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Bibliometric analysis of model vehicle routing problem in logistics delivery

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ABSTRACT

This bibliometric analysis focuses on the vehicle routing problem (VRP) model in the field of logistics delivery. The study utilizes a comprehensive dataset of 2,000 VRP-related publications obtained from the Scopus database, spanning the years 2007 to 2023. Through the application of bibliometric methods, this research aims to uncover key insights regarding research trends, country contributions, and recent topics within the VRP research network. Various bibliometric indicators, including publication count, author productivity, relevant sources, institutional affiliation, and citation frequency, are employed to conduct the analysis. The findings shed light on the evolution and trajectory of VRP research, while also highlighting noteworthy countries and topics that have received significant attention. This study not only enhances the overall understanding of VRP but also serves as a foundation for future investigations aimed at enhancing the efficiency and effectiveness of logistics delivery.

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1. INTRODUCTION

In the logistics industry, freight forwarding and route management are fundamental aspects [1]-[3]. Operational efficiency in logistics delivery can provide significant benefits, including cost savings [4], increased customer satisfaction [5]-[8], and increased productivity [9]. There is a need to analyze and model bibliometric data related to the vehicle routing problem (VRP) model in logistics delivery to increase this efficiency in analyzing literature. Bibliometrics is an analytical approach that uses data and statistical methods to measure and analyze scientific publications [10]. So much research is related to bibliometrics for various purposes, including analyzing publications regarding the analysis of harmony with sustainable development and the impact of coronavirus disease 2019 (COVID-19) [11], reviewing the function of soil agriculture [12], looking at views on social commerce and purchase intention [13] progress electrochemical detection of tetracycline antibiotics [14], analysis international dental journal [15], application of bibliometrics in health [16], [17].

In this study, we used the bibliometrix package found in RStudio. In its use, it requires data extracted from scientific publication databases such as Scopus [18]-[20], Web of Science [21], [22],

Dimensions [23], PubMed [24], Lens.org [25], [26]. In collecting and pre-processing bibliometric data, it is necessary to collect bibliometric data relevant to the VRP model in logistics delivery. This data can be text files, CSV files, or data from bibliometric databases such as Web of Science or Scopus. Next, pre-process the data to clean and prepare the data to suit the needs of analysis [27].

After reviewing and summarizing the existing knowledge, research needs to address the analysis of the VRP model in the logistics sector. This research needs to be done. In order to gain a structured and detailed insight into the current conditions and future directions for the development of the VRP model in the logistics sector, this study uses a literature knowledge mapping technique to analyze the VRP system as a whole. This article uses literature from the Scopus database, including 2,000 publications from 2007 to 2023.

In logistics delivery, bibliometrics aims to understand the latest developments, trends, and patterns in the scientific literature related to the mathematical model of the VRP in logistics cases. Through bibliometric analysis, information can be collected about the development of concepts and methods in modeling logistics shipping routes, the techniques and algorithms used, and the most influential and frequently cited related publications. This analysis can provide valuable insights into understanding scientific developments in this area and help identify research gaps that could be explored.

The aims of this study were to (i) trend the number of VRP publications in the logistics context, (ii) describe the contribution of countries to VRP research in the field of logistics, (iii) analyze trends in emerging research topics in the VRP literature, and (iv) overview of relevant journals in the field of VRP models within logistics. This paper will provide a complete and accurate perspective on VRP research in the last 16 years, assist new researchers in understanding the field, and encourage the development of VRP model research in logistics.

2. METHOD

2.1. Data extraction

The study utilized the Scopus database to gather literature on the VRP models in logistics. A search was conducted using the keyword "VRP logistics model" in the Scopus database. Only articles and reviews were selected as relevant document types. The search was limited to the period from 2007 to 2023. After completing the search process, 2,000 documents that met the specified criteria were obtained.

The search results were saved in a .csv file format containing important information about each document, including title, abstract, author, year of publication, and more. The .csv file format facilitates further data analysis and processing. With this data, researchers can perform statistical analysis, clustering, and visualization to gain comprehensive insights into the VRP model and its solving algorithms within the context of logistical problems. Utilizing the Scopus database in this research provides access to various scientific journals and related publications, enabling researchers to understand the latest developments and trends in VRP research in logistics [18], [20].

