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A Bibliometric Analysis of Green Supply Chain Management Based on the Web of Science (WOS) Platform

Ruifeng Gong [1], Jian Xue [1,*], Laijun Zhao [2,3], Oleksandra Zolotova [1], Xiaoqing Ji [1,*] and Yan Xu [1]

[1] School of Economics and Management, Shaanxi University of Science and Technology, Xi'an 710021, China; 13107214247@163.com (R.G.); Z.aleksandra@mail.ru (O.Z.); 15029883270@163.com (Y.X.)
[2] Sino-US Global Logistics Institute, Shanghai Jiao Tong University,1954 Huashan Rd., Shanghai 200030, China; ljzhao70@sjtu.edu.cn
[3] Antai College of Economics and Management, Shanghai Jiao Tong University, 1954 Huashan Rd., Shanghai 200030, China
* Correspondence: xuejian@sust.edu.cn (J.X.); m18292088518@163.com (X.J.)

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Abstract: To analyse the research progress and frontier dynamics of green supply chain management, this paper uses Web of Science's citation database to search and filter related documents from 2007–2018. A total of 1391 articles were obtained. On this basis, a bibliometric analysis method was utilized to study the literature characteristics and research hotspots of green supply chain management research. Our results show the following: (1) The current amount of published literature on the field of green supply chain management is exponentially increasing. Research on green supply chain management tended to develop after 2013. (2) The current research on green supply chain management has not formed a core author group and among the literatures on green supply chain management, only a few authors reported some influential literatures. (3) It can be seen from the comprehensive average citation frequency and the number of publications that Hong Kong Polytechnic University, University of Southern Denmark and others have a strong research capability and a large field influence in the field of green supply chain management research. (4) There are 13 core journals publishing the research of green supply chain management, covering 10 fields including engineering, mathematics and social issues. (5) At present, the research hotspots of green supply chain management mainly include the following: Green production and innovation, green supply chain management theory and method, and sustainable supply chain environment and performance. Finally, this paper analyses the shortcomings of previous research and proposes a future direction for research development.

Keywords: green supply chain management; bibliometric; literature characteristics; sustainable supply chain

1. Introduction

With the rapid development of the world economy, the increasing shortage of natural resources and the deterioration caused by pollution, the problem of environmental protection has become a vital concern of countries and regions all over the world. The awareness of the importance of the environmental management systems and its relationships with the sustainability, competitiveness and institutional practices increased [1]. In June 2015, the Chinese government submitted a document on strengthening China's national independent contribution (INDC) to climate change action, promising that China's carbon dioxide emissions would be reduced by 60%–65% by 2030 compared with 2005 [2].

Both the government and consumers have called for greening activities in the supply chain and more responsibility for the environment. Consumers have also demanded more environmentally friendly products. Meanwhile, producers are more sensitive to environmental issues, including global warming and air pollution [3]. Looking at the development mode of the supply chain in the past, the production and operation of the supply chain consumes a large amount of energy and resources, produces a large number of pollution-waste goods, and brings greater pressure for environmental protection. The Intergovernmental Panel on Climate Change has emphasized the need to strengthen green supply chain cooperation to accelerate progress. The successful integration of economic, environmental and social sustainability goals has been at the forethought of leading supply chain and operation management [4]. Green supply chain management (GSCM) provides a system-level approach [5]. In the past 10 years, scholars have conducted extensive theoretical and empirical studies on the subject of green supply chain management (GSCM) and published the research in various influential academic journals. GSCM has been established as an important discipline in the academic world and a separate branch of sustainability [6]. According to Awan et al. [7], creativity enables sustainable development with supplier engagement as a boundary condition for the positive effect on green innovation. It is worth noting that the implementation of sustainable solutions in the supply chain is complex and requires a systemic approach [8]. At the same time, some reviews of GSCM appeared in the literature. One hundred and twenty one results were revealed during the research. Various research methods were applied from the initial summary of the research results to the later application through field research, experimental simulation and other methods [9,10]. The study focused on different research objects, such as automobiles, medicine, household appliances, food, steel and products of other industries [11]. The research content varies, from the definition of the supply chain concept to the analysis, quantitative analysis, and the application of the analysis model and factors affecting GSCM [12,13]. However, most of this literature focuses on qualitative analysis or a short-time period in discussing GSCM. Therefore, it is a need to collect the data with the objective approach. In addition, current research also does not use a strategic coordinate diagram to analyse the relationship between the research topic and key words of GSCM. Therefore, it is hard to fully assess the influence of recent research on dynamic changes in GSCM. To comprehensively reflect the research content of GSCM, this paper takes studies related to GSCM using the Web of Science source retrieval from 1997 to 2018 as research samples. This research analysed the current status, characteristics, research hotspots and trends of current GSCM research based on the combination of bibliometrics and scientific maps with analytical tools such as CiteSpace's visualization (CiteSpace V), Bicomb and SPSS. Strategic coordinate diagram was used to study the internal relationship between the themes and keywords of the current research on GSCM.

The purpose of this paper mainly includes two parts: First, based on the papers published before December 2018, a comprehensive review of the relevant literatures on GSCM was conducted to develop the conceptual framework and research propositions; second, according to the shortcomings of the existing literatures, the direction of future research is proposed.

The contributions of this paper are as follows:

(1) This paper used a bibliometric method to analyze the trends and hot issues of green supply chain research. Compared with previous studies, this method can more directly reflect the main content of green supply chain research.
(2) In the literature classification, we list nine categories, which helps readers understand and view the literature from different dimensions.
(3) The strategic coordinate diagram is used to analyze the internal relationship between the themes and keywords of the current research on GSCM. This method has not been used in previous researches on green supply chain.

The paper is organized as follows: Section 1 introduces the writing background of the article. Section 2 explains the data source and research method. Section 3 analyses the basic characteristics of the literature, including the development trend, characteristics of the author and research institutions.

Section 4 summarizes the research hotspot content. Section 5 offers results and discussion and provides recommendations for future research.

2. Data Sources and Analysis Methods

2.1. Data Sources

This paper is based on the Web of Science (WOS) web database, Science Citation Index Expanded (SCI-E). WOS is a premier worldwide database of papers. It contains more than 12,000 authoritative and high-impact academic journals from the SCIE and SSCI. Many scholars have conducted literature searches based on the WOS platform [14–16]. The retrieval mode of this paper is mainly determined by two retrieval terms, green supply chain and environmental. The content of the search is TS= (green supply chain or environmental sustainability) AND (Environmental AND Supply Chain) AND (green supply chain management)). The retrieval time range is from 2007 to 2018 and the deadline is 31 December 2018. According to the research direction (engineering, mathematics, social issues, business economics, operations research management science, transportation, environmental sciences, ecology, energy fuels, computer science, science and technology, social science and other topics), language (English), document type (Article), database (SCI, SSCI), a total of 2947 retrieved results were screened to obtain 1391 references, which were saved according to requirements for the text format by CiteSpace V.

