# A STUDY ON SUPPLY CHAIN 5.0 RESEARCH: A VISUAL ANALYSIS BY BIBLIOMETRIX R-TOOL

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## ABSTRACT

Studies on recent industrial developments and their impacts are one of the majorities of the current literature, and it is a rapidly growing area. With this view, this paper presents a comprehensive bibliometric analysis of research on Supply Chain 5.0 (SC 5.0), an emerging paradigm that integrates Industry 5.0 principles with supply chain management to enhance human-machine collaboration, sustainability, and resilience. Utilizing data from prominent academic databases, this study examines the evolution of SC 5.0 research and identifies key themes. Bibliometrix software, which uses R language and is therefore known as R-tool, is utilized for analysis. It employs various bibliometric techniques, including co-occurrence analysis, keyword co-occurrence, and thematic mapping, to uncover the intellectual structure and trends within the field. Findings reveal a rapid publication growth, emphasizing technological advancements, sustainability, and human-centric approaches. At the end of the study, future research ideas are presented under the themes of supply chain resilience and agility, human-centric approaches in supply chains, impacts of SC 5.0 in emerging economies, and sustainable SC 5.0 concepts. This paper contributes to the academic discourse by providing a detailed overview of the current state of SC 5.0 research, highlighting gaps, and suggesting future research directions to advance the field.

**Keywords:** Supply Chain, Industry 5.0, Industry 4.0, Supply Chain 5.0, Bibliometric Analysis, Digitalization

# TEDARİK ZİNCİRİ 5.0 ÜZERİNE BİR ARAŞTIRMA: BIBLIOMETRIX R-ARACI İLE GÖRSEL ANALİZ

## ÖZ

Son dönemdeki endüstriyel gelişmeler ve bunların etkileri ile ilgili çalışmalar günümüzde hızla artmaktadır. Bu çalışma, insan-makine iş birliğini, sürdürülebilirliği ve dayanıklılığı geliştirmek için Endüstri 5.0 ilkelerini tedarik zinciri yönetimiyle bütünleştiren Tedarik Zinciri 5.0 konusuna odaklanmaktadır. Bu çalışmanın amacı Tedarik Zinciri 5.0 hakkındaki akademik çalışmaların kapsamlı bir bibliyometrik analizini sunmak ve Tedarik Zinciri 5.0 konusuna yönelik araştırmaların gelişimini inceleyerek ilgili alandaki ana temaları belirlemektir. Bibliyometrik analiz gerçekleştirmek için R dilini kullanan ve R-aracı olarak bilinen Bibliometrix yazılımı kullanılmıştır. Analiz içerisinde mevcut yapıyı ve eğilimleri ortaya çıkarmak için birlikte oluşum analizi, anahtar kelime birlikteliği ve tematik haritalama dahil olmak üzere çeşitli bibliyometrik tekniklere başvurulmuştur. Çalışmanın bulguları; teknolojik gelişmelere, sürdürülebilirliğe ve insan odaklı yaklaşımlara önemli ölçüde vurgu yapılan yayınlarda hızlı bir büyüme olduğunu ortaya koymaktadır. Çalışmanın sonunda Tedarik Zinciri 5.0 alanına yönelik gelecekteki araştırma fikirleri; tedarik zinciri esnekliği ve çevikliği, tedarik zincirlerinde insan merkezli yaklaşımlar, Tedarik Zinciri 5.0'ın gelişmekte olan ekonomilere etkileri, sürdürülebilir Tedarik Zinciri 5.0 başlıkları altında sunulmuştur. Bu çalışmanın temel katkıları; Tedarik Zinciri 5.0 ile ilgili yazının mevcut durumuna ilişkin ayrıntılı bir genel bakış sunulması ve araştırma boşluklarını vurgulayarak alanı ilerletmek için gelecek çalışma konularının önerilmesidir

**Anahtar Kelimeler:** Tedarik Zinciri, Endüstri 5.0, Endüstri 4.0, Tedarik Zinciri 5.0, Bibliyometrik Analiz, Dijitalleşme

## INTRODUCTION

Studies on industrial revolutions have become a significant element of the literature in the last decades. Industry 4.0 (I4.0) research has led most operations management and engineering studies. However, in the last couple of years, another transition has come to the forefront, and Industry 5.0 (I5.0) has started to be discussed by scholars, where human well-being is at the center (Leng et al., 2022). The transition from I4.0 to I5.0 represents a significant evolution in industrial practices, focusing on integrating advanced technologies with human-centric approaches (Xu et al., 2021). This transition is related to digitalizing the manufacturing systems and operations, changing the way of doing jobs, and approaching humans (Destouet et al., 2023). Therefore, the altering system affects the entire supply chain and its stakeholders.

