en yüksek etki faktörüne sahip dergi ve "Annals of Operations Research" dergiler arasında en yüksek toplam atıf sayısına sahip dergidir. Bunun yanı sıra, Jinan Üniversitesi toplam yayınlara göre en verimli kurumdur ve yazar performans analizi, Ivanov D. araştırma alanında akademik olarak en etkili yazarlardan biridir. Anahtar kelime analizine göre "lojistik", "yönetim" ve "performans" anahtar kelimeleri yazarlar tarafından sıklıkla kullanılmaktadır.

Anahtar Kelimeler : ***Dijitalleşme, Lojistik, Operasyon, Bibliyografik Analiz, İşbirliği İlişkisi.***

[a] Arş. Gör., Dokuz Eylül Üniversitesi, İşletme Fakültesi, İşletme Bölümü, kevser.yilmaz@deu.edu.tr, https://orcid.org/0000-0003-0415-8844

[b] Doç. Dr., Dokuz Eylül Üniversitesi, İşletme Fakültesi, İşletme Bölümü, askin.ozdagoglu@deu.edu.tr, https://orcid.org/0000-0001-5299-0622

1. INTRODUCTION

The twenty-first-century business world is witnessed the Industry 4.0 revolution and digital technologies. The core characteristic of this revolution is to create Cyber-Physical Systems (CPS) (Cagle et al., 2020: 109) through the digitalization of the whole system to control systems in real-time flexibly (Kagermann, 2015). This term was introduced by the German government in 2011, and the German National Academy of Science and Engineering declared Industry 4.0 paper in 2013(Kagermann et al. 2013: 14) to explain the transformation process. Moreover, China integrated this new revolution into its strategic plan whose called "Made in China 2025" to keep up with technological development (Liu, 2016: 53). In addition, the Industrial Internet of Things (IIoT) concept was introduced by General Electric in 2012, that concept helps to receive cleaver decision-making through using advanced analytics, intelligent machine and connecting the humans (Evans snd Annunziata, 2012).

Furthermore, the digital transformation is grabbed not only the attention of countries and academicians but also managers and the business world. Accenture (2016) researched to discover the digitalization index of Turkey, and this study showed that the average digitalization grade of the 18 sectors was 61 over 100. The transportation and warehousing sector grade were 60; thus, the logistics industry has more steps to take to digitalize its processes.

In addition, a global survey was conducted by Fujitsu across 15 countries in 2017 to explore how businesses are responding to the digital transformation process. The results of this study indicate that nearly 90% of enterprises have several digital transformation projects in different phases; some are planning, some are testing, and others are in implementing steps. Moreover, managers have already received positive results from some of these digital projects (Fujitsu, 2017: 3). Besides that, Fujitsu (2021) managed another study in 2021 to learn about business progression to digital transformation and possible Covid-19 effects. The results show that agility, digitalization, and employee well-being effectively helped organizations respond to the pandemic. Additionally, DMCC (2021) published a report to evaluate the future of trade by focusing on trade growth, the digitalization of commerce, and business finance and infrastructure. This report recommends the company increase investment in digital technologies to deal with the post-pandemic impacts.

Consequently, the digital transformation and pandemic are not only affecting just one sector, but all sectors are also affected, and the logistic industry is one of them. Digitalization of logistics operation gives essential benefits to companies like allocating resources more accurately and cost-effectively, increasing effective communication between supply chain members, and providing flexibility to systems to deal with unexpected circumstances like pandemics (Kagermann et al., 2013; Stock and Seliger, 2016; Herold et al., 2021; Armağan et al., 2021; Özdağoğlu et al., 2022).

Overall, these all results indicate that countries, the business world, sectors, and academia are aware of the importance and enormous potential of digitalization, and accordingly, with the recognition of the benefits and significance of the digital technologies for logistic operation, the related body of literature has increased substantially. This study examines the current digitalization of logistic operation literature using the bibliometric technique to assess the growing body of literature on the digitalization of logistic operation. The bibliometric technique is "the quantitative study of physical published units, bibliographic units, or of the surrogates for either" (Broadus 1987: 376). This technique can be viewed as a collection of scientometric and meta-analytical approaches to evaluate the structure of a specific research field (Shafique, 2013; Zhang et al., 2019) and their relationship within a particular discipline (Vinkler, 2010; Pourkhani et al., 2019).

This study aims to shed light on the current digitalization of logistic operation in the following points: 1) showing how total publications changed during the 1995-2021 time period and learning most productive research areas, 2) summarizing and evaluating the research trends in the logistic operation digitalization, 3) evaluating the contribution of countries/territories, journal, institution and authors, 4) a better understanding of global hot topics with keyword and co-operative keywords relationship analysis, which may contribute to the future development of the literature and affect future research directions. The rest of this paper is organized as follows. Section 2 describes the methodology of the article, while Section 3 presents the analysis of the research and discusses the results. Finally, section

4 summarizes the papers by showing some concluding remarks about the digitalization of logistic operations.

2. METHODOLOGY

The bibliometric analysis relies on quantitative and reliable data; also, mathematical and statistical techniques have been used in research (Wallin, 2005: 261; Zemigala, 2019: 798) so that researchers can reach reliable and unbiased information and learn the current hot topics, research clusters, and the most influential countries, cooperation, journal and authors within the research discipline(Ferreira et al. 2014; Nerur et al.,2008). In the data analysis process, the researchers prefer some package programs such as VOS Viewer(Frazzon et al., 2019) and Bibliometrix R-Package(Cagle, 2020) to find out the research discipline structure and its evolution, learn the best authors, journals, countries and examine the cooperation and collaboration network(Aria and Cuccurullo, 2017; Moral Muñoz et al., 2020; Cagle, 2021). Consequently, this study applies the bibliometric techniques to systematically evaluate digitalization in logistic operation research to draw a rigorous and objective summary of the discipline.

