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MAPPING THE LANDSCAPE OF ARTIFICIAL INTELLIGENCE IN SUPPLY CHAIN MANAGEMENT: A BIBLIOMETRIC ANALYSIS

Industry 4.0 concepts and technologies, which focus on interconnectivity, digitalization, and automation, are critical to the long-term success of both micro and macroeconomic entities. Artificial Intelligence (AI) has emerged as a critical enabler for effective Supply Chain Management (SCM) within this framework. This research study conducts a thorough examination of the current literature to investigate the role of AI in SCM. The study attempts to identify research trends, appraise the present state of knowledge, and provide insights on management implications through a systematic review and the use of bibliometric analytic methodologies. The management implications of this study provide light on the potential benefits and possibilities that AI may provide to SCM operations. The research findings provide firms with the means to improve their supply chain operations, elevate decision-making processes, and achieve a competitive advantage in the changing business landscape by properly using the potential of AI.

Keywords: industry 4.0, artificial intelligence, supply chain management, bibliometric analysis.

1. INTRODUCTION

The advent of Industry 4.0, commonly referred to as the fourth industrial revolution, encompasses a range of concepts and technologies aimed at enhancing the competitiveness of industrial organizations. The focus lies in the realms of interconnection, digitization, and automation (Bag et al., 2021; Chauhan et al., 2022; Ghadge et al., 2020). Within this context, AI can be defined as the field of study and engineering dedicated to intelligent machines, with a specific emphasis on the development of intelligent computer programs (McCarthy et al., 2006). In the realm of AI, a plethora of methodologies and techniques exists. However, for the purpose of this research, we adopt a classification that encompasses five broad categories: (1) techniques involving mathematical optimization, (2) network-based approaches that represent problems as sets of states and transitions, (3) methodologies employing agent-based modeling and interactions within multi-agent

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systems, (4) approaches incorporating automated reasoning based on preexisting knowledge, and (5) machine learning and big data analytics techniques. Leveraging these techniques can yield a multitude of intriguing applications within the field of SCM (Baryannis et al., 2019).

While interest from practitioners and researchers remains high, there is still a need to investigate AI's contribution to the subject of SCM. Several research have emphasized the importance of this requirement (Riahi et al., 2021; Toorajipour et al., 2021). The current study intends to fill this knowledge gap by conducting a literature review and answering the following key research question (RQ): What role does AI play in SCM research? Using bibliometric research, the goal of this study is to identify, present, and analyze essential features connected to the implementation of AI in SCM. The document seeks to accomplish four major goals:

1. To illustrate the evolution of AI scientific production in SCM over time, including the quantity of published documents, research categories, and associated source dynamics.
2. To identify prominent nations and their joint research initiatives in AI in SCM.
3. To identify the most commonly used terms and their relationships with other ideas.
4. To identify the most often utilized AI approach in SCM research.

The study's methodology centered around a comprehensive bibliometric analysis, systematically examining a vast array of literature from the Scopus database to deeply explore and understand the multifaceted role of AI in SCM. A bibliometric analysis was conducted in June 2023. The research sample was established using the Scopus database. From the search topic “supply chain management” a total of 1 076 documents in various languages were identified. Filtered data exported from Scopus were processed using different software solutions, including VOSviewer and Microsoft Excel. Among these, VOSviewer played a crucial role in mapping bibliographic data and identifying prominent concepts and emerging research themes based on average publication year. By accomplishing these goals, this study aims to bridge the research gap by providing a comprehensive understanding of the role of AI in SCM research. The findings will contribute to a deeper understanding of the potential applications, benefits, and challenges associated with the integration of AI in SCM. This knowledge will not only advance academic understanding but also provide practical insights for organizations seeking to harness the power of AI to optimize their supply chain operations.

The structure of this research paper is organized as follows. Section 2 describes the study's chosen research methodology and methodologies, as well as a full explanation of the systematic literature review procedure. Section 3 provides a descriptive and content analysis of the listed studies. Section 4 discusses the research findings. Section 5 outlines the limitations and practical applications. Finally, Section 6 concludes with a quick reflection on the primary contributions of this study.