2.2. Analysis Method

The purpose of the literature review is to map and evaluate the subject of the published literatures to identify the potential research gaps and to highlight the boundaries of knowledge [17]. In addition, existing literature needs to be summarized and categorized based on the keywords and topics to determine the themes and trends of future research [18]. According to these notions, we present research hotspots by providing knowledge maps to reflect intuitively the main content of GSCM researches. Mapping knowledge domains have been used to describe the change of knowledge resources and their carriers over time [19]. Drawing knowledge maps is an important tool for mining analysis to show scientific and technological knowledge and the interrelationship between them [20]. The scientific knowledge mapping tool CiteSpace V used in this paper is a visualization analysis software based on the operating environment of JAVA programming language developed by Dr. Chen, an American professor of Chinese origin at Drexel University. The software can display the evolution of a certain field in the knowledge map, visualize the panoramic view of the knowledge domain, and identify the research hotspots and frontier directions in a certain field [21]. The data was initially processed by the Notepad++ software (such as green supply chain management, GSCM merged into Green supply chain management). Data from 1391 documents was converted and imported into CiteSpace 5.3.R4.SE. "Time Slicing" 2007-2018, "Years" Per Slice are set to one time as a time partition. As "Top N Per Slice" threshold Top50 (the top 50 high frequency nodes are selected in each time zone) was selected. The network node association strength defaults to Cosine. Finally, "keyword" and "author" were selected as the node type. Upon completion, the image was visualized, the author's keyword network knowledge map was demonstrated, and the relationship between the authors was shown. Based on these results, the hot topics of GSCM through keyword co-occurrence mapping can be explored and the emerging frontiers of its development, based on mutation word detection, can be analyzed.

3. Analysis of Document Characteristics of GSCM Research

3.1. Development Trend Analysis

In recent years, the number of articles published in different scientific fields around the world has grown exponentially, and the behavior of the scholars involved in scientific production has changed over time [22]. The change in the number of documents is a direct response to changes in the amount of

scientific knowledge in the field. In addition, the number of published papers is an important indicator for measuring the change in the number of documents in a particular subject. A total of 1391 articles were counted, and changes from 2007 to 2018 are shown in Figure 1. It demonstrates that the number of documents is increasing year by year from 14 articles in 2007 to 367 articles in 2018. The average annual volume of publications increased by 58.83% with an average annual growth rate of 45.51%. The fitting curve $R^2 = 0.9599$ indicates that the cumulative amount of research literature in the field of GSCM has grown exponentially. Since 2013, the distance between the actual value of the accumulated literature volume and the theoretical value has increased every year, indicating that the current GSCM research is more mature after 2013. Therefore, there is still a large potential for research on GSCM.

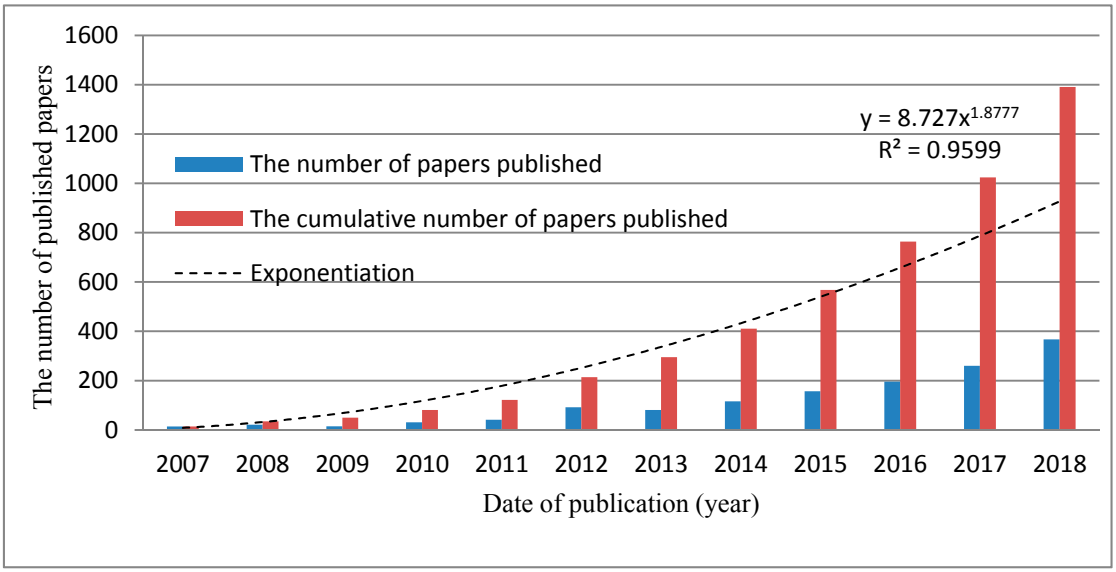

Figure 1. Number of Web of Science (WOS)-based research literature on green supply chain management (GSCM). Source: Literature statistics from the WOS Platform.

3.2. Research Author Analysis

According to statistics, 1391 articles were retrieved including a total of 3230 authors. The paper usually does not refer to a certain individual but to a group of authors who have more research in a certain field and have greater influence on the paper. According to the calculation method of Price's law, $m = 0.749\sqrt{n_{max}}$ (where m represents the author's minimum number of papers published, $\sqrt{n_{max}}$ represents the author's highest number of papers published), the core author group can be determined [23]. The biggest number of citations belongs to Sarkis, who has 49 papers; thus, in this case m equals 7. Therefore, other authors who have published seven or more papers are also well known in the research field of GSCM. According to data statistics and analysis, 31 authors have published seven papers or more. The most frequently quoted author, Sarkis, is cited 4259 times. The next author is Govindan, who has 44 papers and is cited 2572 times. The third is Zhu, who has 25 papers and is cited 2761 times. In particular, "An organizational theoretic review of GSCM literature" by Zhu and Sarkis is cited 579 times [24]. This study uses organizational theory to analyse literature regarding global supply chain management. In addition, it especially emphasizes the role of theory in global supply chain management practices, and based on this, it establishes the basic framework for GSCM research. In later research, the author applied this theory to analyse the coordination of environmental, economic and operational performance and of external and internal practices in global supply chain management. It is suggested that manufacturers need to integrate the internal GSCM practices to fully utilize the performance potential of GSCM, emphasizing the functional coordination with external GSCM practices [25]. The findings of this study have received wide attention and recognition from scholars. The 31 core-authors of GSCM research published 413 papers, which is 29.69% of the total