Table 1. Methodology of the Research

Unit of analysis	Peer-reviewed journal articles, reviews and early accesses articles
Type of analysis	Qualitative and quantitative
Period of analysis	01.01.1975-31.12.2021
Search engines	Web of Science
Query string	ALL FIELDS (“operation” OR “operations” OR “operation process” OR “operations process” OR “operation processes” OR “operations processes”) AND(“digitalization” or “digital” or “digitalisation” or “digitization”) AND(“logistic” or “logistics”)
Index	Social Sciences Citation Index, Science Citation Index Expanded and Emerging Sources Citation Index
First Result	412 Articles
Language	English (N: 407 Articles were remained.)
Exclusion criteria	Elimination of papers which title, keywords and abstracts, did not indicate the concentration on the digitalization of logistic operation
Final Result	266 articles, reviews and early accesses were picked for further analysis.

The summary of the methodology used for the research is shown in Table 1. Data collection is the first stage of this analysis. All data of this study was collected on 12 January 2022 from the Web of Science database (WoS), which is one of the most reputed and widely accepted databases, covering high-impact articles and journals and is accepted as an essential source for the bibliometric analysis(Chen et al., 2014; Skute, 2019; Van Leeuwen, 2006). Thus, the WoS has been selected as the database to extract bibliometric data. Later, a query string was created (see Table 1) by using the “operation” and “operation process” and “digital” and “logistic” keywords and entered the search area. After that, results were filtered by document types, and peer-reviewed journal articles, reviews, and early accesses were selected as document types because the information in these documents passed evaluation processes. Next, social sciences citation index, science citation index expanded, and emerging sources citation index were selected as the web of science index. Lastly, English was chosen as the language, and other language articles were excluded from the sample.

After all, the initial result was 407 articles. Then, the title, keywords, and abstracts of the remaining 407 studies were appraised to find the correct publications concentrating on the digitalization of logistic operation. One hundred forty-one studies were eliminated based on the exclusion criteria. The remaining 266 studies were picked for further analysis in this study, and the Bibliometrix R-Package program was used in the analyzing stages.

3. ANALYSIS AND DISCUSSIONS

3.1. Characteristics of Publications

Table 2 shows some characteristics of the digitalization-logistic operation-related articles between 1995 to 2021. Besides that, the total amount of published articles during 1995-2021 is clearly shown in Figure 1. These results indicate a few studies about logistic operation digitalization between 1995 and 2016. After 2016, the number of publications on logistic operation digitalization increased incrementally between 2017-2021 and peaked in 2021. In addition, the number of authors and references fluctuated with high figures between 1995 and 2016 but steadily increased after 2017 and peaked in 2020 and 2021. For example, while seven authors conducted research in 2016, 263 authors did the research on the subject in 2021.

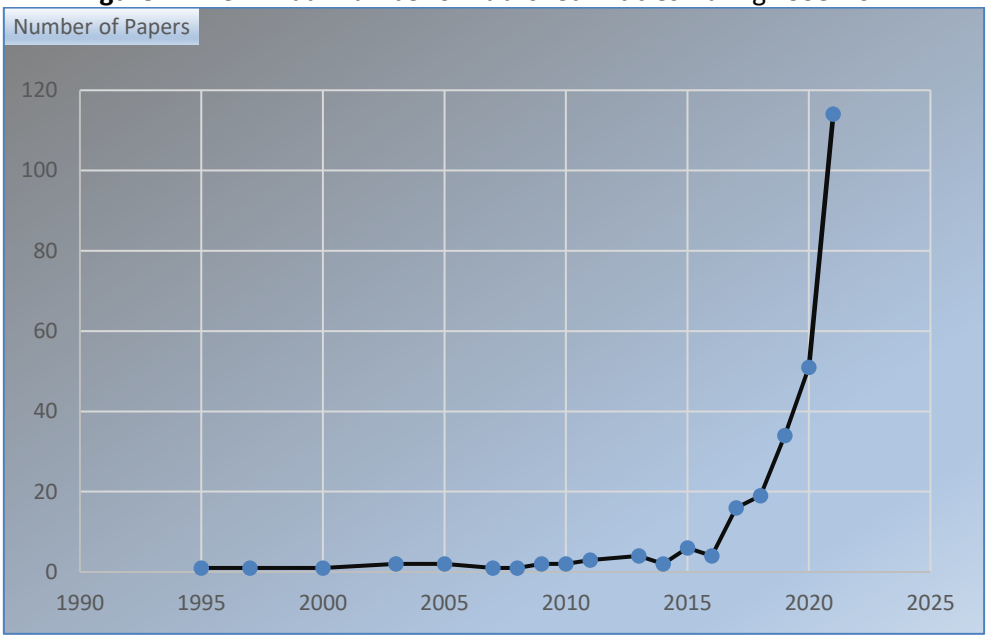
These results are consistent with the time of the Industry 4.0 revolution announcement (Kagermann et al., 2013). Fourth Industrial Revolution, that is introduced by the German government in 2011 is defined as flexible control of producing systems using Cyber-Physical Systems (CPS) technology(Kagermann, 2015: 24). This technology has built up real-time optimized dynamic and flexible manufacturing systems through creating real and computer-oriented world via digital methods. (Rajkumar et al., 2010). Thus, this revolution triggers the digitalization of the systems, and it has not only grabbed the attention of businesses but also researchers. That explains the reasons of the publication increased after 2016.

Table 2. Characteristics of the Published Articles between 1995-2021

Year	TP[a]	AU[b]	AU/TP[c]	NR[d]	NR/TP[e]	PG[f]	PG/TP[g]
1995	1	2	2.00	0	0.00	9	9.00
1997	1	1	1.00	8	8.00	7	7.00
2000	1	2	2.00	34	34.00	15	15.00
2003	2	4	2.00	5	2.50	28	14.00
2005	2	3	1.50	16	8.00	27	13.50
2007	1	2	2.00	48	48.00	25	25.00
2008	1	9	9.00	34	34.00	8	8.00
2009	2	3	1.50	101	50.50	18	9.00
2010	2	5	2.50	139	69.50	18	9.00
2011	3	7	2.33	50	16.67	60	20.00
2013	4	19	4.75	29	7.25	55	13.75
2014	2	6	3.00	154	77.00	20	10.00
2015	6	14	2.33	72	12.00	74	12.33
2016	4	7	1.75	93	23.25	34	8.50
2017	16	38	2.38	448	28.00	263	16.44
2018	19	47	2.47	818	43.05	331	17.42
2019	34	67	1.97	616	18.12	570	16.76
2020	51	129	2.53	635	12.45	869	17.04
2021	114	263	2.31	251	2.20	2142	18.79

[a]TP: the number of total publications during 1995–2021.
[b]AU: the number of authors
[c]AU/TP: the average of authors in a paper.
[d]NR: the number of cited, all databases
[e]NR/TP: the average of cited references in a paper.
[f]PG: the number of total publications pages
[g]PG/TP: the average of pages in a paper

Figure 1. The Annual Number of Published Articles During 1995-2021.