2. RESEARCH METHODOLOGY AND METHODS

The purpose of this research is to conduct a comprehensive review of AI in the context of SCM. Within the field of SCM, the phrases “artificial intelligence”, “machine learning”, and “deep learning” were explored to characterize the study subject and set conceptual limits. A complete and representative study sample was constructed using the Scopus database in June 2023, precisely on the topic of “AI in SCM”. A further study of similar databases, such as Web of Science, Science Direct, and Emerald, revealed no significant

variations in the resultant research studies. As a result, it was decided that Scopus would be the primary database for analyzing secondary data throughout this research investigation. A query based on title, abstract, and keywords was used to discover and collect relevant papers pertinent to the study subject. To achieve a thorough comprehension of the subject of research, author keywords (AK) and keywords plus (KP) were used. For this study, the search strings included "artificial intelligence" AND "keywords". The keywords used were "supply chain", "production", "marketing" and "logistics", which where extracted from the comprehensive definition of SCM by (Stock and Boyer, 2009). They supplement the amount of knowledge about a subject by giving an independent expansion of author keywords. Both AK and KP are required for bibliometric analysis since they disclose commonly recurring phrases and concepts, enabling researchers in gaining a more holistic view of existing research efforts across multiple subfields (Zhang et al., 2016; Pech et al., 2022).

Upon conducting the aforementioned search using the designated methodology, a comprehensive collection of scholarly documents emerged, amounting to a total of 1 098 publications written in various languages. Among these publications, the predominant language of dissemination was English, with a substantial count of 1076 documents. The remaining documents were distributed across other languages, including Chinese (12), German (5), Turkish (3), and Spanish (2). To ensure consistency and coherence within the study, a language-based exclusion criterion was meticulously established. Consequently, all non-English written documents were systematically excluded from further analysis and investigation. By applying this criterion, a refined and homogeneous dataset consisting solely of English-written papers was obtained, resulting in a final count of 1076 articles. To ensure a comprehensive overview of the information encompassed within the Scopus database, the exclusive criterion utilized in this study was the language of the documents, specifically English. By adopting this approach, it aimed to gather relevant insights from a diverse range of sources, including researchers, academics, and practitioners. Consequently, all document types were included, encompassing articles, proceedings papers, book chapters, books, and editorial materials. By incorporating these varied document types, the research sought to establish a meaningful starting point and provide a holistic perspective on the subject matter. Additionally, to capture emerging trends and developments, early access publications were also considered in the research sample.

In order to obtain a comprehensive understanding of the concept of AI in SCM, the analysis encompassed all Scopus categories. This wide-ranging approach facilitated the identification of research trends across multiple domains, such as computer science, engineering, business, management, mathematics, social science, and more. In future research, specific elements within these domains with a high frequency of occurrence will be further identified for a more targeted and focused analysis. Following the collection of 1076 English documents, the acquired records were exported in both Excel (.csv format) and Plain Text File (.txt format) for subsequent processing and analysis. This step was taken to facilitate the examination of the data using specialized software tools such as VOSviewer. By leveraging these software tools, the collected data from the Scopus database underwent a comprehensive analysis. This analysis encompassed the identification of various key aspects within the dataset, including the top categories, publication titles, publishers, significant authors, institutions, and countries. Moreover, collaboration networks were examined to assess the extent of collaborative efforts within the researched field. This analysis aimed to shed light on the interconnectedness and collaborative dynamics among researchers and institutions. Additionally, the data analysis

involved the identification of main conceptual clusters and concept maps, allowing for a visual representation of the interrelationships between different concepts and themes present in the dataset. This visualization aided in understanding the prevailing themes and the connections between them, taking into consideration the occurrences, links, and total link strengths. Furthermore, a co-occurrence analysis of all keywords was conducted to explore the thematic evolution within the researched field. This analysis sought to identify the latest developments, emerging trends, and the interconnectedness of different research themes based on the co-occurrence patterns of keywords.