From this point of view, Supply Chain 5.0 (SC 5.0) represents a paradigm shift in logistics and operations management. Building upon the foundations laid by its predecessors, SC 5.0 integrates cutting-edge technologies, data-driven insights, and collaborative frameworks to create a dynamic and responsive ecosystem (Frederico, 2021). In this digital transformation era, SC 5.0 emerges as a transformative force, redefining how businesses conceive, execute, and optimize their supply chain processes.

I5.0 and SC 5.0 are interconnected yet distinct paradigms within the industrial and supply chain landscapes, emphasizing different focal points and objectives. Industry 5.0 represents the evolution of industrial practices, building upon the automation and digitization foundations of Industry 4.0. It highlights the reintegration of human intelligence into manufacturing processes, fostering collaboration between humans and advanced technologies (Rehman & Umar, 2025). This human-centric approach aims to enhance customization, sustainability, and resilience in production systems, ensuring that technological advancements align with societal and environmental values. SC 5.0, on the other hand, extends the principles of I5.0 into supply chain management. It focuses on creating supply chains that are not only efficient and technologically advanced but also human-centric and sustainable (Kumar & Sigh, 2025). SC 5.0 leverages the collaborative potential of human expertise and digital systems across the supply chains. This approach ensures supply chains can swiftly adapt to market changes and disruptions while maintaining a commitment to environmental and social responsibility. In summary, while I5.0 focuses on transforming manufacturing by integrating human-centric values with advanced technologies, SC 5.0 applies these principles to the broader supply chain context.

At its core, SC 5.0 embodies the convergence of physical and digital realms, leveraging advancements in automation, artificial intelligence (AI), Internet of Things (IoT), blockchain, and machine learning to drive efficiency, transparency, and agility across the entire supply chain network (Varriela et al., 2023). From this point of view, one of the defining features of SC 5.0 is its emphasis on real-time visibility and predictive analytics.

In addition to its technological advancements, human-centric approaches are the most definitive feature of the I5.0, where supply chains are affected by this from the stakeholder point of view (Fornasiero & Zangiacomi. 2021). SC 5.0 fosters collaboration and co-creation among stakeholders across the supply chain ecosystem. It also focuses on sustainability and ethical sourcing. Organizations increasingly integrate sustainability metrics into their supply chain strategies in response to growing consumer demand for transparency and corporate responsibility. Furthermore, SC 5.0 strongly emphasizes talent development and organizational culture (Modgil et al., 2023). Recognizing the critical role of human capital in driving innovation and transformation, organizations are investing in upskilling their workforce, fostering a culture of continuous learning and adaptability, and promoting cross-functional collaboration.

Although there is increasing attention on the SC 5.0 research field (i.e., Chowdhury et al., 2022; Frederico, 2021; Villar et al., 2023), studies that aim to conduct knowledge mapping of the current literature are still limited. Therefore, it is essential to encourage future studies on SC 5.0. From this point of view, this study aims to conduct a literature review and bibliometric analysis of SC 5.0 research to summarize current trends and propose future research ideas to improve the field.

In this regard, bibliometric analysis is a quantitative method used to analyze patterns and trends within academic literature on SC 5.0, and this study uses the Bibliometrix-R tool for conducting bibliometric analysis. The results of this study are expected to be beneficial for scholars looking for a systematic review that focuses on recent studies and potential future research directions.

This study is divided into five sections. After the introduction, section 2 presents the literature review on SC 5.0. Section 3 includes the research methodology. Section 4 presents the results, and finally, section 5 covers the proposed research directions and the conclusion.

## I. THE CONCEPT OF SUPPLY CHAIN 5.0

The evolution from Supply Chain 1.0 to Supply Chain 5.0 reflects significant transformations in logistics and operations, driven by technological advancements and shifting business priorities. Boudouaia et al. (2024) summarized the development of supply chains from 1.0 to 5.0: Supply Chain 1.0, focused on internal optimization with manual processes, where technology is limited. In Supply Chain 2.0 basic software tools and computers were introduced. On the other hand, Enterprise Resource Planning (ERP), digitalization of processes and mass automation are the key concepts of Supply Chain 3.0. The transition to Supply Chain 4.0 aligned with the I4.0, incorporating technologies, and finally, SC5.0 emphasizes a human-centric perspective, where mass customization and sustainability concerns harmonized with digital technologies.

As mentioned, SC 5.0 is an approach in which traditional supply chain management is integrated with digital technologies, and data analytics is used more widely. This approach aims to make the process from product production to consumption more effective and efficient. Although it is a relatively new topic, the literature review shows that authors present studies from different perspectives. Table 1 presents the review summary.