3.2. Research Area

The contributions of the top 10 digitalization-logistic operation-related research from 1995 to 2021 are shown in Table 3. The first five subject categories include Engineering(108 publications), Business & Economics(72 publications), Operations Research & Management Science(61 publications), Computer Science(54 publications), and Environmental Sciences & Ecology(27 publications). Engineering is the most interesting subject with 108 records, accounting for 22.09% of the total records, followed by Business & Economics and Operations Research & Management Science with 14.72% and 12.47% of the total number, respectively.

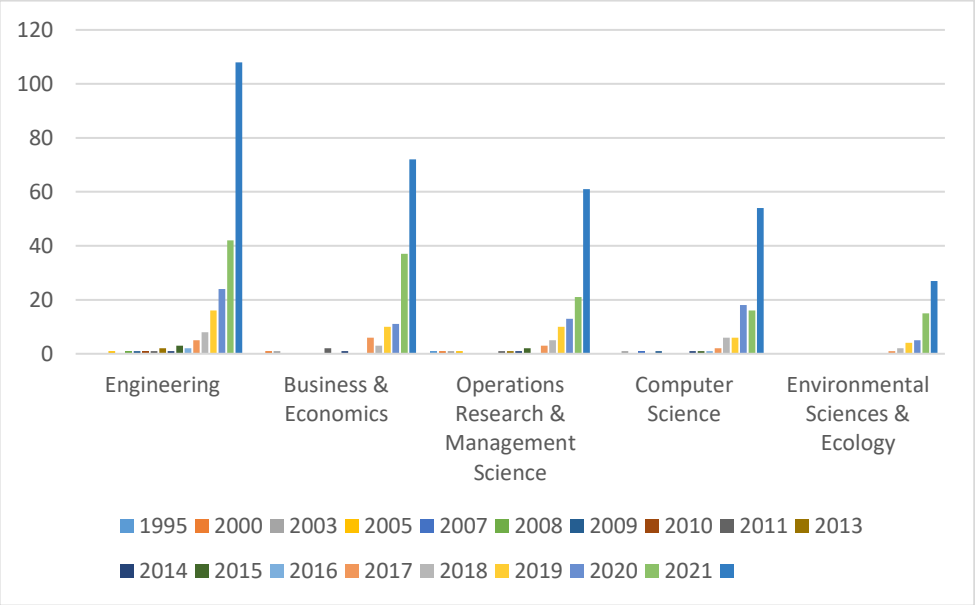
Table 3. The Top 10 most productive subjects, 1995–2021

Rank	Research Area	TP[a]	Percentage (%)
1	Engineering	108	22.09
2	Business & Economics	72	14.72
3	Operations Research & Management Science	61	12.47
4	Computer Science	54	11.04
5	Environmental Sciences & Ecology	27	5.52
6	Science & Technology - Other Topics	26	5.32
7	Transportation	24	4.91
8	Telecommunications	13	2.26
9	Chemistry	11	2.25
10	Physics	8	1.64

TP[a]: the total publications of the research areas during 1995–2021

The top five topics will be further analyzed, and Figure 2 shows the amounts of publications on the top five subject categories from 1995 to 2021. The periodical publications in the top five categories remained steady from 1995 to 2016. The number of publications has significantly increased since 2017, especially Engineering, Business & Economics, and Operations Research & Management Science subject categories have snowballed between 2017 to 2021. Additionally, Engineering subject had increased sharply compared to others and had been leading position in last four years.

Figure 2. Timeline of the Top Five Subject Categories



3.3. Contribution of Countries/Territories

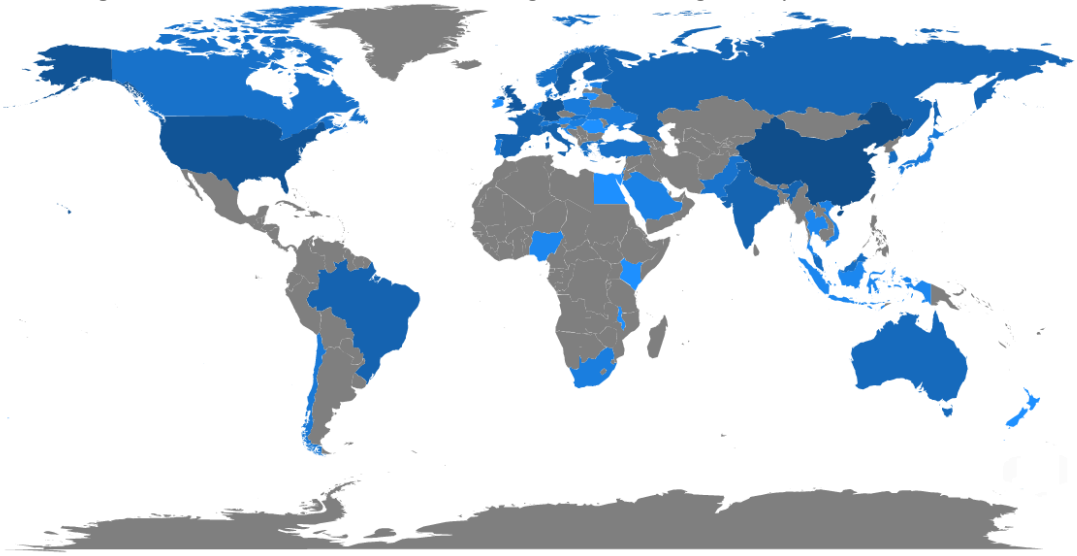
Table 4 indicates the total publications with national and international collaborations, ranks, and citations of the top 10 most productive countries regarding the digitalization of logistic operation study. The map (Figure 3) displays the geographical distribution of the total publications of the digitalization-logistic operation-related articles calculated via the R-package tool based on writers' addresses. The blue color represents the total publication of the country, and the color dark means total publication is higher. Grey means zero publication.