3. RESULTS

This section undertakes a comprehensive examination of the outcomes obtained from querying the Scopus database on the topic of "AI in SCM". The acquired results, spanning the years from 2000 to 2023, were subjected to rigorous analysis utilizing various analytical tools such as VOSviewer and Excel. The subsequent paragraphs present an in-depth and comprehensive exposition of the key findings derived from these analytical processes. Through this analysis, valuable insights and trends within the field of AI in SCM are unveiled, providing a significant contribution to the existing body of knowledge in this domain. Among the 1076 articles that were identified, 407 of them are categorized as conference papers, while 170 are attributed to other forms of publication such as book chapters or books (see Table 1).

Table 1. Categorization of document type

Paper type	Number
Conference paper	499
Article	407
Book chapter	66
Review	60
Conference review	40
Book	13
Others	13

Source: Authors' own processing with data from Scopus.

The cumulated evolution of published documents in the period between 2001 and 2023 is presented in Figure 2. Between the years 2002 and 2007, the publication volume pertaining to the subject of AI in SCM exhibited a relatively modest level, with a gradual upward trend observed, ranging from 5 publications in 2002 to 17 publications in 2007. Subsequently, a noteworthy rise in publication volume occurred from 2008 onwards, indicating an escalating interest in the intersection of AI and SCM. This upward trajectory persisted steadily, punctuated by sporadic spikes in specific years. Notably, between 2008 and 2010, a substantial surge in publication volume was witnessed, culminating in the highest point of 72 publications in 2010. This suggests an increasing recognition and concentrated research focus on the subject during this particular period. Following the peak in 2010, a slight decline in publication volume transpired until 2012, suggesting a potential stabilization or realignment of research endeavors within the field. From 2012 to 2016, the publication volume remained relatively consistent, displaying minor fluctuations but no

significant overall growth or decline. Starting in 2017, another remarkable increase in publication volume emerged, indicative of renewed interest and heightened research activity within the domain. This upward trend persisted through 2022, reaching its zenith with 189 publications in that year, signifying a substantial surge in research output. Examining the most recent data point in 2023, the publication volume slightly decreased compared to 2022; however, it remains substantial, with 103 publications. Collectively, the evaluation of publication volume over the analyzed period reveals a growing research interest and escalating activity in the realm of AI in SCM. Notably, significant growth has been observed in recent years. The expanding volume of publications signifies the presence of a thriving research community dedicated to exploring and advancing the application of AI within the context of SCM.

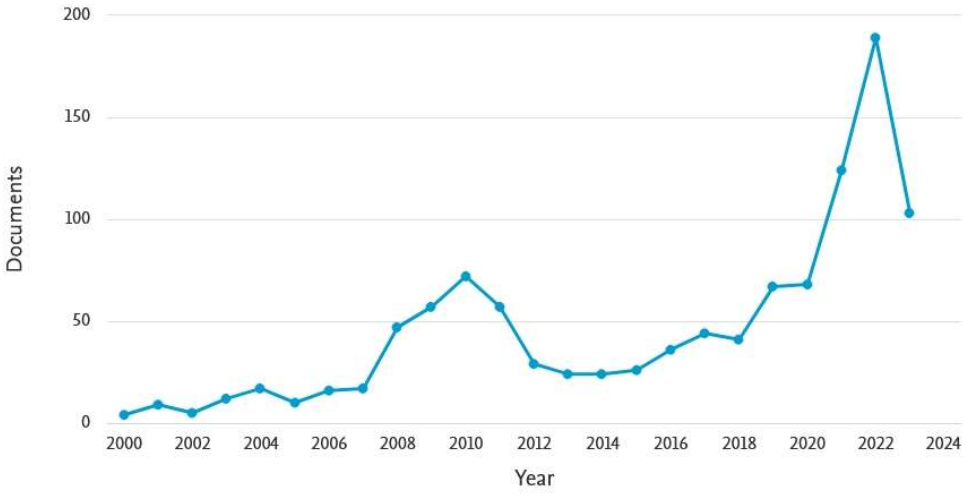

Figure 1. Evolution of publication volume and citation metrics over time

Source: Authors' own processing with data from Scopus.