**TABLE 1 |** Review Summary

| Author(s) | Method | Aim of the Study |
|---|---|---|
| Frederico (2021) | Systematic Literature Review | Presenting the meaning of I5.0 for supply chains. |
| Chowdhury et al. (2022) | Systematic Literature Review | Discussing the barriers in the transition to SC 5.0 |
| Lazzaris et al. (2022) | Systematic Literature Review | Proposing a guideline for supply chain quality management in I5.0 |
| Yuan et al. (2022) | Event Study Method | Examining the supply chains for innovation and stakeholder value concepts under I4.0 and 5.0 |
| Ahmed et al. (2023) | Bayesian Best-Worst Method | Identifying and assessing AI-based necessities of I5.0 for resilient supply chains in a post-pandemic environment. |
| Agrawal et al. (2023) | Systematic Literature Review | Revealing the gaps in I5.0 in the context of supply chains. |
| Dwivedi et al. (2023) | Modified TISM and MICMAC | Identifying and analyzing drivers of I5.0 and circular supply chains. |
| Karmaker et al. (2023) | Best-Worst Method and ISM | Understanding the challenges of I5.0 in a post-pandemic supply chain environment. |
| Villar et al. (2023) | Bibliometric Analysis | Investigating the effects of I5.0 on supply chains in the post-pandemic world. |
| Andres et al. (2024) | Systematic Literature Review | Analyzing concepts of Logistics 5.0 within supply chain management. |
| Boudouaia et al. (2024) | Desk Research | Exploring the SC 5.0 concepts by considering challenges and perspectives. |
| Covaci (2023) | Decentralized Multi-parameter Model | Proposing a multi-parameter decentralized model for SC 5.0 |
| Hsu et al. (2024) | QFD and Hybrid MCDM | Investigating the association among sustainable supply chains, resilience, and I5.0. |
| Jamil et al. (2024) | Structural Equation Modelling | Presenting a theoretical model for I5.0 and sustainable supply chains. |

As seen in Table 1., Frederico (2021) focused on presenting the meaning of the I5.0 from the supply chain point of view. As a result of its systematic review, although the literature is limited, it offers

enlightening and new concepts about I5.0 in the context of supply chain. Moreover, Chowdhury et al. (2022) studied the transition from supply chain 4.0 to SC 5.0 by addressing the significant barriers to existing industrial systems. Furthermore, Lazzaris et al. (2022) found that I5.0 is critical for a more sustainable, resilient, and human-oriented industry, especially towards achieving the EU's 2030 goals. However, it is important to note how supply chain quality management frameworks can cope with the challenges of I5.0. In this study, they aimed to explain how the I5.0 concepts of supply chain, performance, and quality management are related.

In addition, according to Agrawal et al. (2024), the primary purpose of their study is to examine how I5.0 technologies are influenced by disruptive singularities such as pandemics, wars, or climate change in supply chains. In their study, they offer research ideas that will support further exploration of adopting I5.0 technologies to overcome disruptions in supply chains. Moreover, Andres et al. (2024) examined effective technologies that support I4.0 and I5.0 in supply chain logistics. Additionally, the study aims to identify research gaps to direct future studies for I4.0 technologies.

Applying hybrid MCDM (Multi-Criteria Decision Making) methods is the second most common in the SC 5.0-related research. Hybrid MCDM methods combine different MCDM approaches to analyze complex decision-making processes by considering multiple criteria, thus carefully considering complex decision-making processes, especially SC 5.0. For example, Yuan et al. (2022) aimed to popularize the application of core competency theory in supply chain operations to investigate the relationship between Supply Chain Innovation and stock market reaction in the context of I4.0 and I5.0 and by elevating SCI to the level of corporate core competence.

Moreover, Ahmed et al. (2023) focused on the evaluation of the effects of the COVID-19 pandemic, the use of artificial intelligence technologies under the concept of I5.0 to increase supply chain resilience with an integrated approach such as Pareto analysis, Bayesian approach, and Best-Worst Method (BWM). Additionally, Dwivedi et al. (2023) argue that there is a solid conceptual relationship between I5.0 and sustainable supply chains. This study creates a theoretical model that emphasizes the factors affecting I5.0 or Sustainable Supply Chain Applications by integrating theoretical frameworks focused on production, supply chain, and information systems.

In addition, Karmaker et al. (2023) aimed to determine the challenges of implementing I5.0 in supply chains. They used the Best-Worst Method and the Interpretive Structural Modelling method. They mainly focused on these challenges to understand the impact of supply chain disruptions during COVID-19. Moreover, Jamil et al. (2024) focused on examining essential concepts such as I5.0 and Sustainable Supply Chains, which reshape the functioning of modern businesses.

According to Hsu et al. (2024), this study examines the impact of I5.0 drivers in reducing sustainable supply chain risks. Reducing sustainable supply chain risks is critical due to the lack of existing research on using I5.0 to increase supply chain resilience.

