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Visual Analysis of Smart Supply Chain Based on CiteSpace

Lei Song, Wenshuo Xiang*

University of Jinan, Jinan 250022, China

**Author to whom correspondence should be addressed.*

Abstract: Under the trend of economic globalization, the importance of supply chains has gradually become prominent, especially with the transformation and upgrading of China's industrial chains in recent years. Supply chain transformation has emerged as a significant focus of current academic research, and the construction of smart supply chains represents an inevitable development trend. This paper utilizes 1,051 research articles on smart supply chains published in core journals on China National Knowledge Infrastructure (CNKI) from 2014 to 2024 as the data source. It analyzes the literature data using CiteSpace software, visually exploring and revealing the frontiers and hotspots of domestic research on smart supply chains. The data analysis reveals that academic research in this field is at a stage of steady and healthy development. Domestic research trends include the cooperative mechanisms of smart supply chains in manufacturing, the operational mechanisms of smart supply chains in agriculture, and systematic research on influencing factors of smart supply chains.

Keywords: Bibliometrics; CiteSpace; Smart supply chain; Visual analysis

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1. Introduction

China's logistics market has gradually expanded in recent years and has now become the largest logistics market globally. The "Guiding Opinions on Actively Promoting Innovation and Application of Supply Chains" issued by the General Office of the State Council in October 2017 points out that it is necessary to center on improving development quality and efficiency, achieve deep integration among supply chains, the Internet, and the Internet of Things, effectively integrate various resources and elements, and build a smart supply chain system supported by big data, featuring networked sharing, and intelligent collaboration. Against this backdrop, strengthening logistics construction and building an independent and complete supply chain system are of great significance for establishing a new development phase, implementing new development concepts, constructing a new development paradigm, and promoting high-quality development. With the support of national policies and the continuous advancement of reforms, smart supply chain research has garnered significant attention from scholars. To better sort out the research context of smart supply chains, this study employs the CiteSpace analysis tool to conduct a visual analysis of related research on smart supply chains in the CNKI (China National Knowledge Infrastructure)

core database. By synthesizing keyword co-occurrence and clustering, this study analyzes the hotspots and development trends of domestic smart supply chain research.

2. Data sources and research tools

2.1. Data sources

For this study, core journals included in CNKI (such as CSSCI, CSSCD, etc.) were used as the data source, with a search time range set from 2014 to 2024. The search was conducted using precise keywords such as "smart supply chain" or "big data." A total of 1,188 research articles related to smart supply chains were retrieved. After manually excluding irrelevant documents such as conference announcements, authorless documents, interview reports, etc., 1,051 document data were obtained. These data were finally exported and saved in CNKI's Refworks format [1].

2.2. Research Tools

CiteSpace is a data visualization analysis tool dedicated to academic literature analysis, capable of detecting hot topics and their evolutionary characteristics within a discipline or field [2]. The specific steps for analyzing smart supply chain research data using CiteSpace software are as follows: Firstly, the full records and cited references of the 1,051 articles were exported in plain text format, converted, and saved. After importing the saved text data, the panel operation parameters were selected, with "Time Slicing" set to "2014 JAN - 2024 DEC" and "Years Per Slice" set to "1." Through the above analysis, the current research status in the field of smart supply chains was summarized. By selecting "Keyword" under "Node Types," the obtained knowledge map could display the research hotspots in the analyzed field, providing a basis for grasping valuable development directions and research trends.

3. Temporal and spatial knowledge map and analysis of smart supply chain research

3.1. Temporal distribution map of smart supply chain themes

The annual number of publications in a particular field can reflect, to a certain extent, the academic research level and overall development trend of that field. Furthermore, statistical analysis of the annual number of publications in a field helps to objectively understand and predict the research hotspots and development trends in that field [3]. To delve deeper into the knowledge output in the domestic field of smart supply chain research, this study conducted a statistical analysis of research articles related to smart supply chains published in core journals of CNKI from 2014 to 2024. The resulting trend chart of the annual number of publications in the field of smart supply chain research is shown in **Figure 1**.

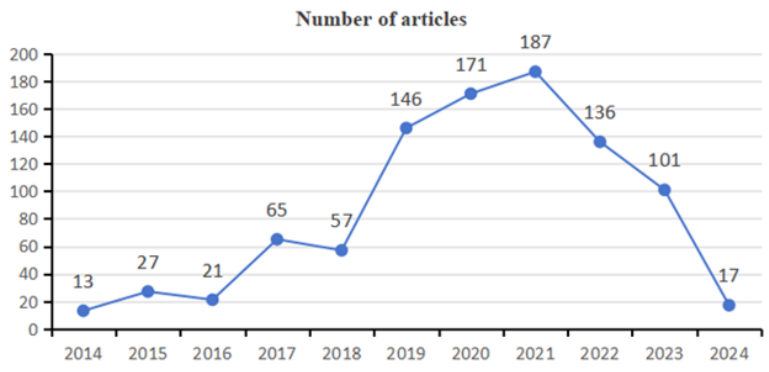

Figure 1. Statistics of annual literature on smart supply chain.