Figure 2 presents the studies' outcome, which have been categories by the authors' country. China demonstrates a remarkable leadership position in terms of publication volume throughout the analyzed period, boasting 190 publications. This substantial output signifies a significant research effort and a keen interest in the field of AI in SCM within the academic community in China. Following closely, the United States exhibits a strong research activity with 154 publications, establishing itself as a prominent contributor in this domain. India also emerges as a noteworthy participant in AI in SCM research, with 140 publications, solidifying its position as a valuable contributor to the existing literature. Germany and the United Kingdom exhibit a relatively high publication volume with 82 and 77 publications, respectively, indicating active research engagement and a commitment to advancing knowledge in these countries. Additionally, France, Italy, Australia, Hong Kong, and Canada contribute to the publication volume in AI in SCM, albeit with comparatively smaller numbers than the leading countries.

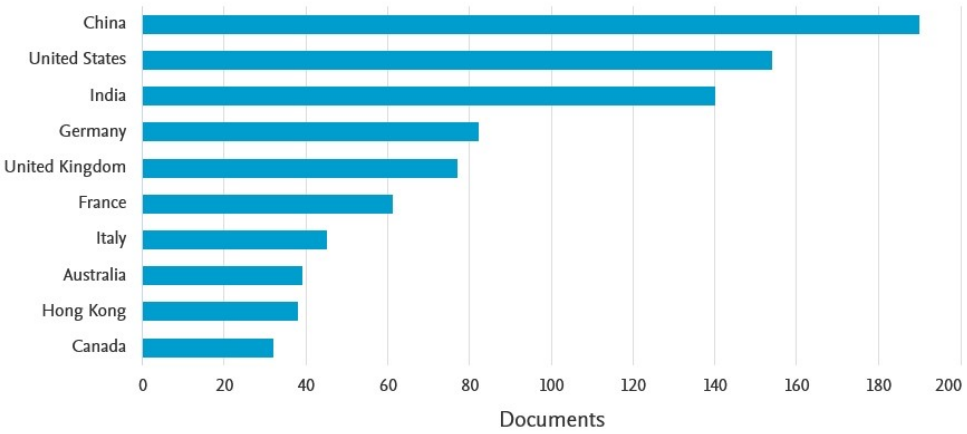

Figure 2. Documents by 10 top country

Source: Authors' own processing with data from Scopus.

For the purpose of co-authorship analysis at the country level, a specific criterion was applied to ensure robustness and meaningful results (Figure 3). Only countries that had a minimum of five documents available in the Scopus database on the researched topic were included in the analysis, irrespective of the number of citations associated with those documents. Following this criterion, a total of 53 countries met the eligibility criteria for inclusion in the study. The collected data, consisting of the co-authorship relationships

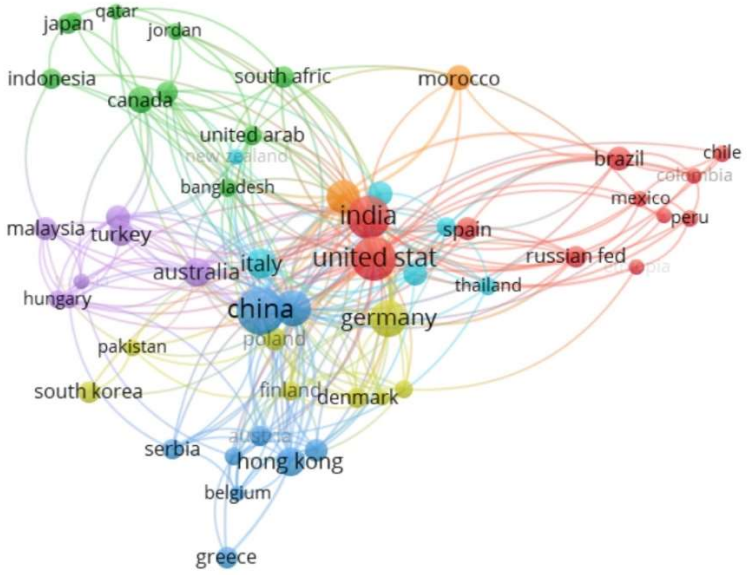

Figure 3. Country as a unit of analysis – Network Visualization

Source: Authors' own processing with VOSviewer.