A different methodological approach presented by Covaci (2023) addresses the challenge of establishing optimal supply chains in decentralized systems while enabling supply chain participants to focus on their goals. The proposed model enables optimal performance to be achieved by participants coordinating by agreeing on a set of parameters. In this context, the Decentralized Multi-Parameter Model method applied in the study approaches the supply chain creation problem as a benefit maximization problem. It makes the decision-making process more realistic by using utility functions.

At the same time, Boudouaia et al. (2024) conducted desk research to explore the emerging paradigms of SC 5.0 and systematically analyze the SC 5.0 literature, identifying the main trends of studies in this field and providing insights into future trends.

In addition, although bibliometric analysis is critical in terms of conducting analysis to understand the scope and depth of the literature in the field, as a result of the literature review, only one study containing bibliometric analysis specifically for SC 5.0 was found. Villar et al. (2023) aim to contribute to conceptualizing the concept of "supply chain 5.0" by conducting bibliometric analysis. For this purpose, the effects of I5.0 in the supply chain field between 2016 and 2022 are examined.

From another point of view, generally, sustainability is one of the most discussed topics in these studies because supply chain 5.0 and sustainability are two concepts that are highly related. While SC 5.0 allows businesses to digitize and optimize supply chain processes, sustainability is essential for long-term success, especially social impacts. Therefore, sustainability-related studies in SC 5.0 is a promising topic, and mentioned in many studies such as Dwivedi et al. (2023), Karmaker et al. (2023), Jamil et al. (2023).

Based on the results of the literature research, SC 5.0 is a relatively new field with much promise. On the other hand, it is clear that post-pandemic research is limited to theoretical foundations and is the main focus of the present study. This draws attention to a significant gap in the literature by exposing the need for more thorough, prospective studies on SC 5.0. Closing this gap is essential to fully realize the potential of SC 5.0 and progress in this field. As a result, more studies on SC 5.0 are needed to fill in research gaps and improve its usefulness in real-world settings. However, there is a good chance that more thorough research will be conducted in this area. Bibliometric analyses and studies based on real-world examples are crucial for deepening and advancing research in this field. In this way, the effects of SC 5.0 in the business world can be better understood, and it can be essential in developing holistic approaches and strategies for the future.

## II. RESEARCH METHODOLOGY

Bibliometric analysis is a powerful tool for gaining insights into the academic landscape and tracking research trends. By leveraging bibliometric techniques, researchers can enhance their understanding of complex phenomena, foster interdisciplinary collaborations, and contribute to advancing knowledge in their respective domains. It is a well-established method of analyzing publications in an area, guiding researchers to understand better the field (Borregab-Alvarado et al., 2020). Bibliometric mapping is a significant research area in bibliometrics. It employs diverse techniques like citation analysis, bibliographic coupling, and co-occurrence analysis to measure, quantify, and visualize the progress of a particular field or area. It allows for the generation of knowledge through data analysis. (Gaviria-Marin et al., 2019). The general bibliometric mapping process is defined as study design, data collection, analysis of data, visualization of data, and interpretation by Aria and Cuccurullo (2017).

Different software can be used to conduct bibliometric analysis, such as Citespace, Vosviewer, Bibexcel, etc. (Büyükkıdık, 2022). Bibliometrix, an R-tool, uses the R programming language and requires a freely available online interface called the "biblioshiny" package. The main advantage of Bibliometrics is that analyzing and mapping bibliographic data is possible simultaneously (Derviş, 2019). This study uses Bibliometrix to conduct a bibliographic analysis of SC 5.0 research.

This study uses a 5-stage workflow to conduct bibliometric analysis on SC 5.0 research. These stages are presented in Figure 1.

**FIGURE 1 |** Process of the Bibliometric Analysis
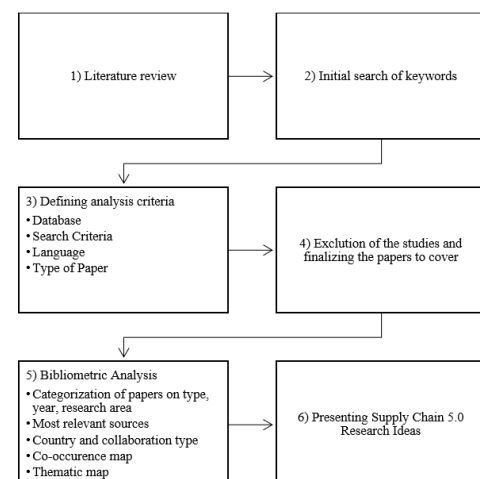
The process starts with a literature review of the field without any limitations on databases. This part aims to have a common understanding of the field regarding keywords without making a quantitative analysis. The second stage consists of the initial keyword search to examine the current knowledge in the field. The third stage defines the analysis criteria, such as database, keywords to search, language limitations, and the type of the paper. When SCOPUS and Web of Science (WoS) are analyzed, it is revealed that SCOPUS coverage is broader. Therefore, only the SCOPUS database is examined for SC 5.0 research. Search criteria are defined as conducting a keyword search using the title and keywords of the papers, and the papers written in English are considered. Furthermore, only "editorial" papers are excluded from the study.