Table 4. Top 10 Most Productive Countries

Country	TP[a]	TP Rank (%)[b]	CP[c]	CP Rank (%)[d]	TC[e]	TC Rank (%)[f]
CHINA	47	1(17.66)	184	1(19.72)	652	2(18.72)
USA	31	2(11.65)	108	2(11.58)	428	3(12.29)
GERMANY	26	3(9.77)	88	3(9.43)	791	1(22.72)
UK	19	4(7.14)	73	4(7.82)	224	6(6.43)
SWEDAN	12	5(4.51)	43	5(4.61)	105	8(3.02)
SPAIN	11	6(4.14)	33	7(3.54)	103	9(2.96)
INDIA	9	7(3.38)	31	10(3.32)	10	22(0.29)
FINLAND	8	8(3.01)	29	11(3.11)	144	7(4.14)
ITALY	8	9(3.01)	37	6(3.97)	263	5(7.55)
AUSTRALIA	7	10(2.63)	19	13(2.04)	25	16(0.729

TP[a]: the total publications of the country without international collaborations during 1995–2021.
TP Rank (%)[b]: Rank and the percentage publications without international collaborations.
CP[c]: Total publications with international collaborations
CP Rank (%)[d]: Rank and the percentage of publications with international collaborations.
TC[e]: the number of total citations
TC Rank (%)[f]: Rank and the percentage of publications based on total citation

Figure 3. The Global Distribution of Digitalization-Logistic Operation Related Articles

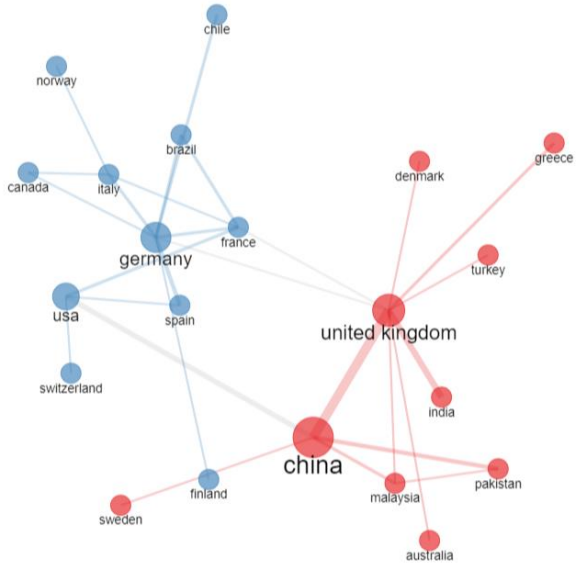


The Top 10 countries published 178 articles, accounting for 66.9% of the total articles. China, accounting for 17.66% and 19.72% of all the publications with national and international collaborative publications, respectively, is the most productive country based on the total publications. It shows that China is not only dedicated to making national collaborations but also works and makes international collaborations with other countries such as the United Kingdom, Sweden, Turkey, Greece so on(see Figure 4).

Following China, the USA, accounting for 11.65% and 11.58% of the total searched publications with national and international collaborations, respectively, ranks second in the total number of articles. Germany is ranked third in total publications both national and international collaborative publications. Moreover, Germany has the highest total citation (791) among the countries, followed by China (652) and the USA (428). This shows that Germany is an academically productive and most influential country than others.

Figure 4 illustrates the research collaboration among the top 21 countries from 1995 to 2021. This map is plotted using Bibliometric R-Package "Biblioshiny" software program. The lines between the two countries display they have a cooperative relationship. When the collaboration is strong between countries, the line becomes thicker. In addition, the node size shows the centrality of a country, so that the bigger node means, the bigger the centrality. Figure 4 shows the state of collaboration between the most productive countries.

Figure 4. The Academic Collaborative Relationships among Top 21 Countries



As can be seen from figure 4, there are two core clusters as follows: countries surrounding China (the red cluster) and European countries (the blue cluster). China is in the central position for its cluster, but no dominant country for the blue cluster exists. China is highly connected to the United Kingdom, Turkey, Denmark, Greece so on in its cluster and collaborates with the USA in the blue cluster. Besides, when looking at the blue cluster, Germany, the USA, Switzerland, Canada, Italy, and other European countries cooperate with each other and work together. This result may be explained by the fact that these European countries' geographical and cultural proximity may play active roles in increasing collaboration.

To sum up, China is the country has the biggest node size, so it is the center of international collaboration and mainly works with the UK and the USA, respectively. Moreover, China, the USA, and Germany are the most productive countries with the largest number of total publications and citations, indicating that they are academically productive, influential, and core countries to make major contributions to the digitalization-logistic operation-related research. These results seem consistent with the digital transformation process triggered by the fourth industrial revolution. Industry 4.0 has induced the digital transformation of the whole industry and systems and created digital, smart factories distribution channels and added value for supply chain members (Kang et al., 2016; Schroeder et al., 2019; Qu et al., 2019). This transformation grabbed not only the attention of academia but also countries. So, Germany, China, and the USA put digital transformation on their agenda immediately by creating a unique strategic plan at the beginning of the digital transformation (Evans and Annunziata, 2012; Kagermann et al., 2013: 24; Liu, 2016), thereby, they are pioneering countries for digital transformation.

3.4. Contribution of Institutions

Table 5 shows the performances of the top 10 productive institutions, four of them come from China, and two of them come from Germany. That reveals that Chinese and German universities are more active in digitalizing logistic operation studies than other countries. A possible explanation for this might be that these three countries have officially started the digitalization process and support the institutions to accelerate the acceptance and activities of digitalization.