2.2. Data analysis

The trend in annual scientific publications was analyzed to understand the growth and fluctuations in VRP-related research over the specified timeframe. This involved visualizing the data using graphs and identifying key patterns, including notable surges or declines in publication counts. The geographical distribution of VRP-related publications was investigated to identify the leading contributors. Metrics such as the number of articles, most cited paper ratio (MCP ratio) [28], and self-citation percentage (SCP) [29] were considered for a comprehensive evaluation of each country's research impact.

The frequency of keywords associated with VRP research topics was analyzed over time to identify trends. This involved tracking the occurrence of specific terms to understand the evolving research focus. Key journals in the field of VRP models within logistics were identified based on the number of articles published. This analysis aimed to highlight the platforms that researchers frequently chose for disseminating their findings.

To gain a deeper understanding of the relationships between different research topics, a network co-occurrence analysis was conducted [30]. This involved clustering topics based on their co-occurrence patterns, leading to the identification of distinct thematic clusters. A word cloud was generated to visually represent the most frequently used words in VRP-related article abstracts. This analysis provided insights into the central themes and emphases within the VRP and logistics research community. The impact of VRP research from different countries was assessed based on total citation counts and average article citations. This involved distinguishing between the highest total citations and the highest average article citations, providing a nuanced understanding of research influence. The preprocessed data is analyzed to identify various bibliometric indicators. This includes analyzing publication trends, country contributions, trending topics, relevant sources, and citation analysis.

2.2.1. Publication trends

The trend in annual scientific publications was analyzed to understand the growth and fluctuations in VRP-related research over the specified timeframe. This involved visualizing the data using graphs and identifying key patterns, including notable surges or declines in publication counts [31].

$$annual\_publications(y) = \sum_{i=1}^{N} \delta(y_i = y) \quad (1)$$

Where δ is the Kronecker delta, y_i is the year of the i-th publication, and y is the year of interest.

2.2.2. Country contributions

The geographical distribution of VRP-related publications was investigated to identify the leading contributors. Metrics such as the number of articles, MCP ratio [28], and SCP [29] were considered for a comprehensive evaluation of each country's research impact.

$$country\_publications(c) = \sum_{i=1}^{N} \delta(c_i = c) \quad (2)$$

Where c_i is the country of the i-th publication, and c is the country of interest.

The MCP ratio is calculated as:

$$MCP\ Ratio\ =\ Number\ of\ MCPs/Total\ Number\ of\ Publications \quad (3)$$

To determine MCPs, we count publications with authors from multiple countries:

$$Number\ of\ MCPs\ =\ \sum_{i=1}^{N} \delta(num\_countries(i)\ >\ 1) \quad (4)$$

where $num\_countries\ (i)$ is the number of distinct countries associated with the i-th publication.

2.2.3. Trending topics

To identify trending topics, we analyze the frequency of keywords associated with VRP research topics over time [32]:

$$keyword\_frequency(k, y) = \sum_{i=1}^{N} \delta(k \in keywords(i) \wedge y_i = y) \quad (5)$$

where k is a keyword, and y is the year.

Trending topics are identified by significant increases in keyword frequency over recent years:

$$trending\_topics\ =\ \{k\ \mid\ keyword\_frequency(k, y)\ is\ increasing\ over\ time\} \quad (6)$$

2.2.4. Relevant sources

To analyze relevant sources, we count the number of publications per journal [33]:

$$journal\_publications\ (j) = \sum_{i=1}^{N} \delta(j_i = j) \quad (7)$$

where j_i is the journal of the i-th publication, and j is the journal of interest.

2.2.5. Citation analysis

For citation analysis, we compute key metrics such as total citation count (TCC) and h-index. Additionally, the impact of VRP research from different countries was assessed based on total citation counts and average article citations. This involved distinguishing between the highest total citations and the highest average article citations, providing a nuanced understanding of research influence [34].

$$TCC = \sum_{i=1}^{N} C_i \quad (8)$$

Where C_i is the number of citations for the i-th publication.

The h-index is calculated as (9).

$$h\ =\ \max\{\ h\ \mid\ at\ least\ h\ publications\ have\ h\ or\ more\ citations\} \quad (9)$$

2.3. Data visualization

To facilitate interpretation, the analyzed data is visualized using plots and charts. These visualizations help in understanding trends, contributions, and impact in a more intuitive manner.