The fourth stage includes excluding the studies and finalizing the papers considered for the bibliometric analysis. Moreover, the fifth stage includes conducting a bibliometric analysis. To use the Bibliometrix R-tool, raw data set from the SCOPUS database is downloaded and analyzed using the Biblioshiny package. Before using the bibliometric tool, SCOPUS outputs are also analyzed. The tool derives the most relevant sources, country and collaboration type, co-occurrence map, and thematic map in the bibliometric analysis part. The final stage presents SC 5.0 research ideas in light of the results of bibliometric analysis.

## III. RESULTS

At the beginning of the analysis, an abstract search criterion was also used during the search. However, after careful consideration of the studies found, it is realized that although there are studies with "Industry 5.0" and "supply chain" words in the abstracts, those studies do not cover the concept of supply chain transformation in I5.0. Therefore, the search is limited to "title" and "keywords" to consider studies directly related to SC 5.0 concepts.

The search criteria for the SCOPUS database are as follows:

( TITLE ( "INDUSTRY 5.0" AND "SUPPLY CHAIN" ) OR TITLE ( "SUPPLY CHAIN 5.0" ) OR KEY ( "INDUSTRY 5.0" AND "SUPPLY CHAIN" ) OR KEY ( "SUPPLY CHAIN 5.0" ) )

After the initial search, 89 publications were revealed. According to the search criteria presented in the previous section, 2 "editorials" were excluded, and an analysis was conducted with 87 papers. Studies that were published or articles in the press stage by the end of April 2024 are included in the analysis. All the studies were in English; therefore, there were no eliminations based on the language criteria.

The first study was published in 2019, so the analysis covers 2019 to 2024. Figure 2 presents the yearly distribution of the publications.

**FIGURE 2 |** Number of Documents per Year
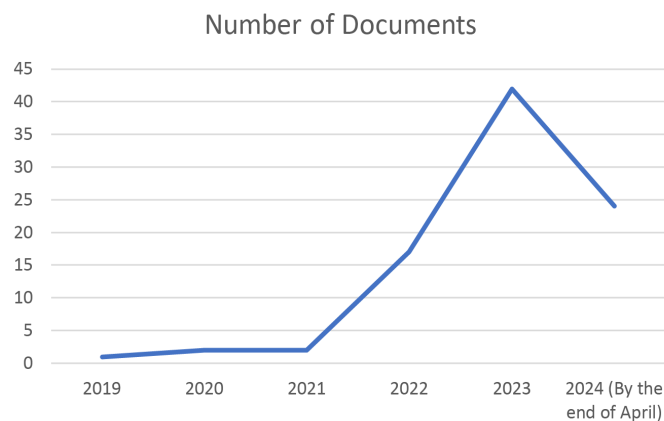


As can be seen from Figure 2, there has been a significant increase in attention paid to the SC 5.0 area. Especially after 2021, a sharp rise was observed, with the number of publications increasing from 2 to 17 and then 42 between 2021 and 2023. Although the analysis only covered publications by the end of April 2024, there have already been 24 papers published in the field. Based on the current trend, the number of publications will increase in the upcoming period.

The second categorization is based on the document types. As mentioned earlier, articles, conference papers, review papers, book

chapters, and books are included in the analysis. Figure 3 presents a graph showing the distribution according to the document type.

**FIGURE 3 |** Types of Documents
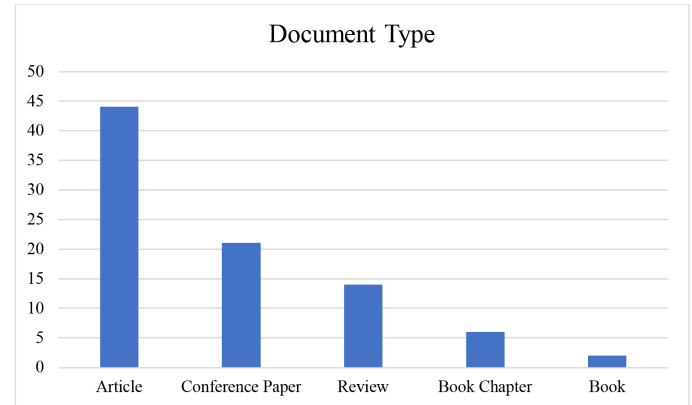


According to the graph presented in Figure 3, most publications are journal articles, followed by conference papers and review papers. On the other hand, there are only a few books and book chapters in the field, which could be understandable in terms of publishing books that require more background knowledge, and SC 5.0 is still an emerging concept.