among these 53 countries, was subjected to further processing using advanced automated clustering algorithms provided by VOSviewer. This enabled the generation of a comprehensive map (Figure 3) that visually represented the interconnections among the countries based on their co-authorship relationships. The generated map provided valuable insights into the research collaboration landscape, revealing key metrics such as the number of organizations involved (53), the number of distinct clusters formed (7), the total number of links (279), and the overall strength of the co-authorship connections (481) between the countries.

In terms of the word cloud based on KP (Figure 4), the most prominent concepts are: chain (433); management (366); supply (330); intelligence (265); systems (238); artificial (219); analysis (135); system (115); optimization (101); data (91); decision (86); models (84); programming (69); planning (65); control (60) etc. These results demonstrate the significance and frequency of these concepts within the analyzed dataset.

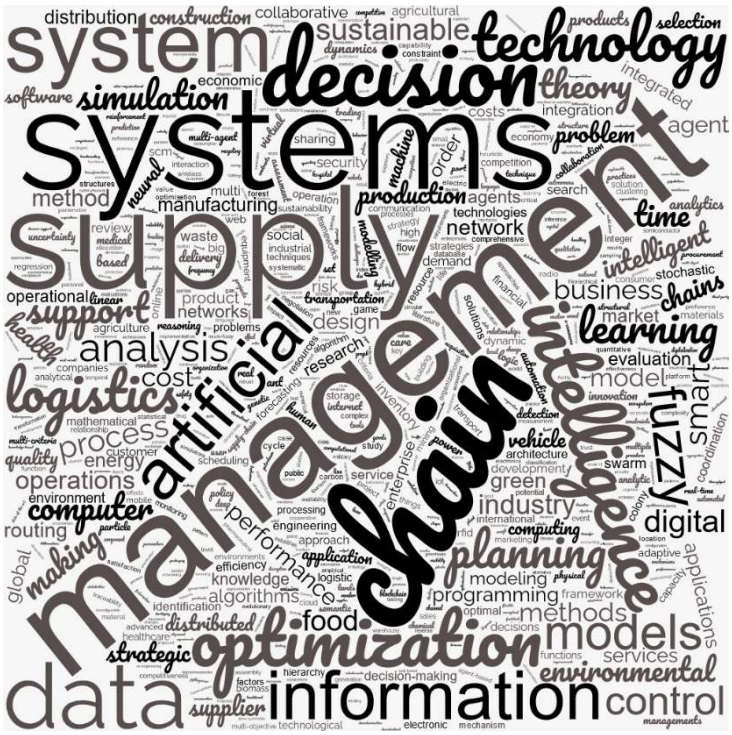

Figure 4. Word Cloud based on Keywords Plus (KP)

Source: Authors' own processing with classic.wordclouds.com

Table 2 shows a classification of AI approaches used in SCM. The number of instances of each approach is presented, showing the frequency with which these techniques were used in the study literature under consideration. Machine learning is the most common approach, with 171 instances in the literature. This demonstrates the broad use of machine learning methods and models in SCM research. Machine learning allows for the examination of big datasets in order to extract useful insights and make data-driven

decisions (Lee & Mangalarah, 2022). Another common AI approach in SCM is genetic algorithms, which occur 55 times in the literature. The Genetic technique is a sophisticated optimization technique that is inspired by natural selection and genetics. Fuzzy Logic and Data Mining techniques also demonstrate significant utilization, with 32 and 39 occurrences, respectively. Fuzzy logic is used to deal with imprecise or unclear data (Shore & Venkatachalam, 2003), whereas data mining is the process of discovering meaningful patterns and insights from vast databases (Kusiak & Smith, 2007). Artificial Neural Networks (ANN), a computer model inspired by the neural structure of the human brain, occur in 25 instances. These networks are particularly well-suited to pattern recognition and prediction applications (Silva at al., 2017). With 12 instances, Support Vector Machine (SVM), a supervised learning technique used for classification and regression problems, is significantly less common.