Additionally, a network co-occurrence analysis was conducted to identify distinct thematic clusters based on their co-occurrence patterns [30]. A word cloud was generated to visually represent the most frequently used words in VRP-related article abstracts, providing insights into the central themes and emphases within the VRP and logistics research community.

3. RESULTS AND DISCUSSION

3.1. Annual scientific publications

The data used in this study was obtained from the Scopus database, with 2,000 documents downloaded in .csv format. The data was collected using the keywords "vehicle," "routing," "problem," "model," and "logistics". The data collection period spans from 2007 to 2023, and the collection was finalized on May 24, 2023 as can be seen in Figure 1.

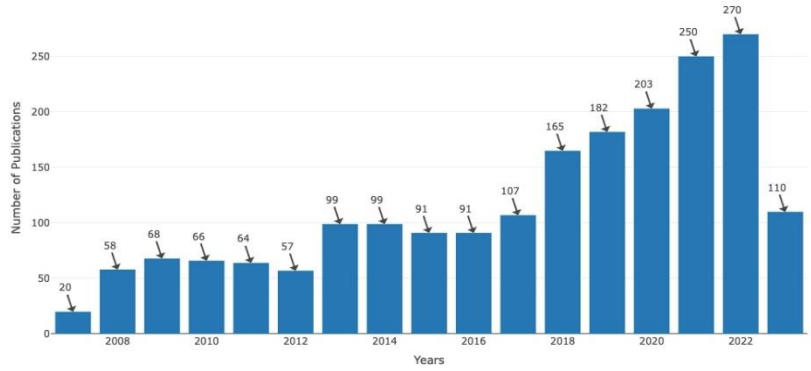

Figure 1. Graph presents a graph depicting the number of publications from 2007 to 2023

The graph in Figure 1 shows a consistent increase in publications over the years. Starting with 20 publications in 2007, the count steadily rises to 250 in 2021 and 270 in 2022. This indicates a positive growth trend in terms of publication output. Notably, a significant publication surge can be observed between 2017 and 2022, where the count jumps from 107 to 270. This period likely represents a period of heightened research interest and activity.

Throughout the years, there have been fluctuations in the number of publications. For instance, from 2013 to 2016, the count remains relatively stable, ranging between 91 and 99. However, in 2017, there was a sharp increase to 107, followed by a substantial spike in the subsequent years. The year 2023 reaches a peak with 270 publications, indicating an intensified level of research during that period. The graph illustrates a positive growth trajectory in VRP-related publications, with notable increases observed in recent years. This signifies the growing significance and interest in VRP research in logistics. The fluctuations in publication counts reflect varying levels of research activity and focus during different periods.

3.2. Analysis of the country that produced the publication

China has the most articles related to the logistics VRP model, with 2,845 articles based on Figure 2. This highlights China's substantial research contribution to logistics VRP models. Additionally, several other countries also made notable research contributions, including the United States (340 articles), Iran (289 articles), and Turkey (227 articles). These countries demonstrate active engagement in research related to the logistics VRP model.

In Europe, several countries exhibit significant contributions to logistics VRP models as can be seen in Figure 2. These include Italy (186 articles), France (174 articles), Germany (174 articles), and the Netherlands (60 articles). These countries indicate the widespread research on logistics VRP models across Europe. Developing countries such as India (157 articles), Brazil (115 articles), and Indonesia (97 articles) also show substantial research contributions to the logistics VRP model. This highlights the significant research interest and activity within these countries. The total number of citations by country of origin can be seen in Figure 3.

Additionally, other countries contribute significantly to research on logistics VRP models. These countries include Canada (114 articles), Spain (98 articles), Australia (93 articles), Colombia (86 articles), South Korea (69 articles), Singapore (64 articles), Mexico (62 articles), and Japan (60 articles). Overall, the

involvement of these countries demonstrates the global interest and extensive research conducted in logistics VRP models. Most relevants countries by corresponding author can be seen in Table 1.

The data in Table 1 provides insights into the country's contribution to VRP research. China leads with the highest number of articles (718), followed by Iran (83) and the United States (72). This demonstrates significant research interest and activity within these countries.