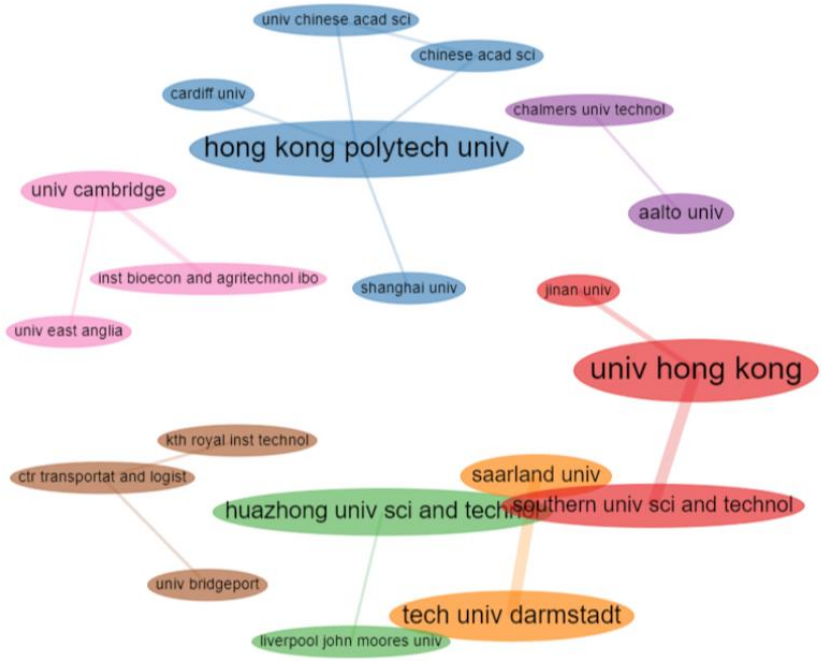
Jinan University ranked 1st with respect to total publications. Most of the ten research institutions are from developing countries, Aalto University, Berlin School of Economics and Law, Darmstadt Technical University of Darmstadt, and Kth Royal Institute of Technology from developed countries. Thus, developing countries are the most productive. Moreover, the most productive institutions are universities that prove universities are a core part of the focus on developing and revealing new findings of digitalization in logistic operation.

Table 5. The most 10 productive institutions, 1995-2021

Rank	Institution	Country	Number of Articles
1	JINAN UNIVERSITY	CHINA	12
2	HONG KONG POLYTECH UNIVERSITY	CHINA	11
2	HUAZHONG UNIVERSITY OF SCIENCE AND TECHNOLOGY	CHINA	11
2	KHALIFA UNIVERSITY	UNITED ARAB EMIRATES	11
5	AALTO UNIVERSITY	FINLAND	10
5	KOSICE TECHNICAL UNIVERSITY OF KOŠICE	SLOVAKIA	10
7	UNIVERSITY HONG KONG	CHINA	9
8	BERLIN SCHOOL OF ECONOMICS AND LAW	GERMANY	8
8	DARMSTADT TECHNICAL UNIVERSITY OF DARMSTADT	GERMANY	8
10	KTH ROYAL INSTITUTE OF TECHNOLOGY	SWEDEN	7

In addition, Figure 5 displays the academic collaborative relationships between the top 20 most productive institutions. The lines between the two organizations show a cooperative relationship. When the collaboration is strong, the line becomes thicker, and the node size shows the centrality of an institution so that the bigger node means bigger the centrality.

Figure 5. The Cooperation Network of the Top 20 Most Productive İnstitutions



As shown in Figure 5, there are six clusters, and each group has just a few universities collaborating. For example, Hong Kong Polytech University has the bigger node for the blue cluster. It mostly works with the University of Chinese Academy of Sciences and the Chinese Academy of Sciences, all located in China. For the red cluster, the University of Hong Kong has the bigger node and collaborates with the Southern University of Science and Technology and Jinan University; again, three of these universities are located in China.

There are three institutions in the pink cluster, 2 of them are in England, and one is in Greece. A possible clarification for these collaborations might be that geographical and cultural proximity may play active roles in increasing cooperation. In addition, Chinese institutions are pioneering in digitalizing logistic operation studies. Moreover, the result shows that the institutions collaborate with another one within the national counterparts. This reveals that researchers have cooperated and worked with national researchers on digitalizing logistic operations.

3.5. Journal Distribution

Table 6 indicates the top 10 productive journals from 1995 to 2021 in the digitalization-logistic operation-related studies. Also, this table gives information about the total publication, citation, and 2020 impact factor of these top journals. More than 27% of the digitalization-logistic operation-related articles are published in the top 10 journals. Sustainability is the most productive journal with 18 articles, followed by Annals of Operations Research(8) and Transportation Research Part E-Logistics and Transportation Review(8). International Journal of Production Research is 6th in the number of publications. Still, it has the highest impact factor(8.43) among the top 10 most productive journals, followed by Transportation Research Part E-Logistics and Transportation Review(6.875) and Computers & Industrial Engineering(5.97).

Furthermore, Annals of Operations Research has the highest total citation(592) among the journals, followed by Transportation Research Part E-Logistics and Transportation Review(210) and IEEE Access(167). In addition, these three journals had been ranked as the top three in the citation per publication categories. Overall, it seems that Annals of Operations Research, Transportation Research Part E-Logistics and Transportation Review, Sustainability, and International Journal of Production Research are the most influential journals in the digitalization-logistic operation-related studies. Similarly, other top journals support the fields, but the total publication, impact factor, and citation are relatively less.

Table 6. The Top 10 most productive journals during 1995-2021

Rank	Journal	TP[a]	TP(%)[b]	IF 2020(Rank)[c]	TC[d](Rank)	CPP[e]
1	SUSTAINABILITY	18	6.77	3.251(7)	153(4)	8.50
2	ANNALS OF OPERATIONS RESEARCH	8	3.01	4.854(5)	592(1)	74.00
2	TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW	8	3.01	6.875(2)	210(2)	26.25
4	IEEE ACCESS	7	2.63	4.48(6)	167(3)	23.86
4	INTERNATIONAL JOURNAL OF LOGISTICS MANAGEMENT	7	2.63	5.89(4)	89(5)	12.71
6	APPLIED SCIENCES	6	2.26	2.679(8)	17(9)	2.83
6	INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	6	2.26	8.43(1)	43(6)	7.17
8	BRAZILIAN JOURNAL OF OPERATIONS & PRODUCTION MANAGEMENT	5	1.88	0.336(9)	13(10)	2.60
8	LOGISTICS	5	1.88	0.152(10)	19(8)	3.80
10	COMPUTERS & INDUSTRIAL ENGINEERING	4	1.50	5.97(3)	31(7)	7.75

TP[a]: the total publications of the journal during 1995–2021
(%)[b]: The percentage of the publications of the journal
IF 2020[c]: the impact factor of journal in 2020
TC[d]: the number of total citations
CPP[e]: the citations per publication

3.6. Performance of Authors

Table 7 and 8 shows the performances of the ten most productive authors based on the total publications and total citations, respectively, regarding the digitalization of logistic operation study. According to the results, based on the total publication, the most productive author is Wang Y. with six articles, followed by Huang G.Q. (5 papers) and Glock C.H., Guo D., and Ivanov D. (4 articles for each). The most productive author is Ivanov D. (4), considering the H-index.