The third categorization in the bibliometric analysis is conducted for the subject area. SCOPUS database subject areas are considered. The division of studies is presented in Figure 4.

**FIGURE 4 |** Categorization of Subject Areas
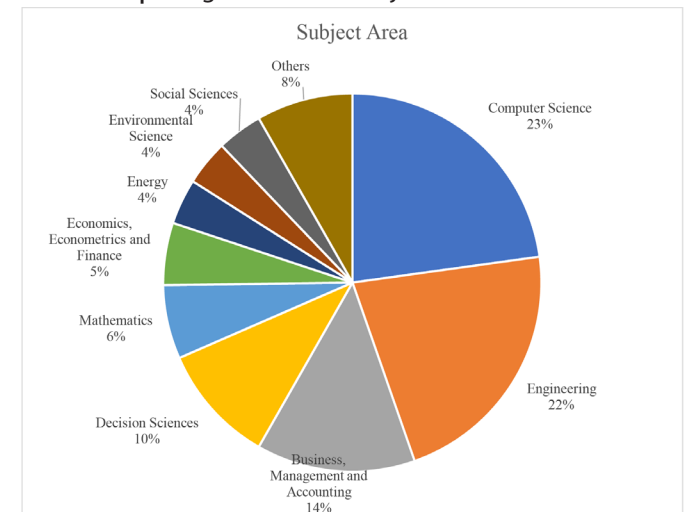


In Figure 4, computer science and engineering studies are at the forefront, covering 45% of the total research. Business, management, and accounting studies follow them, with 15%, and decision science with 10%. In the categorization, "others" includes subject areas with three or fewer studies (Agricultural and Biological Sciences, Chemical Engineering, Materials Science, Physics and Astronomy, Biochemistry, Genetics and Molecular Biology, Chemistry, Earth and Planetary Sciences, Psychology).

After presenting the categorization derived from the SCOPUS database search outputs, different analyses were conducted using Bibliometrix R-tool's package Biblioshiny. The first analysis was made for more relevant sources that published SC 5.0 researchers eligible for the search criteria. It is revealed that "Information Systems Frontiers" has the highest publication rate in SC 5.0-related research. Also, recent conferences, such as "IEEE International Conference on Industrial Engineering and Engineering Management" published papers in the field.

When the studies are investigated in terms of global division and collaboration type, Bibliometrix R-toll allows an analysis of the corresponding author's countries by categorizing the studies as single-

country publications (SCP) and multiple-country publications (MCP) in terms of the collaboration type. This categorization is presented in Figure 5.

**FIGURE 5 |** Countries and Collaboration Type of Corresponding Authors
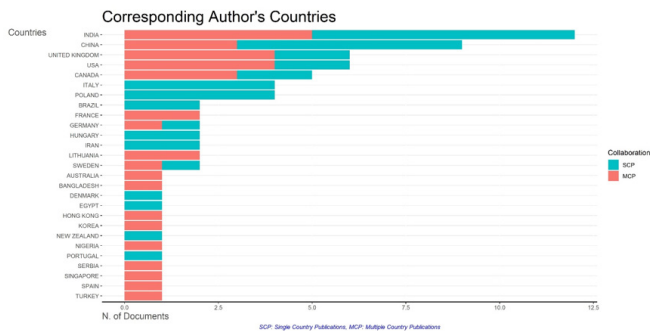


According to Figure 5, India has the highest number of corresponding authors, where both SVP and MCP collaborations were conducted. India follows China. When the results are analyzed for Türkiye, only a single publication appears to be conducted.

Furthermore, a compelling feature of the bibliometric analysis is providing network maps that include co-occurrence analysis of the keywords. This led the researchers to categorize critical concepts in clusters. To create logical co-occurrence maps via the Bibliometrix-R tool, the first stage combines the synonyms (i.e. blockchain and blockchain, I4.0 and fourth industrial revolution, etc.) and eliminates unnecessary words or syntax errors. After making these selections and arrangements, the co-occurrence network map of keywords is presented in Figure 6 in this study. This co-occurrence network map helps understand the current tendencies in the research field and visualizes the current knowledge.