Table 2. Categorization of AI technique

AI technique	Number
Machine learning	171
Genetic algorithm	55
Agen-based systems	45
Data mining	39
Fuzzy logic	32
Artificial neural networks	25
Support vector machine	12

Source: Authors' own processing with data from Scopus

Table 3 summarizes the distribution of publications in several domains linked to the application of AI in SCM. The table provides useful insights into the areas of AI research in SCM that are concentrated, as well as the diverse levels of participation across different disciplines. With a total of 696 publications discovered in the literature study, the discipline of computer science stands out as the most productive. Researchers in this subject are critical to the advancement of AI algorithms, models, and frameworks that may be used to optimize supply chain processes. Their experience substantially helps to the development and implementation of AI-driven SCM systems, enabling improvements in automation, predictive analytics, and optimization. Engineering, with 486 articles, comes in second. Engineers offer their experience to the use of AI techniques in SCM, concentrating on the development and integration of AI-based solutions to optimize supply chain operations. Their contributions vary from boosting logistics and transportation efficiency to inventory management and production planning procedures. The subject of Business, Management, and Accounting also has a significant amount of publications, with a total of 294 articles. This demonstrates the rising acknowledgment of the influence of AI on SCM from a commercial and management perspective. Their research offers light on the managerial consequences and strategic concerns related with the adoption and deployment of AI in SCM. With 179, 99, and 88 articles, the domains of Mathematics, Social Science, Economics, Econometrics, and Finance likewise contribute significant contributions to AI in SCM research. Researchers in these fields contribute to the theoretical underpinnings and quantitative analysis of AI approaches in SCM, allowing for a better understanding of their influence on supply chain dynamics. The relatively modest number of publications in

the domains of Energy and Environmental Science, with 63 papers each, reflects an increasing interest in using AI approaches to optimize energy use, decrease environmental impact, and promote sustainability within supply chain activities. Finally, 31 articles in the Materials Science area highlight possible uses of AI approaches in the management and optimization of materials procurement throughout the supply chain.

Table 3. Categorization of subject area

AI technique	Number
Computer science	696
Engineering	486
Business, Management and Accounting	294
Decision Science	257
Mathematics	179
Social Science	99
Economics, Econometrics and Finance	88
Energy	63
Environmental Science	63
Materials Source	31

Source: Authors' own processing with data from Scopus

4. DISCUSSION

In addressing the main RQ concerning the role of AI in SCM, we now present a clear and comprehensive answer. The application of AI techniques in SCM has yielded valuable insights and advancements in optimizing various aspects of the supply chain. One specific AI technique that has emerged as a valuable optimization tool in SCM is GA have emerged as valuable optimization tools in SCM. They are frequently employed in supply chain network design (Altiparmark, 2009), where they aid in determining the optimal configuration of facilities, distribution centers, and transportation routes (Yeh, Chuang, 2011; Zhou et al., 2002). Additionally, GA is utilized in optimizing inventory management (Hiassat et al., 2017), production scheduling (Naso et al., 2007), and vehicle routing problems (Lau et al., 2009). Leveraging the principles of natural evolution and selection, GA provides an efficient approach for solving complex optimization problems encountered in SCM (Lau et al., 2009). Furthmore, Data Mining techniques play a pivotal role in extracting valuable insights and patterns from extensive datasets, thereby contributing significantly to SCM. Within SCM, Data Mining finds application in various areas, including demand forecasting (Aburto, Weber, 2007), customer segmentation (Tsiptsis, 2011), market basket analysis (Kaur, 2016), and identification of patterns related to product quality and supply chain disruptions. By analyzing historical data, Data Mining enables businesses to identify trends, anomalies, and areas for improvement, facilitating data-driven decision-making and the optimization of supply chain operations (Vercellis, 2011).