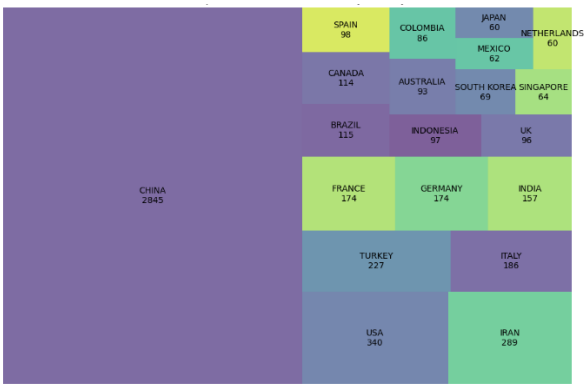

Figure 2. Treemap of number of countries that have publications related to the logistics VRP model

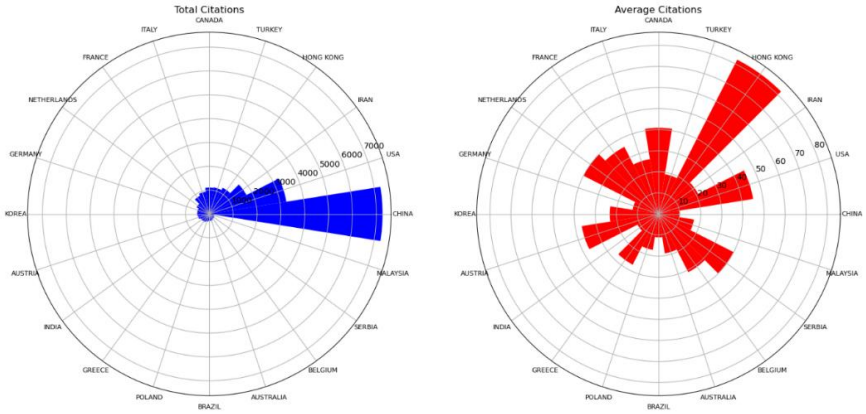

Figure 3. Circular bar plot of total number of citations by country of origin

Table 1. Most relevant countries by corresponding author

Country	Articles	Freq	SCP	MCP	MCP ratio	Country	Articles	Freq	SCP	MCP	MCP ratio
	718	0.491781	601	117	0.163		22	0.015068	16	6	0.273
	83	0.056849	71	12	0.145		19	0.013014	13	6	0.316
	72	0.049315	54	18	0.25		18	0.012329	10	8	0.444
	59	0.040411	51	8	0.136		15	0.010274	9	6	0.4
	41	0.028082	31	10	0.244	香港	15	0.010274	7	8	0.533
	36	0.024658	23	13	0.361		15	0.010274	8	7	0.467
	36	0.024658	30	6	0.167		14	0.009589	14	0	0
	27	0.018493	18	9	0.333		13	0.008904	9	4	0.308
	26	0.017808	15	11	0.423		13	0.008904	6	7	0.538
	24	0.016438	15	9	0.375		13	0.008904	7	6	0.462

The MCP ratio significantly represents cited articles' ratio. Brazil, Spain, and Hong Kong have high MCP ratios (0.423, 0.444, and 0.533, respectively), indicating significant recognition and citation of articles

in VRP research. The SCP represents the percentage of self-citations in articles. The data shows variations in self-citation rates, with countries such as India (36 articles with SCP 0.361) and Poland (19 articles with SCP 0.316) having a higher percentage of self-citations. The Freq column represents the relative frequency of the number of articles in the dataset. China has the highest frequency (0.491781), indicating its dominance in the dataset. The data in Table 1 also provides information on the contribution of VRP research from countries such as Germany, Italy, Canada, France, South Korea, the Netherlands, and Singapore. The number of articles and related metrics gives an idea of the level of research contribution and impact from these countries.

Based on Figure 3, China has the highest number of citations, with 7,264 citations, followed by the United States (3,268 citations) and Iran (1,745 citations). This suggests that research originating from these countries has received significant recognition and influence in the field of VRP research. However, a different pattern emerges when considering the average article citations per country. Hong Kong has the highest average article citations, with 82.13 citations, followed by the United States (45.39 citations) and Canada (40.89 citations). This indicates that other researchers in the VRP research community frequently cite articles from these countries.

It is essential to note the distinction between the highest total citations and the highest average article citations. While China has a high total citation count, the average citation per article is relatively low (10.12). On the other hand, Hong Kong has a high average citation per article despite having a lower total citation count. This highlights that the number of citations only sometimes reflects the average influence or recognition each article receives. The data also reveal variations in the impact of VRP research across different countries. Countries such as the United States, Hong Kong, and Canada have high average article citation counts, indicating that their research has garnered significant recognition and citations within the VRP research community.