number of papers—that is, far below the 50% Price's law standard. That result means that the current research on GSCM is deeper and has achieved greater results, but a stable, core author-group has not yet been formed. Therefore, scholars in this field are still required to continue intensive study as are deeper investigations in order to publish more influential research and promote the further development of GSCM. The CiteSpace V software was used to examine cooperation among authors. The results are shown in Figure 2. An author's mediation centre is represented by the size of the node. A larger node indicates a higher mediation centre. The size of the node's centre circle represents the number of papers. A larger circle refers to a larger number of papers published. The thickness of the connection between nodes represents the amount of cooperation between authors, that is, the thicker connection indicates more cooperation. It is demonstrated in Figure 2 that the authors who published more papers show obvious network characteristics, indicating a number of high-performing research teams which have been formed to study GSCM. Among the networks that connect authors, there are two large research teams which centered on Sarkis and Govindan. Furthermore, there are six centers concentrated on Zhu, Lai, Tseng, Kannan, Jabbour, and Diabat. There are also some small research teams, such as Guansekaran and Diabat et al. However, these research teams have formed close cooperative relationships. For example, the author Zhu is not only close to Sarkis' team, but he is also an important collaborator of Govindan's team and participates in the work of Lai's teams.

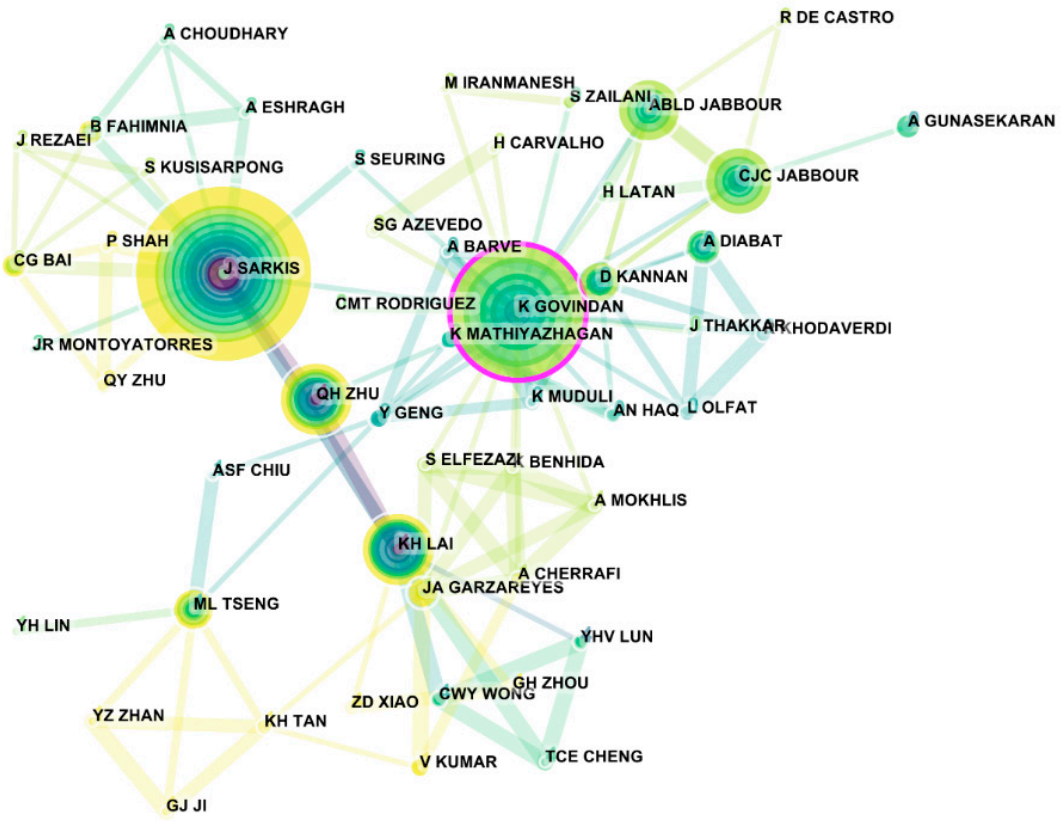

Figure 2. Author cooperation map. Source: Authors' own construction.

3.3. Analysis of the Research Institutions Affiliated with the Literature

Statistical analysis of high-output scientific research institutions in the field of GSCM will help to understand the most authoritative institutions in this area. According to the analysis of the literature, 1391 articles belong to 1269 scientific research institutions (see Figure 3). As can be seen from Figure 3, Hong Kong Polytechnic University, University of Southern Denmark, Indian Institute of Technology, Dalian University of Technology, Worcester Polytechnic Institute, Chinese Academy of Sciences, Islamic

Azad University, Clark University, Universidade Estadual Paulista, and Tianjin University have a major influence on the field of GSCM research.