Fuzzy Logic techniques are another essential tool applied in SCM to address uncertainties and imprecise data. Fuzzy Logic finds utility in various SCM decision-making processes, such as supplier selection (Ordoobadi, 2009), production planning (Sharma et al., 2022; Min, 2010), and inventory control (Tirkolaee, 2021; Jain et al., 2022) quality control (Pournader et al., 2021). By considering the varying degrees of relevance

and importance associated with different factors, Fuzzy Logic enables decision-makers to incorporate imprecise and subjective information, thereby fostering flexible and adaptive decision-making in uncertain environments.

One of the key applications of AI in SCM is through the use of ANN. These networks consist of interconnected nodes, or „neurons", which process and transmit information. These networks are capable of learning from data, making predictions, and identifying patterns in complex datasets. They are frequently used in demand forecasting models to assess past sales data, market trends, and other relevant aspects, allowing for reliable estimates of future demand. ANN models are also used in inventory management to optimize stock levels and improve order fulfillment operations (Li & Kuo, 2008; Baryannis et al., 2019). Furthermore, ANN is important in predictive maintenance because it can detect trends and abnormalities in equipment performance, allowing for preemptive maintenance activities (Foo et al., 2018; Lim et al., 2022). SVM a powerful machine learning technique, finds extensive application in SCM for classification and regression tasks. SVM finds applications in SCM for demand forecasting (Yue, 2007), quality control (Pallathadka et al., 2023), and supply chain risk analysis (Toorajipour et al., 2021), enabling accurate prediction of future demand, effective detection of defects, and proactive management of supply chain risks.

This study efficiently answered the major RQ about the function of AI in SCM. Significant insights into the contributions and consequences of various AI approaches and their applications in SCM have been achieved via a thorough investigation of their applications. The study's findings show the critical significance that AI techniques such as GA, Data Mining, Fuzzy Logic, ANN, and SVM play in optimizing various areas of the supply chain. These methodologies have found use in fields such as supply chain network design, inventory management, demand forecasting, quality control, and supply chain risk analysis. The study's findings emphasize the need of utilizing AI in SCM to increase operational efficiency and decision-making processes, implying the potential for enhanced supply chain performance.

5. LIMITATIONS AND IMPLICATIONS

As with any research endeavor, this study has inherent limitations. The literature review conducted in this research focused exclusively on the Scopus database. While Scopus is widely recognized and comprehensive, limiting the search to a single database may have influenced the scope and comprehensiveness of the findings. To ensure a more comprehensive understanding of the contribution of AI to SCM studies, it is recommended to compare the results obtained from Scopus with other relevant databases. The primary goal of this study was to encompass a broad body of knowledge on the topic. Consequently, it was not feasible to delve into the specifics of each individual study identified in the literature review. Therefore, a more focused and in-depth evaluation of specific AI techniques or aspects is highly recommended to gain a more nuanced understanding of their contributions to SCM studies.

It is important to acknowledge that the breadth of the subject matter may have resulted in a trade-off between breadth and depth in this study. Consequently, certain nuances and intricacies of individual studies may not have been fully explored. Future research efforts could benefit from narrowing the focus to specific AI techniques or subfields within the broader field of interest. This approach would allow for a more comprehensive examination and analysis of the selected areas. Moreover, the limitations of this study extend to the

availability and accessibility of published literature. Despite employing comprehensive search strategies within the Scopus database, it is possible that relevant studies from other databases or sources may have been inadvertently excluded. To address this limitation, researchers are encouraged to expand their search to additional databases and sources to ensure a more comprehensive coverage of the existing literature.