On the other hand, although, Chiappetta Jabbour C.J., Godinho Filho M., Lopes De Sousa Jabbour A.B., and Roubaud D. wrote one article names “Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations” that has been receiving the most citation (280) than others so that they are ranked as top authors based on total citations. In addition, Ivanov D. ranked 2nd with respect to total citation (263).

Table 5. The Top 10 Productive Authors Based on the Publications, 1995-2021

Author	TP[a]	TC[b]	H-Index[c]
WANG Y	6	5	2
HUANG GQ	5	65	3
GLOCK CH	4	63	2
GUO D	4	45	3
IVANOV D	4	263	4
CHEN Y	3	35	2
GUO H	3	25	3
JAYARAMAN R	3	17	3
LI H	3	14	2
LIU J	3	30	2

TP[a]: the total publications of the author
TC[b]: the number of total citations

In conclusion, Ivanov D. is one of the most academically influential authors in the field based on the H-index (4) among the authors. Moreover, his performance ranked 2nd and 3rd in the total citation and publication, respectively. He focuses on supply chain management, digital technologies, and operational system; among the four articles, three of them are cited more than 50 times. In addition, Chiappetta Jabbour C.J., Godinho Filho M., Lopes De Sousa Jabbour A.B., and Roubaud D. are

the other most influential authors in literature because their work is followed and cited by other researchers more frequently than others.

Table 6. The Top 10 Productive Authors Based on the Citations, 1995-2021

Author	TP[a]	TC[b]	H-Index[c]
CHIAPPETTA JABBOUR CJ	1	280	1
GODINHO FILHO M	1	280	1
LOPES DE SOUSA JABBOUR AB	1	280	1
ROUBAUD D	1	280	1
IVANOV D	4	263	4
KACHE F	1	225	1
SEURING S	1	225	1
DOLGUI A	2	215	2
QUEIROZ MM	1	166	1
WAMBA SF	1	166	1

TP[a]: the total publications of the author
TC[b]: the number of total citations

3.7. Research Hotspot

3.7.1. High Cited Articles Analysis

Table 9 displays the top 20 most frequently cited articles in digitalization of logistic operation with the total citations for 1995-2021. This table shows the important articles that can be helpful for scientists working in the logistic operation area by reading field-related articles to understand the research area better.

Table 9. Characteristics of the Most Frequently Cited Articles During 1995-2021

Rank	TC[a]	TCY[b]	PY[c]	Article Title	Journal Name	Author/s
1	280	70.00	2018	"Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations"	Annals of Operations Research	Lopes de Sousa Jabbour, A. B., Chiappetta Jabbour, C.J, Godinho Filho, M., & Roubaud
2	225	45.00	2017	"Challenges and opportunities of digital information at the intersection of Big Data Analytics and supply chain management."	International journal of operations & production management	Kache, F., & Seuring, S.
3	166	83.00	2020	"Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review."	Annals of operations research	Queiroz, M. M., Ivanov, D., Dolgui, A., & Fosso Wamba, S
4	140	46.67	2019	"A review of building information modeling (BIM) and the internet of things (IoT) devices integration: Present status and future trends."	Automation in Construction	Tang, S., Shelden, D. R., Eastman, C. M., Pishdad-Bozorgi, P., & Gao, X.
5	134	44.67	2019	"The mean-variance approach for global supply chain risk analysis with air logistics in the blockchain technology era."	Transportation Research Part E: Logistics and Transportation Review	Choi, T. M., Wen, X., Sun, X., & Chung, S. H.
6	129	10.75	2010	"A Sub-W Embedded CMOS Temperature Sensor for RFID Food Monitoring Application"	IEEE journal of solid-state circuits	Law, M. K., Bermak, A., & Luong, H. C.
7	127	31.75	2018	"Blockchain in logistics and supply chain: A lean approach for designing real-world use cases."	IEEE Access	Perboli, G., Musso, S., & Rosano, M.
8	113	14.13	2014	"Digital manufacturing-driven transformations of service supply	Supply Chain Management: An	Holmström, J., & Partanen, J.

				chains for complex products."	International Journal.	
9	75	12.50	2016	"Dual-objective scheduling of rescue vehicles to distinguish forest fires via differential evolution and particle swarm optimization combined algorithm."	IEEE Transactions on intelligent transportation systems	Tian, G., Ren, Y., & Zhou, M.
10	68	5.23	2009	"eMaintenance—Information logistics for maintenance support."	Robotics and Computer-Integrated Manufacturing	Candell, O., Karim, R., & Söderholm, P.
11	54	13.50	2018	"Use of twitter data for waste minimisation in beef supply chain."	Robotics and Computer-Integrated Manufacturing	Mishra, N., & Singh, A.
12	52	13.00	2018	"A B2C e-commerce intelligent system for re-engineering the e-order fulfilment process."	Expert Systems with Applications	Leung, K. H., Choy, K. L., Siu, P. K., Ho, G. T., Lam, H. Y., & Lee, C. K.
13	51	25.50	2020	"Understanding artificial intelligence adoption in operations management: insights from the review of academic literature and social media discussions."	Annals of Operations Research	Grover, P., Kar, A. K., & Dwivedi, Y. K.
14	50	16.67	2019	"The digital twin implementation for linking the virtual representation of human-based production tasks to their physical counterpart in the factory-floor."	International Journal of Computer Integrated Manufacturing	Nikolakis, N., Alexopoulos, K., Xanthakis, E., & Chryssolouris, G.
15	50	12.50	2018	"An extension of ARAS methodology under interval valued intuitionistic fuzzy environment for digital supply chain."	Applied Soft Computing	Büyüközkan, G., & Göçer, F.
16	49	12.25	2018	"A survey on control theory applications to operational systems, supply chain management, and Industry 4.0."	Annual Reviews in Control	Ivanov, D., Sethi, S., Dolgui, A., & Sokolov, B.
17	48	3.20	2007	"An industrial network flow information integration model for supply chain management and intelligent transportation."	Enterprise Information Systems	Hsu, C., & Wallace, W. A.
18	46	9.20	2017	"Value stream mapping 4.0: Holistic examination of value stream and information logistics in production."	CIRP Annals	Meudt, T., Metternich, J., & Abele, E.
19	41	13.67	2019	"Digitization in wood supply–A review on how Industry 4.0 will change the forest value chain."	Computers and Electronics in Agriculture	Müller, F., Jaeger, D., & Hanewinkel, M.
20	40	13.33	2019	"Digital twin aided sustainability-based lifecycle management for railway turnout systems."	Journal of Cleaner Production	Kaewunruen, S., & Lian, Q.