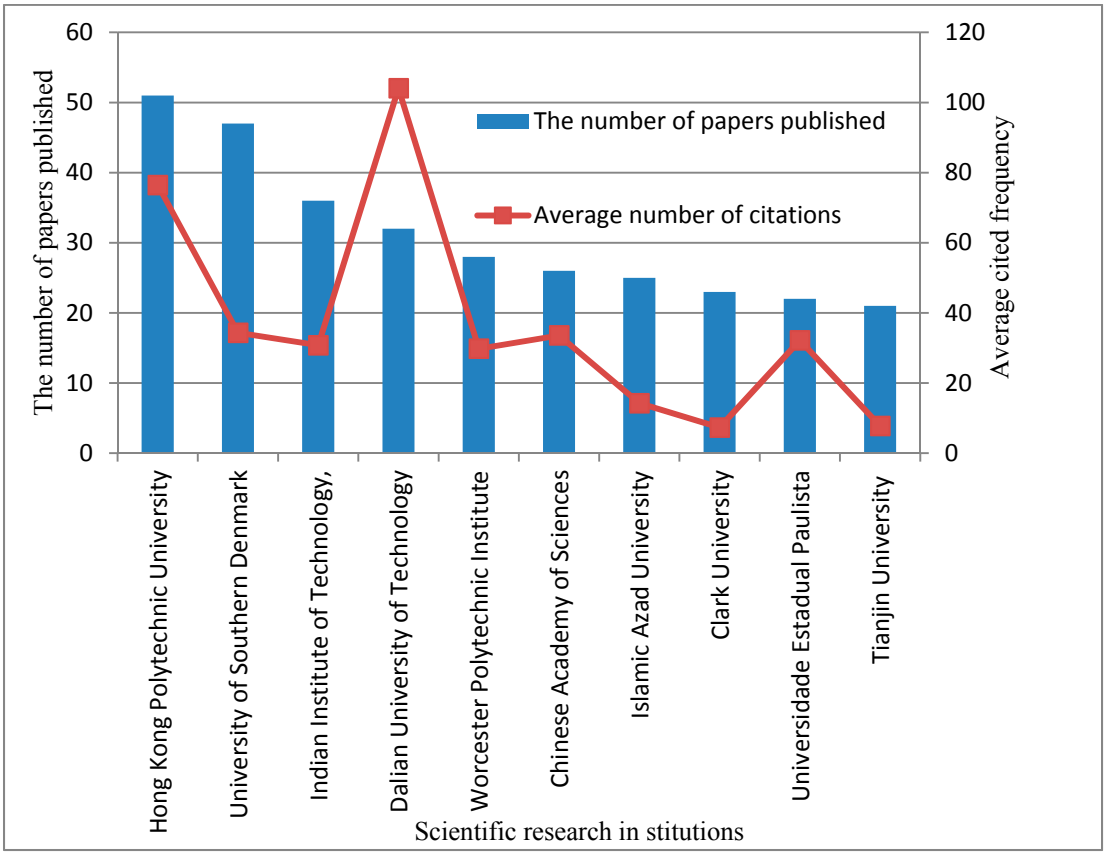

Figure 3. Research institutions and cited frequency. Source: Literature statistics from the WOS Platform.

3.4. Source of Literature and Analysis of Research Areas

After counting the SCI and SSCI journals which totalled 1391 papers, it was found there were 133 journals with a focus on GSCM content. There are 112 journals with two or less publications. In fact, the papers on GSCM research mainly focus on 21 (that is 133 minus 112) journals. Based on Bradford's law, journals are arranged in descending order according to the publication of a professional paper, which can be divided into three parts—the core area, the relevant area and the non-related area. The core area can be calculated by the Bradford calculation method, that is, $P = 2\ln(E^e \cdot Y)$. , where P is the number of the core areas, e is the Euler coefficient, e = 0.5772, and Y is the largest quantity of periodicals [26]. In this study, $P = 2\ln(1.781 \times 333) = 12.77$; that is, the top 13 journals are in the core area, as shown in Table 1:

It can be seen from Table 1 that the total number of publications located in the core area was 955 (=333 + 134 + … 15), accounting for 68.7% of the total retrieved literature (1391). The Journal Citation Report (JCR) database partitions of the above papers are Q1 and Q2, respectively. It can be proved that scholars have a certain depth in the research of GSCM, which has been affirmed in current academic circles. At the same time, research on GSCM mainly focuses on six fields: environmental sciences & ecology, operations Research & management science, engineering, transportation, computer science, and business & economics. Among publications, the Journal of Cleaner Production is ranked first due to the number of papers. It published a total of 333 papers in this field from 2007 to 2018, that is, 23.9% of the total number of research papers.

Table 1. Analysis of sources of publications in the core area. Source: Literature statistics from the WOS Platform.

Item	Source Publication	Number of Records	Research Areas	JCR Partition	Proportion
1	Journal of Cleaner Production	333	Environmental Sciences & Ecology	Q1	0.239
2	International Journal of Production Economics	134	Operations Research & Management Science	Q1	0.096
3	Sustainability	131	Environmental Sciences & Ecology	Q2	0.094
4	International Journal of Production Research	73	Operations Research &Management Science	Q1	0.052
5	Resources Conservation and Recycling	48	Engineering	Q1	0.035
6	Computers Industrial Engineering	39	Computer Science	Q1	0.028
7	Transportation Research part E Logistics and Transportation Review	37	Operations Research & Management Science	Q1	0.027
8	Production Planning Control	33	Operations Research & Management Science	Q2	0.024
9	European Journal of Operational Research	25	Business & Economics	Q1	0.018
10	Industrial Management Data Systems	25	Engineering	Q1	0.018
11	Expert Systems with Applications	20	Operations Research & Management Science	Q1	0.014
12	Transportation Research Part D Transport and Environment	16	Transportation	Q1	0.012
13	Journal of Manufacturing Technology Management	15	Business & Economics	Q2	0.011

3.5. GSCM Highly Cited Literature Analysis

By analyzing highly cited literature in the field of GSCM, the academic papers and major research scholars with important influence in this field can be indicated. Out of 1391 articles, there are 107 articles that are highly cited. Among them, Sarkis et al.'s [24] "An organizational theoretic review of green supply chain management literature" was cited up to 579 times. Then, Vachon and Klassen's [27] "Environmental management and manufacturing performance: The role of collaboration in the supply chain" was cited 563 times. These data is shown in Table 2:

Table 2. High-cited literature analysis of GSCM. Source: Literature statistics from the WOS Platform.

Citing Frequency	Author (Year)	The Titles of the Articles	Literature Sources
579	Sarkis et al. (2011)	An organizational theoretic review of green supply chain management literature [24].	International journal of production economics
563	Vachon et al. (2008)	Environmental management and manufacturing performance: The role of collaboration in the supply chain [27].	
437	Zhu, Q et al. (2008)	Confirmation of a measurement model for green supply chain management practices implementation [28].	
316	Yang et al. (2011)	Impact of lean manufacturing and environmental management on business performance: An empirical study of manufacturing firms [29].	

Table 2. *Cont.*

Citing Frequency	Author (Year)	The Titles of the Articles	Literature Sources
349	Brandenburg et al. (2014)	Quantitative models for sustainable supply chain management: Developments and directions [30].	European Journal of Operational Research
290	Dekker et al. (2012)	Operations Research for green logistics—An overview of aspects, issues, contributions and challenges [31].	
332	Hassini et al. (2012)	A literature review and a case study of sustainable supply chains with a focus on metrics [32].	International journal of production economics
211	Gimenez et al. (2012)	Sustainable operations: Their impact on the triple bottom line [33].	
235	Ageron et al. (2012)	Sustainable supply management: An empirical study [34].	
303	Diabat et al. (2011)	An analysis of the drivers affecting the implementation of green supply chain management [35].	Resource conservation and recycling
293	Ahi et al. (2013)	A comparative literature analysis of definitions for green and sustainable supply chain management [36].	Journal of cleaner production
234	Kuo et al. (2010)	Integration of artificial neural network and MADA methods for green supplier selection [37].	
205	Hsu et al. (2009)	Applying hazardous substance management to supplier selection using analytic network process [38].	
269	Melvill et al. (2010)	Information systems innovation for environmental sustainability [39].	MIS Quarterly
247	Wu et al. (2011)	Balancing priorities: Decision-making in sustainable supply chain management [40].	Journal of Operations Management
244	Zhu et al. (2008)	Green supply chain management implications for "closing the loop" [41].	Transportation research part E-logistics and transportation review
212	Chiou et al. (2011)	The influence of greening the suppliers and green innovation on environmental performance and competitive advantage in Taiwan [42].	
243	Wang et al. (2011)	A multi-objective optimization for green supply chain network design [43].	Decision support systems
302	Buyukozkan et al. (2012)	A novel hybrid MCDM approach based on fuzzy DEMATEL, fuzzy ANP and fuzzy TOPSIS to evaluate green suppliers [44].	Expert systems with applications
233	Shaw et al. (2012)	Supplier selection using fuzzy AHP and fuzzy multi-objective linear programming for developing low carbon supply chain [45].	
216	Lin et al. (2014)	Survey of Green Vehicle Routing Problem: Past and future trends [46].	
213	Lee et al. (2008)	Drivers and Enablers That Foster Environmental Management Capabilities in Small- and Medium-Sized Suppliers in Supply Chains [47].	Production and Operations Management