As can be seen from **Figure 1**, research on smart supply chains is currently in a rapid development phase, with a significant focus on big data, artificial intelligence, and smart logistics, among other areas [4]. Based on a growth model, the development of smart supply chain research can be divided into two stages: from 2014 to 2018 was the exploratory phase of smart supply chain research, with an average annual publication volume of less than 100 articles domestically and internationally before 2019. From 2019 to 2024 is the rapid growth phase, during which the domestic publication volume has increased, averaging more than 100 articles per year. Overall, the number of publications on smart supply chain research over the years has shown a steady upward trend. Even though the COVID-19 pandemic has affected recent years, there has been no decrease in the number of publications; instead, there has been a significant increase. This indicates that more scholars hold a high level of enthusiasm for research and have begun to prioritize the smartening of supply chains. Therefore, there is a strong possibility of continued growth in related fields in the future.

3.2. Spatial distribution map of disciplines in smart supply chain research

To understand the current high-productivity academic groups and institutions in the field of smart supply chain research, this study counted the number of papers published by various research institutions in this field. The top five institutions with the highest number of papers are Tianjin University, Renmin University of China, Jiangsu University, Jiangxi University of Science and Technology, and China Federation of Logistics and Purchasing. This indicates that these five institutions possess greater research depth and potential in the field of smart supply chain research. Among them, Tianjin University, Nankai University, Northeastern University, Hunan Business University, and the National Natural Science Foundation of China have formed small-scale cooperative research groups [5]. The top 15 research institutions have all published more than 5 papers, demonstrating that smart supply chain research has received widespread attention from academic groups and institutions in recent years and has achieved certain research results.

Research institutions are the main force in discipline research and undertake many scientific research tasks. In recent years, a large number of research institutions focused on smart supply chains have emerged. To understand the cooperation between different research institutions, CiteSpace software was used, and "institution" (research institution) was selected as the keyword in the node type box to generate a map of institutions involved in smart supply chain research. The nodes represent institution names, the size of the nodes indicates the number of published papers, the font size of the labels represents the level of centrality, and line segments connect cooperating institutions [6]. The cooperation network diagram of smart supply chain research institutions contains 358 nodes and 106 lines, with a network structure compactness of 0.0016. This indicates that the academic groups engaged in smart supply chain research are relatively dispersed, with limited cooperation and strong cohesion among different research institutions. A cohesive research institution network has yet to be formed.

4. Analysis of hot topics and trends in smart supply chain

4.1. Analysis of research hotspots in smart supply chain

4.1.1. Keyword-based analysis of research hotspots

High-frequency and high-centrality keywords serve as the focal points and essence of articles, reflecting to some extent the hot topics that experts and scholars in the field have concerned over a period of time. By conducting a keyword analysis using CiteSpace, the top 23 high-frequency keywords is obtained, along with a co-occurrence knowledge graph of these keywords, to explore the research hotspots in the field of smart supply chain. Apart from the most central keyword "smart supply chain," terms such as "smart logistics," "Internet of Things (IoT),"

"big data," "smart agriculture," and "blockchain" are located at the center of the graph and closely related to other keywords, indicating their tight integration with supply chain management, logistics, and big data construction.

These keywords represent the popular topics in smart supply chain research. In the co-occurrence network of keywords related to smart supply chain, there are 275 nodes and 149 connections, with a network density of 0.0111. Compared to the knowledge graph of institutional collaborations, it can be observed that the structural compactness of the keyword co-occurrence network has significantly improved, but it remains relatively loose overall. In future scientific research, besides maintaining close cooperation among academic groups, it is also necessary to maintain focus and conduct in-depth research on these topics [7].

Based on the **Table 1** analysis, "smart logistics" is the keyword with the highest frequency of occurrence in smart supply chain literature, primarily because "smart logistics" constitutes a major domain of the subject searched for in this research literature [8]. In addition, other high-frequency keywords mainly include "supply chain," "Internet of Things (IoT)," "big data," "smart agriculture," "new retail," "blockchain," and "Internet Plus." The high-frequency keywords in smart supply chain research topics tend to change over time, reflecting to some extent the shifts in research focus during the in-depth promotion and development of this field. Among all high-frequency keywords, the selected 23 keywords account for 31% of all keywords in smart supply chain research topics, indicating that these selected high-frequency keywords can effectively capture the hot topics in smart supply chain research.