TC[a]: total citations

TCY[b]: total citations per year

PY[c]: publication year

Among all the researchers, Lopes de Sousa Jabbour et al. (2018) is the most cited article in the digitalization-logistic operation-related publication, followed by Kache & Seuring in 2017.

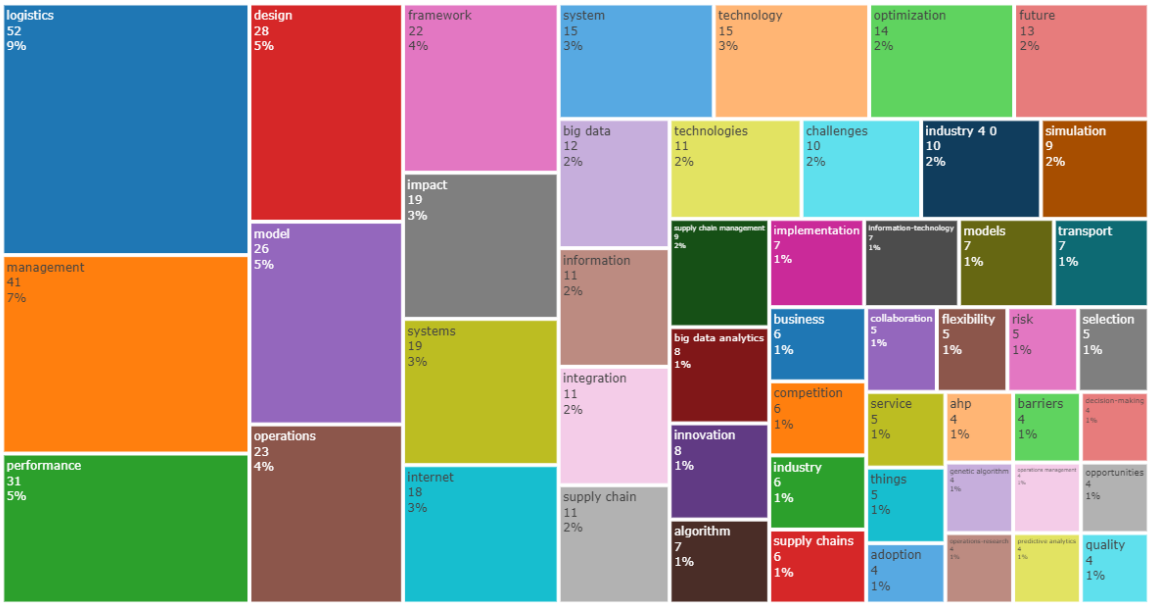
Besides that, the "Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review" study (Queiroz et al., 2020) receives the highest total citations per publication (83). These three articles mainly focus on different Industry 4.0 technologies, potential impacts of Big Data Analytics, digitalization, and supply chain management. In addition, the Annals of Operations Research is one of the most influential journals as it published 3 of 20 articles listed in the most frequently cited research.

The one with the highest total citations is titled "Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations". This article was published in the Annals of Operations Research journal in 2018 and received 280 total citations. The major contribution of this article is to reveal how various Industry 4.0 technologies can support circular economy strategies and explain how those technologies can help and contribute to managers in the decision-making process for sustainable operations management.

3.7.2. Keyword Analysis

Figure 6 displays the frequently used top 50 author keywords in a tree map to ensure that the results are reviewable and understandable. Thus, Figure 6 represents the main topics and subtopics of digitalization of logistic operation articles. If a keyword has a bigger area, it is used more frequently in the papers. Based on the analysis of the keywords, the top five keywords are logistics (52), management (41), performance (31), design (28), and model (26).

Figure 6. Tree Map of Top 50 Keywords



Moreover, the cooperative relationship among the top 50 keywords in the subject area from 1995 to 2021 is also plotted via the Bibliometric R-Package tool and shown in Figure 7. Each keyword is defined by its label in a rectangle. The bigger rectangle means the higher the frequency of utilization, and the most used keywords are situated in the central position in the cluster. Besides that, the line between the keywords shows the co-occurrence links; if the co-occurrence is stronger, the connection becomes thicker. The keyword's thick size indicates the number of articles in which the keywords are used together.

It can be seen from Figure 7 that there are three core clusters as follows: keywords surrounding the Logistics (the red cluster), keywords surrounding Management and Performance (the green cluster), and keywords surrounding the Models, Design, Operation, and Systems (the blue cluster). Logistics, Management, and Performance are in their cluster's central position, but there is no certain dominant keyword for the blue cluster.