It can be seen from Table 2 that there are 22 cited documents with a frequency of citation more than or equal to 200 times. There are also differences in definition of a green supply chain, such as Handfield et al. [48] who considered a green supply chain (GSC), also known as an environmental supply chain, to be a modern approach to management that takes environmental impact and resource efficiency into consideration in the whole supply chain. Sarkis et al. [24] used the term GSCM and defined it as integrating environmental concerns on the inter-organizational practices of SCM including reverse logistics. The paper introduced nine theories which include: complexity; ecological modernization; information; institutional; resource-based view; resource dependence; social network; stakeholder; and transaction cost economics theories. This approach was also utilized to investigate various issues related to GSCM [49,50]. Srivastava et al. [51] and Mitra et al. [52] identified GSCM practices that consisted of reverse logistics, product recovery and reuse of used products, green design, green purchasing, and collaboration with suppliers and customers. Zhu et al. [53] suggest that GSCM is

a type of developed supply chain management that is associated with being green, a stable environment, waste reduction and optimum use of resources. Anwar et al. [50] studied the impact of global supply chain management practices and its impacts on the environment and environmental cost savings, and found that GSCM can integrate environmental management systems, ecological design, and external environmental practices. Bowen et al. [54] analysed the relationship between supply management capabilities and green supply practices, and then they identified internal drivers for implementing green supply policies.

4. Hotspots in GSCM Research

4.1. Co-Occurrence Keyword Visualization Analysis of Research Topics

The key words summarize the main purpose of the literature to a certain extent, and they can comprehensively interpret its content. CiteSpace's visualization (CiteSpaceV) function can deeply analyse the keywords of a large number of documents and identify the hotspots of GSCM research through the interpretation of keyword co-occurrence maps. Based on the CiteSpaceV software, this study draws a key co-occurrence map of GSCM research from 2007 to 2018 (see Figure 4).

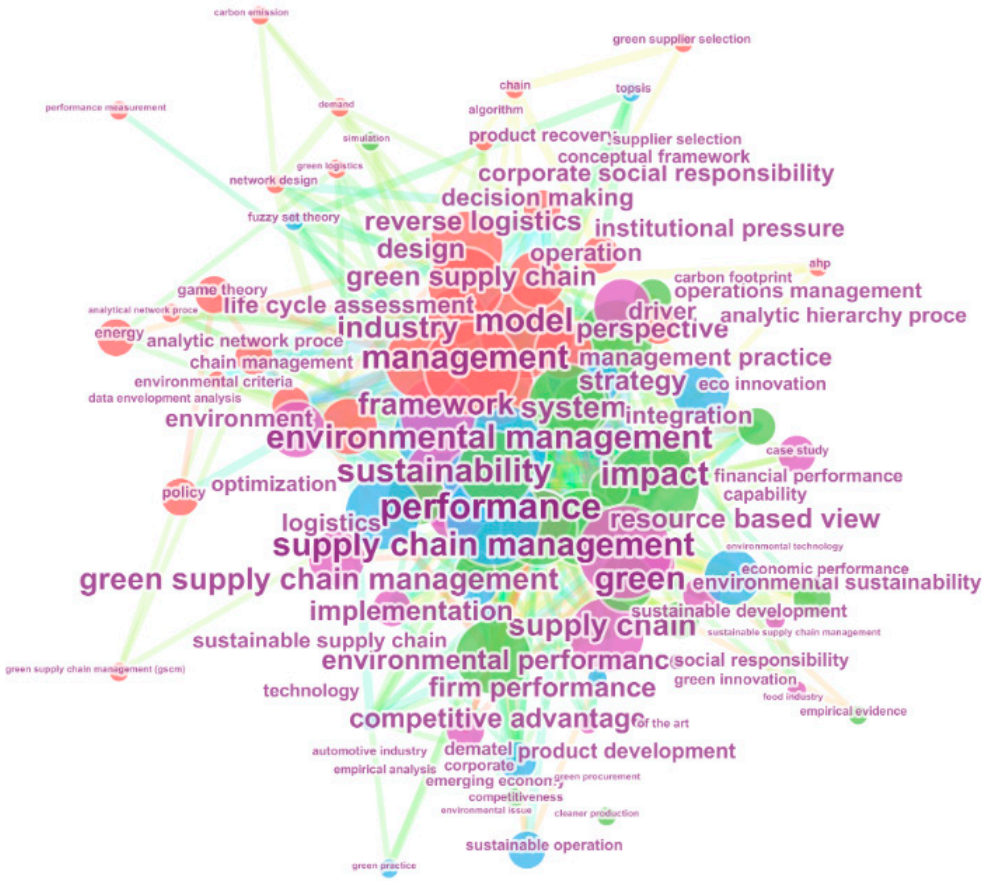

Figure 4. Keyword co-occurrence map in the field of GSCM research. Source: Authors' own construction.

The node size shown in Figure 4 is positively correlated with the frequency of occurrence or in other words, the larger node indicates the higher frequency of occurrence. This is demonstrated in Figure 4. Sustainability, model, industry, management, framework, performance, supply chain management, green, impact and green supply chain management are the most frequently used keywords in the 12-year period from 2007 to 2018.