3.3. Analysis of the trending topics

The data in Table 2 provides insights into trending topics. From the table, frequency of topics of mathematical models in VRP research based on keywords has shown an increasing trend since 2009, reaching its peak in 2013. Subsequently, the frequency has gradually decreased. The utilization of computer simulations in VRP research has steadily risen since 2010, peaking in 2016. After that, the frequency of occurrence has shown a declining trend. Network routing in VRP research has experienced a consistent increase since 2011, reaching its peak in 2015. After that, the frequency displayed a decreasing trend. Routing algorithms have gained significant attention in VRP research since 2011, with a remarkable increase in frequency leading to a peak in 2020. This indicates an intense research focus on developing routing algorithms during this period. The trending topics can be seen in Table 2.

Table 2. Trending topics

Item	Frequency	Year Q1	Year median	Year Q3
Mathematical models	93	2009	2011	2013
Computer simulation	38	2010	2012	2016
Network routing	136	2011	2013	2015
Routing algorithms	339	2011	2015	2020
Logistics	340	2011	2016	2019
Optimization	329	2013	2017	2020
Vehicle routing	965	2016	2019	2021
Decision making	108	2018	2020	2021
Sensitivity analysis	68	2019	2021	2022
Optimisations	55	2021	2022	2022

The topic of logistics has shown a rising trend in frequency in VRP research since 2011, reaching its peak in 2019. Following that, the frequency has remained relatively stable. Optimization topics in VRP research have witnessed a continuous increase in frequency since 2013, reaching a peak in 2020. This highlights the strong interest in optimizing VRP solutions through various optimization methods. Vehicle routing has gained significant prominence in VRP research since 2016, with a substantial increase in frequency culminating in a peak in 2021. This signifies a strong research focus on developing models and algorithms for efficient logistics delivery using vehicles. The frequency of decision-making in VRP research has shown an upward trend since 2018, reaching its peak in 2021. This reflects an interest in studying decision-making aspects within the context of VRP. Sensitivity analysis in VRP research has increased since 2019, peaking in 2022. This indicates a growing interest in understanding the sensitivity of VRP solutions to changes in specific parameters or conditions. Network co-occurence can be seen in Figure 4 and word cloud can be seen in Figure 5.

Optimizations in VRP research have shown an increasing trend since 2021, with a stable frequency until 2022. This underscores the attention given to various optimization methods in searching for optimal VRP solutions. The trends in these topics shed light on the evolving research focus and areas of interest within the VRP research community over the years.

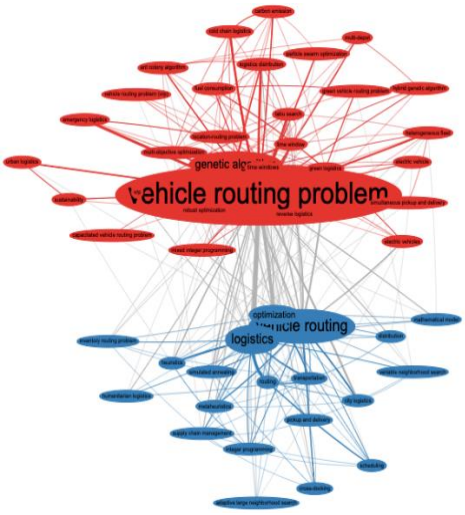

Figure 4. Network co-occurrence

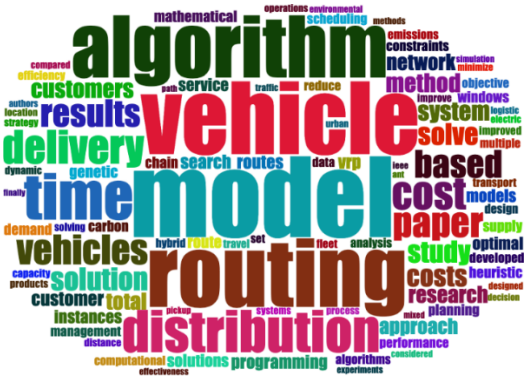

Figure 5. Word cloud

In Figure 4, cluster 1 (marked in red) encompasses topics closely related to logistics issues, including VRP, genetic algorithms, time windows, reverse logistics, green logistics, and logistics distribution. Cluster 2 (marked in blue) covers a broader range of topics, including vehicle routing, logistics, optimization, routing, city logistics, transportation, and heuristics. Cluster 1 strongly focuses on specific logistics-related issues, such as VRP and essential aspects like time windows, green logistics, and reverse logistics. This cluster also involves optimization techniques, such as genetic algorithms and tabu search, to enhance the efficiency and effectiveness of logistics distribution.