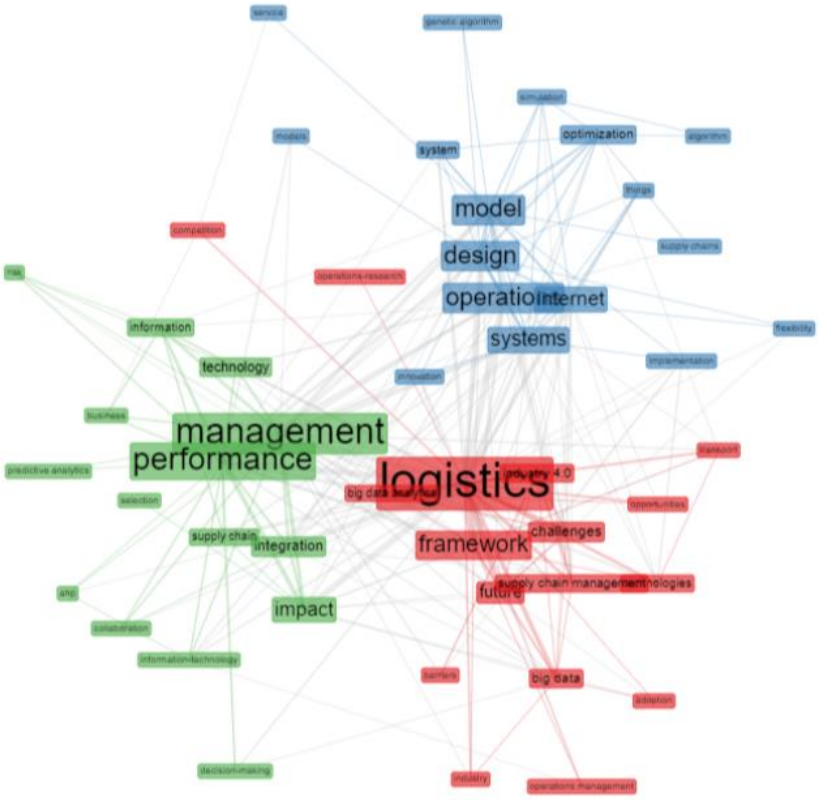
For the red cluster, the Logistic is highly connected to the Framework and Challenges keywords, frequently used together in an article. In general, the red cluster aggregates papers related to digital technologies and logistics. For example, an article offers computer systems that focus on the digitalization of the food package life cycle to improve the efficiency of logistics operations, reduce food loss, and support package reuse and recycling (Vanderroost et al., 2017); the other study examines the cost of usage Cloud-Based Booking Platforms (CBBPs) in warehouse operations (Giuffrida et al., 2021).

Furthermore, for the green cluster, the Management and the Performance are strongly connected. The papers focus on logistics, operation, supply chain management, and performance

measurement and evaluation in this cluster. For instance, Asdecker & Felch (2018) examine the current Industry 4.0 maturity models and develop a model for the delivery process in supply chains. Besides, Ahmad and his co-workers (2021) discuss the potential role of blockchain technology in port logistic operations and logistics management. Moreover, Balakrishnan & Ramanathan (2021) investigate the role of digital supply chain technologies in the automotive sector to improve supply chain performance. On the other hand, in the blue cluster, The Models, Design, Operation, and Systems are moderately connected. Still, there are no dominant, highly connected keywords in that cluster.

Overall, as shown in Figure 6, the most frequently used keywords are "logistics," "management," and "performance," which have the highest link strength among other keywords (Figure 7), so they play a vital role in the cooperation network.

Figure 6. The Network of the Most Frequently used 50 Keywords



4. CONCLUSION

Industry 4.0, known as the fourth industrial revolution, emphasizes the importance of digital transformation, and logistic companies face a significant challenge to digitalize their systems to flexibly control them and take advantage of the digitalization. Thereby, this transformation takes both attention of managers and academicians, and digitalization literature is growing incrementally; thus, this paper employed bibliometric analysis to evaluate the increasing body of literature on the digitalization of logistic operation.

This paper reveals that the number of articles increased substantially after 2016 and peaked in 2017. To sum up, the literature on the digitalization of logistic operations has grown over the past five years. "Engineering" is the most productive research area with 108 publications, accounting for 22.09% of the total records. China is an essential contributor to the topic on hand, with the most national and international collaborative publications among the countries. Following China, the USA and Germany rank second and third respectively in the total number of articles.

Moreover, China has played a crucial role in the collaboration network for its cluster and primarily works with the United Kingdom and the USA. The study has also shown that "Sustainability" is the most productive journal (18 publications) based on the total publications, "International Journal

of Production Research" and "Annals of Operations Research" journals the other most important journal in the field based on the impact factor and total citation respectively.

Additionally, Jinan University has 12 articles about the topic, so it is the most productive institution based on total publications. Ivanov D. is one of the most academically influential authors based on the H-index. Moreover, the most highly cited article entitled "Industry 4.0 and the circular economy: a proposed research agenda and original roadmap for sustainable operations", authored by Lopes de Sousa Jabbour and her co-workers (2018) and published in "Annals of Operations Research" journal and had been cited 280 times. Finally, the paper found five core keywords which are "logistics," "management," "performance," "design," and "model," and identified core keywords which are "logistics," "management," and "performance." play a crucial role in the cooperation network as having the highest link strength among other keywords.

The study employed the use of the bibliometric method to analyze the characteristics of the digitalization of logistic operation literature from 1995 to 2021 have been examined. The research found that total publications changed during the 1995-2021 time period and learning most productive research areas. Moreover, the paper summarized and evaluated the research trends in logistic operation digitalization. Finally, the study evaluated the contribution of countries/territories, journals, institutions, and authors to the topic. These results revealed the significance of bibliometric techniques as methods for exposing research trends globally.

There are several limitations to this research. This paper is limited to analyzing only the Web of Science database. Further studies can be developed by analyzing different databases such as Science Direct, Scopus, etc. Moreover, this study followed the essential standard procedures to assure the reliability and generalizability of the findings. On the other hand, future research can build on the current study by doing a broader and less restrictive search protocol and examining the existing themes within a more extensive literature, which includes industry reports, conference papers, and materials in several languages.

This paper is the first attempt to summarize the most current state of the research and make recommendations for further study in the digitalization of logistic operation. These research findings are the future lines of research that might be utilized as a starting point for further research on the issue of digitalization of logistic operations. The paper summarized how total publications and the research trends are changed and evaluated the contribution of countries/territories, journals, institutions, and authors so that researchers can have more specific targets when carrying out the relevant research. For instance, highly cited papers in this area can give essential ideas to researchers for developing new opinions; also, scientists can pay great attention to the writings of the most successful authors. Additionally, these findings are helpful not only for researchers but also for managers. The results may offer the managers insightful policy information that will enable them to identify the most well-known authorities in the field and obtain more precise consulting services for their decision-making. This paper provided the researchers and the managers with a better understanding of global hot topics with keyword and co-operative keywords relationship analysis, which may contribute to the future development of the literature and affect future research directions.

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