4.2. Key Words Cluster Analysis in the Field of GSCM Research

The common word clustering-analysis method aims to gather closely related keywords to form a new independent category. Thus, that similarity of the particular category is the largest that is possible, and the attributed similarity between different categories is the smallest. Cluster analysis reflects the close relationship between keywords, which can further reflect the current research hotspots of GSCM. The principle of keyword clustering analysis is to analyse the frequency of occurrence of keywords in the same paper and to use clustering statistical methods to group closely related keywords [55]. First, we used Bicomb to process the high frequency vocabulary to generate a 32×32 common word analysis matrix. Second, the co-word analysis matrix was imported into SPSS20.0, and the analysis-system clustering-cosine was selected to find the pair of co-occurrence keywords with the largest cosine value. Then similarity matrix was generated centering on the co-occurrence keywords with the largest cosine value, and the similarity matrix was imported into Excel and converted into a dissimilar matrix. Next, the similar matrix was imported into Excel and converted into the dissimilar matrix. Finally, the results of the dissimilar matrix of the keywords were imported into the SPSS20.0 to generate the clustering graph. The results are shown in Figure 5. According to the cluster analysis result graph, the connection distance between clusters is displayed, and the keywords are aggregated into nine categories. (We excluded categories with only one keyword).

Category 1 involves green case studies, including three keywords: Green, lean, and case study. The environmental research of supply chain management is actually reflected more in the research of green environment content, including life cycle theory and sustainable development theory. Category 2 covers research on sustainable supply chain management, including five key words: Sustainability, supply chain, supply chain management, environment, and life cycle assessment. Category 3 involves green production research, including two keywords: Green manufacturing and lean manufacturing. Category 4 involves environmental management and performance research, including three key words: Environmental management, China, Brazil, and performance. Category 5 refers to research on green innovation and fuzzy indicators, including two keywords: Fuzzy TOPSIS and green innovation. Category 6 involves research on reverse logistics and analytic hierarchy processes, including two keywords: Reverse logistics and AHP. Category 7 involves multi-objective planning and game theory research in green supply chains, including three keywords: Green supply chain, multi-objective optimization, and game theory. Category 8 deals with sustainability performance studies, including three keywords: Sustainable development, environmental performance, and sustainable operations. Category 9 refers to sustainable supply chain management theory and method research, including five keywords: Sustainable supply chain management, fuzzy set theory, DEMATEL, supplier selection, and environmental sustainability.

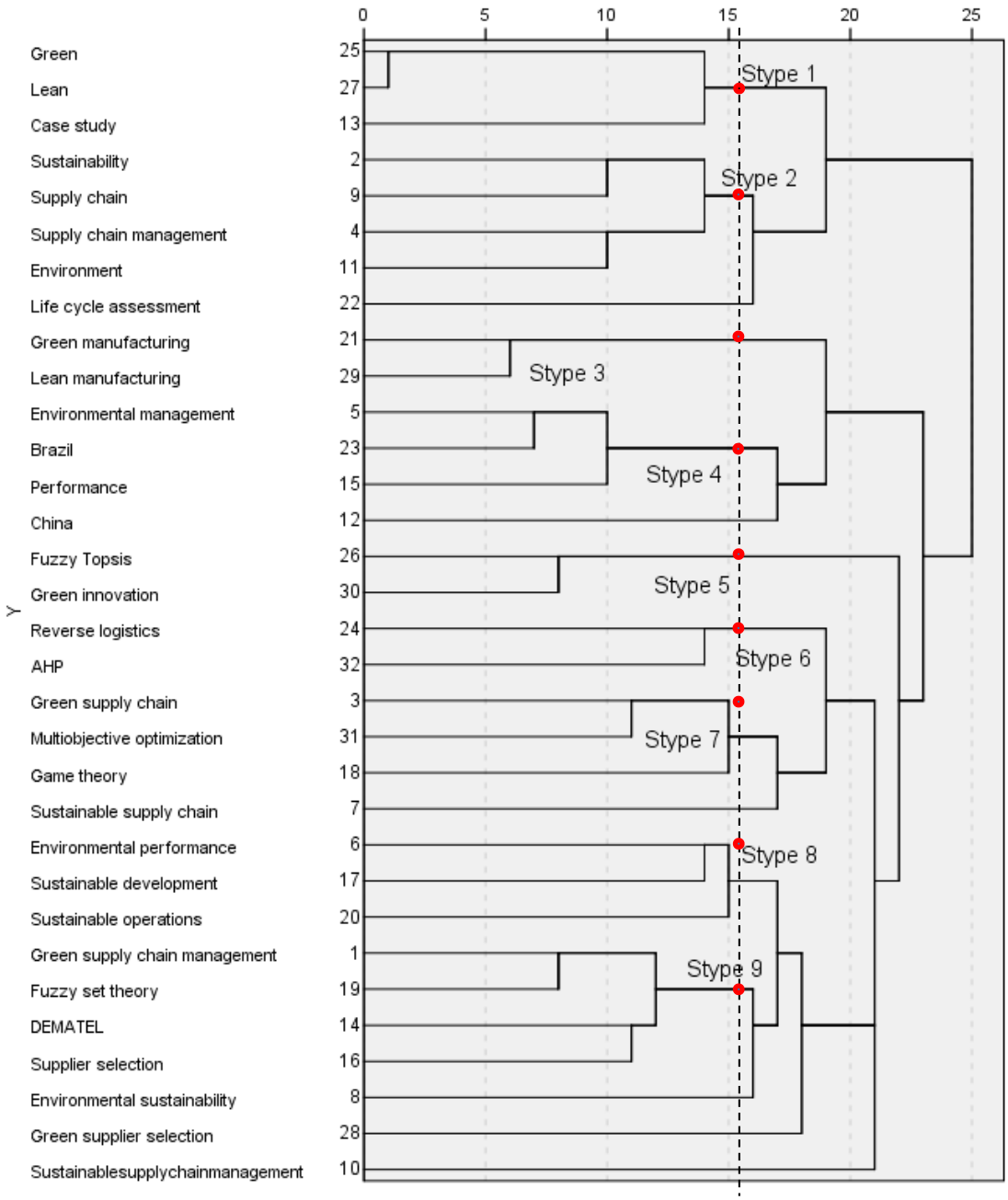

Figure 5. Keyword co-occurrence map in the field of GSCM research. Source: Authors' own construction.