Table 1. Keyword distribution in the research field of smart supply chain (Part)

Rank	Centrality	Word frequency	Key words
1	0.36	106	Smart Logistics
2	0.38	78	Supply Chain
3	0.09	28	Internet of Things
4	0.08	24	Big data
5	0.02	14	Smart agriculture
6	0.03	14	New retail
7	0.02	13	Blockchain
8	0.07	13	Agricultural products
9	0.01	13	Internet+
10	0.04	12	Smart tourism

4.2. Analysis of research hotspots based on keyword clustering

The keyword clustering function of CiteSpace can identify hot topics and development trends in a particular research field [4]. The keyword clustering analysis of the literature data was conducted using CiteSpace software. The clustering analysis yielded a Q-value (modularity value) of 0.5857 and an S-value (average silhouette value) of 0.6949, indicating that the cluster structure divided by clustering is sufficiently significant and the clustering results are convincing. However, the keywords cover a wide range of research fields, making it difficult for them to naturally cluster into tightly connected groups. This diversity may lead to less cohesive clustering results, consequently lowering the Q-value and resulting in a moderate level of significance. A total of 13 clusters were obtained through clustering analysis in the field of smart supply chain research. The clustering analysis revealed that each cluster contains 2 nodes, i.e., 2 keywords. The specific clustering results are shown in **Table 2**.

Table 2. Keyword clustering results

Serial number	Clustering results	Cluster keywords
1	Clustering#1	New retail, smart logistics
2	Clustering#2	Supply chain, big data
3	Clustering#3	Artificial intelligence, smart tourism
4	Clustering#4	Smart agriculture, Internet of Things
5	Clustering#5	Digitization, blockchain
6	Clustering#6	Agricultural products, Internet+
7	Clustering#7	Supply chain visualization, ai prediction
8	Clustering#8	Automated storage, chain finance
9	Clustering#9	Sensor Technology, analytics hub
10	Clustering#10	Data-driven, predictive analytics
11	Clustering#11	Blockchain tracing, green logistics
12	Clustering#12	Data analysis, supply chain resilience
13	Clustering#13	Supply chain networks, supply chain innovation

4.3. Analysis of research frontiers in teacher education disciplines

4.3.1. Analysis of research frontiers based on emerging keywords

Research frontiers refer to a series of emerging dynamic concepts and potential research questions, while emerging vocabulary denotes terms that are frequently cited or appear in relevant literature within a short period [9]. Over a certain timeframe, the scientific issues or themes discussed in a group of literature based on emerging vocabulary can serve as one of the criteria for identifying and predicting research frontiers. In this study, the CiteSpace tool is utilized to analyze and explore sample data related to the field of smart supply chain research, and 13 emerging keywords are identified, as shown in **Table 3**.

Table 3. Emerging keywords in the research field of smart supply chain

Key words	Emergent strength	Start year	End year
Smart logistics	5.85	2014	2018
Internet of Things	3.2	2014	2016
Logistics management	1.28	2014	2015
Smart port	1.5	2015	2018
Mode innovation	1.02	2016	2017
Collaborative Development	1.77	2017	2019
JD.com	1.77	2017	2019
Countermeasures	1.14	2017	2018
Information technology	1.14	2017	2018
Smart manufacturing	1.05	2018	2019
Pandemic	1.7	2020	2021
Smart supply chain	1.54	2020	2021
Development pathway	1.17	2022	2024

5. Conclusion

There are valuable research opportunities in smart supply chain research, and future studies can be conducted from the following three aspects. Firstly, identifying the obstacles to the operation of smart supply chains. Taking corporate smart supply chains as the research object, it is necessary to address the obstacles in the operation of smart supply chains across different industry sectors [10]. Breakthroughs can be sought in areas such as the standardization of data and processes, intellectual property protection, and the cultivation of digital human resources. Secondly, optimizing smart supply chains in specific industries. In addition to smart supply chains in the circulation industry, further efforts should be made to enhance the optimization of smart supply chains in manufacturing, agriculture, and new retail, thereby improving the performance of smart supply chains. Thirdly, studying the evolution of smart supply chain ecosystems. Smart supply chains constitute an ecosystem comprising smart procurement, smart logistics, smart warehousing, and smart distribution. A key driving force within this ecosystem is data resources. Digital twins can enable innovation and integration within smart supply chains. In the context of digital twins, future research will focus on smart supply chain modeling, real-time optimization of smart supply chains, data utilization in smart supply chain collaboration, and the evolution of smart supply chain ecosystems.

Disclosure statement

The authors declare no conflict of interest.

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