On the other hand, cluster 2 encompasses a broader scope, including topics related to logistics management, optimization, routing, city logistics, transportation, and heuristics. This cluster may concentrate more on managing and optimizing the supply chain and logistics system, encompassing vehicle routing planning and inventory management. This interpretation provides an overview of the topics associated with the two distinct clusters, highlighting the different focuses within the study of logistical issues. Cluster 1 delves into specific concerns like vehicle routes and green logistics, while cluster 2 encompasses a broader spectrum of logistics management aspects.

The wordcloud in Figure 5 describes the words that appear most frequently in article abstracts related to VRP and logistics. Words that stand out include “model,” indicating the importance of using models in this study, as well as “vehicle” and “routing”, which describe the close relationship between VRP and vehicle management and route planning. The word “algorithm” also stands out, highlighting the role of algorithm development and implementation in solving VRP problems. In addition, “logistics” and “distribution” focus on supply chain management and delivery of goods. The aspect of time is also a concern, along with the word “time”, which illustrates the importance of estimating delivery times and efficient scheduling. Words such as “proposed”, “delivery,” and “cost” indicate research on model development, delivery of goods, and cost aspects in the context of VRP and logistics. Altogether, this word cloud provides an overview of the main topics researched and cared for in the VRP and logistics fields. Most relevance sources of journal in the field of VRP can be seen in Figure 6.

Figure 6 provides an overview of relevant journals in the field of VRP models within logistics, along with the number of articles published in each. Lecture notes in computer science (including the subseries lecture notes in artificial intelligence and lecture notes in bioinformatics) stands out with the highest number of articles, totaling 49. This journal publishes research in computer science, encompassing artificial intelligence and bioinformatics. With 45 articles, computers and industrial engineering focuses on applying computer engineering in industry and industrial engineering, covering topics such as optimization, supply chain management, and production planning. Similarly, the European journal of operational research also features 45 articles and explores operational research and the utilization of analysis methods to address

complex problems. Topics covered include mathematical optimization, linear programming, risk analysis, and decision-making. Expert systems with applications consists of 41 articles and emphasizes the practical application of intelligent systems and artificial intelligence (AI) across various domains. The articles in this journal cover pattern recognition, natural language processing, decision-making systems, and AI applications in diverse industries. Transportation research part E: logistics and transportation review comprises 40 articles that specifically delve into logistics and transportation aspects. It examines topics such as optimizing shipping routes, supply chain management, transportation performance analysis, and the latest advancements in transportation technology. Other notable journals like sustainability, computers and operations research, annals of operations research, and IEEE access also contribute significantly to the VRP and logistics models domain. Overall, these findings reflect a broad research interest in VRP and logistics models, focusing on developing optimization methods, intelligent systems applications, and operational analysis to enhance the efficiency and performance of logistics systems.