4.3. GSCM Research Keywords Strategic Coordinate Graph Analysis

Law [56] proposed a strategic coordinate map of research status for analysing various aspects of knowledge in a certain field. This indicator can reflect the internal relationship and interrelationship of research content in a particular area. Different from a cluster analysis, a strategic coordinate map can identify the evolution trend and relationship between different categories. The strategic graph is a two-dimensional coordinate system drawn with centripetal and density parameters, where the X-axis is centripetal and the Y-axis is density. Density is used to measure the strength of internal linkages within a category, indicating the ability of the category to maintain and develop itself. Centripetality is mainly used to measure the degree of interconnection between a category and other categories. The greater centripetality means that there are more central categories in this discipline [57]. The density and centripetal calculation formulas used in this paper are:

$$\text{Density} = \frac{\sum \begin{matrix} E_{ij} \\ i,\ j \in \varnothing_{x(i \neq j)} \end{matrix}}{n-1} \quad (1)$$

$$\text{Centrality} = \frac{\sum \begin{matrix} E_{ij} \\ j \in \varnothing_{s,\ i \in (\varnothing - \varnothing_s)} \end{matrix}}{N-n} \quad (2)$$

where n is the number of keywords in the category, N represents the number of all keywords in the entire keyword network, $\varnothing$ represents the entire keyword network, E_{ij} refers to the Equivalent Index, that is, the correlation coefficient between the keyword i and the keyword j, which is expressed as follows:

$$E_{ij} = \frac{F_{ij}^2}{F_i F_i} \quad (3)$$

For this reason, based on the keyword clustering analysis and according to the density and centripetal degree of the clustering category, the density is the horizontal axis, and the centripetality is the vertical axis. The average value (0.917, 0.646) is used as the origin to draw a strategic coordinate map, which causes nine clusters to be placed in different quadrants. The results are shown in Figure 6:

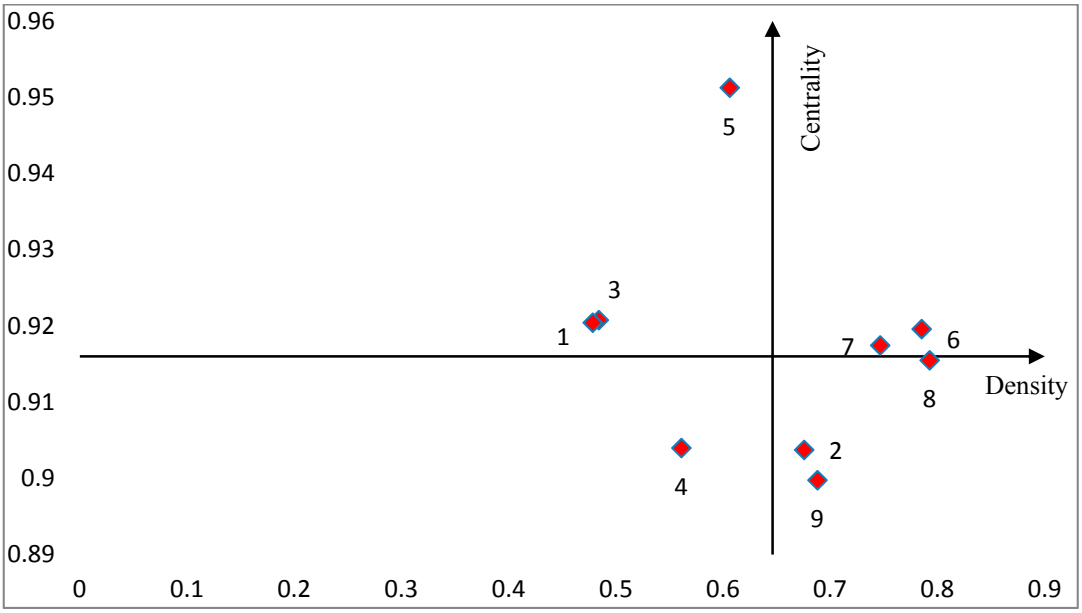

Figure 6. Strategic map of the research field of GSCM. Source: Authors' own construction.

From the perspective of centripetal distribution, the centripetal degree of cluster 5, "green innovation and TOPSIS evaluation", is much higher than other clusters, indicating that this cluster has a core position in the field of GSCM research and has a close relationship to other clusters. The reason is "Fuzzy TOPSIS" and "Green innovation" are the core contents of GSCM research, and they are also the focus of scholars. The centripetal degree of cluster 1, "green case", cluster 3, "green production", cluster 6, "reverse logistics and analytic hierarchy process", and cluster 7, "multi-objective planning and game theory of green supply chain", are greater than the average values. The value of 0.917 shows that four research topics are highly correlated with other clusters. This is due to key scholars in the GSCM research who have applied a large number of cases to analyse the status quo of green development through different research methods, hoping to attract the attention of governments, enterprises and consumers to the production of green products. The centripetal degree of cluster 8, "sustainable development performance", is on the average, indicating that cluster 8 has a certain position in the field of GSCM research, has certain relevance to other research topics and will be related in future research.

It needs to further deepen and improve. The centripetal degree of the remaining clusters are below the average, especially cluster 9, "sustainable supply chain management theory and method", which has the lowest centripetality. Second, cluster 2, "sustainable supply chain management", and cluster 4, "environmental management and environmental performance", have low centripetality, indicating that the relationship between these research topics and other topics is small, and the research content is not concentrated.

From the perspective of density distribution, cluster 8, "sustainable development performance", and cluster 6, "reverse logistics and analytic hierarchy process", are at a higher density level, indicating that the subject research is in-depth, with a clear and mature theoretical context and development path. The density of cluster 2, "sustainable supply chain management", cluster 7, "multi-objective planning and game theory of green supply chain", cluster 9, "sustainable supply chain management theory and method", are all greater than the average value of 0.646, indicating that a research framework for the three themes has been formed, but it still needs to be supplemented and improved. The density of the remaining clusters is below the average level, indicating that these research topics are not mature enough and that the logical architecture is not formed.

From the distribution of the four quadrants, there are clusters 6, "reverse logistics and analytic hierarchy process", and cluster 7, "multi-objective planning and game theory of green supply chains", in the first quadrant. Their centripetality and density are both greater than the average and are at a high level, indicating that these three themes are the hotspots and core content of GSCM research. Cluster 1, "green case", cluster 3, "green production", cluster 5, "green innovation and TOPSIS evaluation", are located in the second quadrant. Their centripetality is higher than the average. However, their density is lower than the average, indicating that these three themes are within the core scope of the GSCM research field, but they are at an immature stage and are a likely development trend of future research. There is cluster 4, "Environmental Management and Environmental Performance", located in the third quadrant, where the centripetality and density are lower than the average and at a lower level. The study of "environmental management and environmental performance" is not in the core area of GSCM research but on the edge of research. The research content is scattered and does not form a complete research system. There is cluster 2, "sustainable supply chain management", and cluster 9, "sustainable supply chain management theory and method", located in the fourth quadrant. The density of these two clusters is higher than the average, and the centripetalness is lower than the average, indicating that the study on sustainable supply chain management and method topics is on the edge of GSCM research. Additionally, it is a relatively mature research field.

Based on the above analysis of different perspectives of strategic coordinates, the hotspots of GSCM research focus on the following three aspects:

(1) Green production and innovation research: Green production is a modern production model that uses green production strategies (goals and principles) and methods (technology and innovation) to achieve higher environmental performance [58]. Specifically, the goal of green production is to minimize the negative impact on the environment throughout the life cycle, maximize the utilization of resources and enable enterprises to achieve optimal economic and social benefits.