**FIGURE 6 |** Co-occurrence Map for Keyword Plus
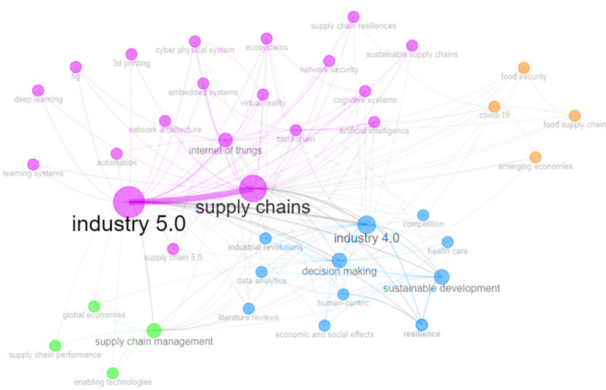


In Figure 6, a co-occurrence network map for keywords is presented. According to the Figure, four main clusters appear in purple, blue, orange, and green. The size of the clusters varies based on the coverage and the relationship between concepts. As expected, I5.0 and supply chain are the dominant keywords in the map and are revealed in the purple cluster. When the features of clusters are analyzed, it is seen that the largest purple cluster includes mostly digital technologies and methodological approaches.

On the other hand, I4.0, decision-making, and sustainable development stand out in the blue cluster, and more conceptual terms such as industrial revolution, resilience, and human-centric come to the forefront. Furthermore, the orange cluster only includes concepts related to food supply chains, COVID-19, and emerging economies. This might be because some specific studies focus on these concepts in the context of SC 5.0. Finally, supply chain management, performance, global economies, and enabling technologies appear in the green cluster.

Another network approach derived from the Bibliometrix R-tool

is the thematic map, which categorizes concepts according to their relevance and degree of development relative to the main concept. The thematic map has four main categorizations: "niche themes," "motor themes," "emerging or declining themes," and "basic themes." The thematic map for this study is presented in Figure 7.

**FIGURE 7 |** Thematic Map for Supply Chain 5.0 Research
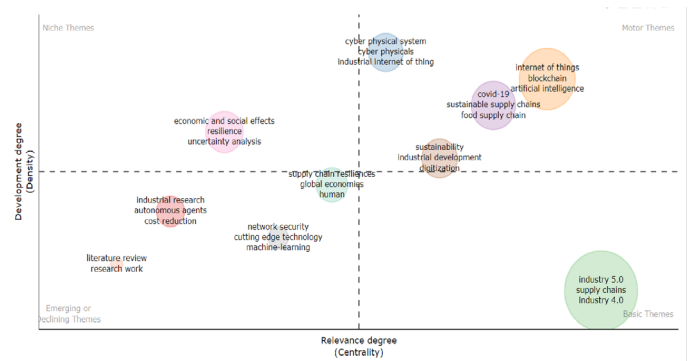


The thematic map (Figure 7) reveals that the concepts of I5.0, supply chains, and I4.0 are grouped and appear in the basic themes area. These concepts are the core of SC 5.0 research. On the other hand, motor themes include four groups with concepts such as cyber-physical systems, the Internet of things, sustainability, and COVID-19. A single group appeared in the niche themes area with keywords such as economic and social effects, resilience, and uncertainty analysis. Finally, the emerging or declining themes revealed four groups with different concepts. Due to the nature of this research, this area includes the emerging themes since SC 5.0 research is in the developing stage. The findings in the thematic map also guide future research ideas, which are presented in the following section.

## FUTURE RESEARCH AND CONCLUSION

Although there is increasing attention on SC 5.0 research, there is great potential to develop new research and strengthen the SC 5.0 field. In this study, the author considers the results of the bibliometric analysis to define 5 research themes. These themes are warehousing 5.0, supply chain resilience and agility, human-centric approaches in supply chains, impacts of SC 5.0 in emerging economies, and sustainable SC 5.0 concepts. In the following paragraphs, these future research ideas are presented respectively.

*Warehousing 5.0:* Warehousing is a critical element of supply chains, and variations through SC 5.0 directly affect warehousing operations. It is expected that warehousing 5.0 would be beneficial for all stakeholders in the supply chains (Smith, 2021). Due to its strong relationships with SC 5.0, it is essential to extend the research field of warehousing 5.0. Future research may propose new models for integrating intelligent technologies and warehouse workforce. Focusing on human-machine interaction with a human-centric perspective could be another research topic. Furthermore, more operational studies can be conducted by integrating SC 5.0 into warehouse operations, such as receiving, sorting, picking, packing, and storing.

*Supply Chain Agility and Resilience:* Supply chain agility focuses on understanding and responding to market changes (Oliveira-Dias et al., 2022). Therefore, it is very crucial for organizations when the current dynamic market environments are considered. Due to rapid changes caused by digital transformations and customer demand, supply chain resilience can only be possible with an agile process. In this sense, SC 5.0 is expected to be useful for agile and resilient supply chains. Future research can focus on technology integration to enhance agility and resilience, and human-centric collaborations and flexible network designs can be made. Furthermore, studies can integrate post-pandemic approaches regarding agility and resilience and SC 5.0.