To overcome these limitations, it is recommended that researchers undertake more targeted and specialized investigations concentrating on specific AI techniques or subdomains within the broader field of interest. This approach would enable a more detailed and comprehensive evaluation of the literature, leading to a deeper understanding of the contributions of AI to SCM studies. Furthermore, it would facilitate comparisons across different databases, enhancing the overall understanding of the topic.

The literature review on the contribution of AI to SCM reveals a managerial implication that centers around recognizing the potential advantages and opportunities associated with incorporating AI into SCM practices. The review underscores the diverse applications of AI techniques, including ANN, Fuzzy Logic, GA, Data Mining, and SVM, in enhancing decision-making, optimizing operations, and overall improving supply chain performance. Understanding the contributions of AI to SCM empowers managers to identify specific areas within their supply chain where AI techniques can be effectively utilized. This knowledge facilitates informed decision-making regarding the adoption and implementation of AI technologies. For instance, AI can be leveraged in demand forecasting models, inventory management systems, predictive maintenance strategies, and supply chain risk analysis, among other areas. Managers can evaluate their unique supply chain needs and identify the AI techniques that align with their organizational objectives and challenges.

Furthermore, the literature review provides valuable insights into the potential challenges and limitations associated with the adoption and implementation of AI in SCM. Managers can capitalize on this understanding to proactively address these challenges and develop strategies to mitigate potential risks. For example, investments can be made in data quality and availability to ensure accurate AI predictions and analyses. Additionally, managerial focus can be directed toward building the necessary technological infrastructure and cultivating the required capabilities within the workforce to effectively harness AI tools. Additionally, the review emphasizes the significance of a focused and targeted approach when integrating AI into SCM practices. Managers can employ insights from the literature review to identify specific AI techniques or subfields that align with their organization's distinct supply chain requirements. This approach enables a more efficient and effective implementation of AI technologies, ensuring appropriate allocation of resources and yielding tangible benefits.

6. CONCLUSIONS

This research presents a comprehensive examination of the role of AI in SCM through a bibliometric analysis. By conducting a literature review and analyzing research trends, this study has revealed valuable insights and implications. The analysis of publication volume over time has revealed a substantial increase in research interest and activity at the intersection of AI and SCM, particularly in recent years. This growth signifies the growing recognition of the potential benefits and applications of AI in SCM practices. Furthermore, the evaluation of publication volume by country has underscored the global interest in this field, with China, the United States, and India emerging as significant contributors to the

scholarly literature. The categorization of AI techniques used in SCM has shed light on the diverse array of approaches employed in research. ANN, Fuzzy Logic, GA, Data Mining, and SVM have been identified as key techniques that contribute to enhancing decision-making, optimizing operations, and improving overall supply chain performance. Each technique offers specific benefits and finds applications within SCM, spanning from demand forecasting to inventory management and supply chain risk analysis.

For future study, a more in-depth look into certain AI approaches inside SCM is recommended, with an emphasis on their unique contributions in various supply chain scenarios. To increase the research's comprehensiveness, future studies could utilize a larger range of academic databases in addition to Scopus. The inclusion of case studies or primary research with firms actively applying AI in SCM might provide useful insights. Furthermore, researching new AI approaches and their scalability in the changing environment of SCM will be beneficial. This methodology would allow for a more comprehensive view of AI's role and potential in current supply chain procedures.

The research acknowledges its limitations. The literature review focused exclusively on the Scopus database, and it is recommended to expand the coverage to include other databases for a more comprehensive understanding of the topic. Additionally, the broad scope of the subject matter limited the depth of analysis for individual studies, highlighting the need for more focused and specialized investigations into specific techniques or subfields within AI and SCM. The research findings yield managerial implications, emphasizing the recognition of the potential benefits of AI and the importance of a targeted approach. Managers can leverage the insights gained from this research to identify suitable AI techniques for their supply chain, address challenges, and make informed decisions regarding the adoption and implementation of AI technologies. Proactive measures, such as investing in data quality and building the necessary technological infrastructure, can enable organizations to maximize the benefits of AI in SCM.

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