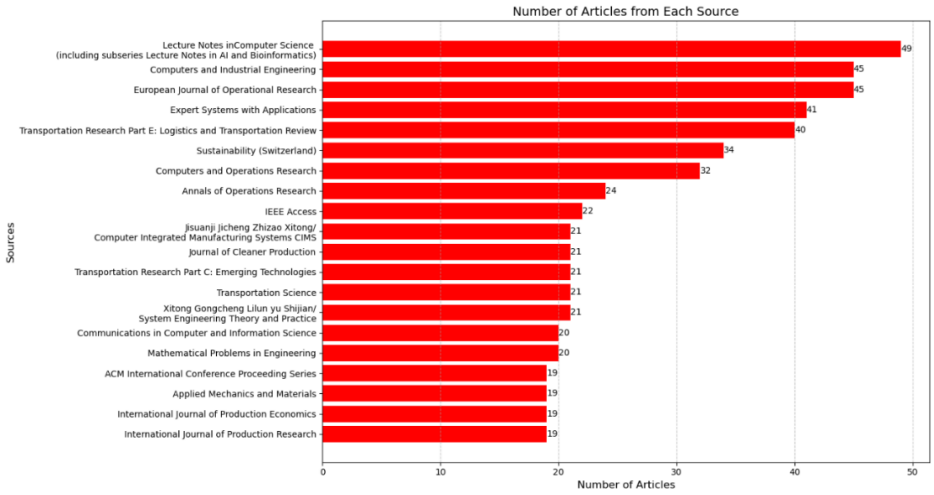

Figure 6. Most relevant sources

3.4. Discussion

The presented research findings provide valuable insights into the development and understanding of the VRP model research within the logistics domain. The study covers various aspects, including the annual scientific publications, analysis of the countries producing the publications, trending topics in the field, and relevant sources of research. Each section of the research contributes to a comprehensive understanding of the current state of VRP research in logistics.

The study begins by analyzing the trends in annual scientific publications related to VRP models in logistics. The data, collected from the Scopus database, spans from 2007 to 2023. The graph illustrates a consistent increase in publications over the years, with a significant surge between 2017 and 2022. This indicates a period of heightened research interest and activity. The fluctuations in publication counts over different years reflect varying levels of research focus and activity during different periods. Overall, the increasing trend signifies the growing importance and interest in VRP research within the logistics domain.

The research also examines the countries contributing significantly to VRP research in logistics. China emerges as a dominant contributor, followed by the United States, Iran, and Turkey. European countries like Italy, France, Germany, and the Netherlands, as well as developing countries like India, Brazil, and Indonesia, demonstrate active engagement in VRP research. This analysis underscores the global interest and extensive research conducted in the field of logistics VRP models. Additionally, the analysis of the MCP ratio and SCP provides insights into the recognition and citation impact of research from various countries, contributing to a deeper understanding of the influence of different nations' research outputs.

The research delves into the trending topics within VRP research. Mathematical models, computer simulations, network routing, routing algorithms, logistics, optimization, vehicle routing, decision making, sensitivity analysis, and optimizations are identified as significant topics. The temporal trends associated with these topics are analyzed, providing a clear understanding of the evolving research focus over the years. The clustering of topics based on co-occurrence highlights two distinct clusters, emphasizing logistics-related issues and broader logistics management aspects. Furthermore, a word cloud representation visually summarizes the most frequent keywords in VRP and logistics research, shedding light on the central themes and areas of emphasis in the field. The study also identifies relevant sources of VRP research. Journals such

as lecture notes in computer science, computers and industrial engineering, European journal of operational research, expert systems with applications, and transportation research part E: logistics and transportation review stand out as key platforms for publishing research in the field. These journals encompass a range of topics, from computer science and engineering to operational research and application of intelligent systems, demonstrating the interdisciplinary nature of VRP research within logistics.

This research provides a comprehensive analysis of the development and understanding of VRP model research in the logistics domain. The findings shed light on the trends in annual publications, countries contributing significantly, trending topics, and relevant research sources. This holistic approach offers valuable insights for researchers, policymakers, and practitioners interested in advancing the field of logistics through VRP models. The results of this study contribute to a deeper understanding of the current landscape, research trends, and areas of focus within the VRP research community.

4. CONCLUSION

In conclusion, this study utilized a bibliometric approach to analyze the VRP model within the logistics delivery context. The research data was obtained from the Scopus database, comprising 2,000 VRP-related publications from 2007 to 2023. The bibliometric analysis revealed key findings regarding research trends, country contributions, and dominant topics within the VRP research network. The analysis demonstrated substantial publication growth, with a notable peak between 2017 and 2022. China emerged as the leading contributor to VRP research, followed by the United States, Iran, and other actively engaged countries. Prominent topics within VRP research encompassed mathematical models, routing algorithms, optimization techniques, and logistics-related subjects.

Furthermore, network co-occurrence analysis identified two main clusters. Cluster 1 concentrated on specific logistics issues such as VRP, reverse logistics, and green logistics. In contrast, Cluster 2 emphasized broader logistics management aspects, including logistics, optimization, and transportation. Journals such as lecture notes in computer science, computers and industrial engineering, European journal of operational research, and expert systems with applications are the leading platforms for research publication in this field. The findings of this study enhance our understanding of the development and research trajectory within the field of VRP. They shed light on the countries and topics that garnered significant attention and research efforts. These insights contribute to the overall comprehension of VRP and provide a foundation for future research endeavors to enhance logistics delivery efficiency and effectiveness.

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