*Impacts of Supply Chain 5.0 in Emerging Economies:* Digitalization is transforming the different sizes of economies and societies (Ali, 2020). The impacts of industrial revolutions are different for developed and emerging economies, and it is also vital to embrace emerging economies and support their transition. Triggers such as advanced

technologies are sourced by developed economies, where financial power is the definitive element. Therefore, research in supply 5.0 in emerging economies can provide valuable insights into the unique challenges and opportunities emerging economies face in adopting SC 5.0. For instance, researchers can investigate the challenges and barriers to SC 5.0 transition in emerging economies. Technology adoption models can be designed for emerging economies to help understand and apply SC 5.0. Also, the economic and social impacts of SC 5.0 on emerging economies can be investigated in terms of the need for new job profiles and the education system consequently.

*Human-Centric Approaches in Supply Chains:* With the increasingly complex structure of the supply chain, not only efficiency and cost optimization but also a human-centric perspective has begun to come to the fore. The human-centric approach aims to be sensitive to the needs of employees and supply chain stakeholders and to increase their satisfaction and welfare. SC 5.0 highlights digitalization, automation, data integration, and the integration of the human factor into supply chain processes. This approach strengthens human collaboration, effective communication, and cooperation with artificial intelligence-supported decision-making systems (Villar et al., 2024). Among future research themes, developing strategies to increase the welfare of stakeholders through supply chains from the SC 5.0 perspective is an important issue. In addition, to align their profitability and growth targets with sustainability and social responsibility principles, businesses must work on issues that integrate sustainability and ethical values in SC 5.0 operations. Research on how cultural diversity and different perspectives can be implemented from a SC 5.0 perspective is highly critical. These studies strengthen cultural understanding in the global business world by supporting the integration of different cultural perspectives into product and service development processes. Managing cultural diversity and increasing cultural awareness through SC 5.0 applications positively contribute to supply chain management's effectiveness and sustainability. These research themes are essential to a more sustainable, efficient, and human-centric future.

*Sustainable Supply Chain 5.0 Concepts:* Supply chain sustainability and transformation through new industrial revolutions are mutually reinforcing topics that should be evaluated together (Dwivedi et al., 2023). With SC 5.0, positioning humans in the digitalized system is changing; therefore, social sustainability is expected to be at the forefront. In future research on sustainable SC 5.0, circular economy models can first be presented to explore how circular economy principles can be integrated into SC 5.0 to reduce waste and improve resource efficiency. Furthermore, another topic could be investigating the social dimensions of sustainability within supply chains, focusing on fair labor practices, community impact, and employee well-being. The impacts of governmental policies and regulations on the sustainability of supply chains can be investigated from a social point of view. Last but not least, the relationship between customer behavior and the adoption of sustainable practices in supply chains can be examined.

These research themes can also be used to develop practical implementations. To start with, warehousing 5.0 integrates smart automation, AI-driven inventory management, and human-robot collaboration to create adaptive, efficient, and worker-friendly distribution hubs. More sustainable operations could be possible by embracing SC5.0 approaches in warehouses, which would have positive impacts on all stakeholders. To enhance supply chain resilience and agility, companies can implement digital twins, predictive analytics, and blockchain for greater visibility and risk mitigation. These technologies are useful, especially in dealing with unexpected internal or external events that affect supply chains. Human-centric approaches should focus on collaborative robotics, worker upskilling, and well-being metrics to create safer, more adaptive workplaces. The applicability of these systems requires top management support and major changes in the infrastructure. Moreover, in emerging economies, decentralized manufacturing, AI-driven market access for SMEs, and affordable automation can drive supply chain modernization. However, it is also crucial to educate the potential workforce; therefore, collaboration with higher education institutions is needed to balance the needs of new advanced systems and the knowledge that has been created during education. Finally, sustainability can be achieved through circular

economy models, AI-driven carbon footprint optimization, and green energy-powered warehousing, reducing environmental impact while maintaining efficiency.

However, limitations such as high implementation costs, data security concerns, and workforce adaptation to new technologies remain significant. While collaborative robots enhance efficiency, their widespread adoption requires investment in training programs to support human-machine collaboration. Moreover, the shift towards sustainable supply chains requires businesses to redesign their logistics networks, considering carbon emissions and circular economy principles. Therefore, while SC5.0 offers transformative potential, its successful implementation depends on overcoming technological, financial, and organizational barriers.

This future research agenda can be extended as time passes and new technologies and approaches are introduced. This study aimed to present the current knowledge in SC 5.0 by conducting a bibliometric analysis. Understanding current knowledge and tendencies systematically may lead future research to develop in the research area. The main limitation of this research is caused by the dynamic and rapidly developing environment, where SC 5.0 is a rapidly evolving area. Bibliometric analysis might not capture the latest trends and emerging concepts due to the time lag in publication and indexing. However, efforts have been made in this research and are expected to be beneficial, especially for scholars who want to work in this field, by presenting a knowledge map and conducting bibliometric analysis on SC 5.0.

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