Green innovation is also known as eco-innovation and environmental innovation. It is a new product or process that is based on the enhanced background of consumers' green awareness, which can provide value to businesses and customers while significantly reducing the negative impact on the environment [59]. With the deepening of the concept of innovation and green and coordinated development, stimulating enterprises to strengthen green technology innovation has become an important path to promoting the efficiency of industrial green production.

From the research theme of green production and green innovation, there are two main perspectives. From the static perspective, it is believed that green production reduces the "cost of compliance" of the company's ability to innovate. That is, green production increases the production cost of the enterprise, thereby reducing the productivity of the enterprise and the competitiveness on the international market [60,61]. From the dynamic perspective, rational green production encourages innovation

through the "innovation compensation" effect, prompts enterprises to increase R&D innovation investment, enhances their own innovation level, and compensates for the negative impact of the "cost of compliance". In fact, no matter which form is more difficult to distinguish in quantitative analysis, the empirical research results more comprehensively cover the combined outcomes of the two effects. Some scholars have verified this view from empirical research. While the intensity of green production increases as time passes, the impact of green production on innovation presents a "U" shape [62].

(2) Research on the theory and method of GSCM: It is a modern manufacturing model based on green manufacturing theory to establish alliances and applies environmental management ideas to supply chain management [63]. It is based on the natural-resource-based view (NRBV), i.e., environmental management within the organization and environmental management between organizations are important components of GSCM. It can be specifically divided into green procurement, ecological design, internal environmental management, green consumption and investment recovery [64].

Hazen et al. [65] used the analysis of variance in statistics to determine that there is no necessary positive correlation between the practice of green supply chain management and the improvement in the core competitiveness of enterprises, so the practice will have a negative impact on the diffusion of green supply chains. Jabbarzadeh et al. [66] used the multi-objective robust optimization method to analyse the green elasticity of the power supply chain network from three aspects: Economic (maximum profit), environment (minimum greenhouse gas emission) and elasticity (network elasticity maximization). Liu et al. [67] established a game model between the government and enterprises. The research results show that the government plays an important role in the implementation of green supply chains. Ozer Uygun et al. [68] screened out GSCM evaluation indicators: Green design, green purchase, green conversion, green logistics and reverse logistics. Comprehensive fuzzy multi-objective decision-making technology was used to evaluate a company's green supply chain performance and to improve its green activities.

(3) Environmental and performance research for sustainable supply chains: Sustainable supply chain management aims to coordinate the management of logistics, information flow and capital flow in each node of the supply chain, to fulfil the needs of customers and shareholders, and at the same time achieve the goal of coordinated development of the economy, environment and society [69]. Sarkis [70] first began research on how sustainable supply chain management can improve a company's economic performance. Then, Theyel and Gregory [71] pointed out that cooperation with suppliers has a significant impact on improving corporate economic performance. Zhu et al. [72] found that in the case of failing to meet the quality and environmental requirements of foreign companies, the introduction of external continuous supply chain management methods by Chinese companies can make the performance of enterprises better. Mentzer et al. [73] considers that sustainable supply chain management is a systematic coordination of traditional supply chains, integrating social, economic and environmental benefits within a single enterprise or between enterprises. The goal is to improve the long-term sustainability performance of companies and the entire supply chain and to consider the sustainability of the entire supply chain from both upstream and downstream perspectives.

5. Conclusions and Suggestions for Future Research

This paper systematically reviewed the relevant literature on GSCM research. On this basis, the knowledge map was used to visually show the development trends, main research institutions, core authors, research topics and research hotspots in the research of GSCM. In this field of research, a large number of academic papers were published in the past decade. This also included a section on the review of GSCM and sustainable SCM. However, through literature metrology and network analysis, the literature on the use of knowledge maps to conduct in-depth research on GSCM in these literatures, was relatively rare, not to mention the effective identification of clusters of influential works and authors. The main research content of GSCM was further reflected in the research of this paper. Through our research, we found that: The number of papers published had grown exponentially,

and researches on GSCM had matured since 2013. At present, the research hotspots of GSCM mainly include the following topics: Green production and innovation, GSCM theory and method and the environment and performance of sustainable supply chains. At the same time, there are 13 core journals published in the field of GSCM, including engineering, mathematics, social issues, Business economics, operations research management science, transportation, environmental sciences, ecology, energy fuels, computer science, science and technology, social science and other topics. However, it can be seen from the comprehensive average reference frequency and the number of postings that the most influential institutions were as follows: Hong Kong Polytechnic University, University of Southern Denmark, Indian Institute of Technology, Dalian University of Technology and Worcester Polytechnic Institute. In addition, among the literature on some of the GSCM researches, the more influential literatures were mainly from a few authors. Such as Sarkis, Vachon, Zhu, Govindan et al. However, with the deepening of green supply chain researches, more and more authors begun their researches on GSCM and extended the research object to other subject areas. Fortunately, the literatures on normative and quantitative modeling were increasing. We believe that this research method will become the future research direction, especially with the use of real data to analyze practical problems in GSCM. Therefore, it is a good research method for the relevant authors who use GSCM as the entry point to solve real-world problems, such as research on environment, sustainable development and other related issues. However, we also found some shortcomings concerning the present researches. For example, some authors did the same research work repetitively. Although their research content had certain influence, the narrow scope of their research may lead to certain limitations in their later research. Their methods and research ideas may be stagnant. From the analysis of the results given above, we hope that later research can concentrate on a more innovative study from multiple dimensions. In a word, relevant researches in the field of GSCM are constantly deepening and maturing. However, there are not many influential references in the field. The total number of published articles in the core publications is 955, while the number of citations with citations greater than or equal to 200 is only 22. Therefore, there is still much room for the development in the research of GSCM in the future.

Future research should address the following aspects: (1) Through the life cycle theory, the whole process of the introduction period of green products, including the growth period and recession period, can be analysed further. However, for various types of products, the degree of popularity is also different. If there is an opportunity for reasonable innovations in a certain kind of green product (home appliances, automobiles, food, etc.), it will help to extend the life cycle of green products. (2) The research on GSCM can be divided into five stages: The plan or strategy, purchase, manufacturing, delivery and logistics, and the return system [74]. Most of the current research only focuses on the discussion of one certain stage. If the process of the entire supply chain is effectively linked, it will become the new direction of GSCM research. (3) In the study of GSCM issues, a large number of papers use hypothetical data or qualitative scales to collect various indicator data and rarely use real data to verify the results. It would be meaningful to be able to verify the data in a real-world environment during the study. (4) Green incentives among supply chain partners can be further strengthened. In the market economy, green requirements from supply chain partners are more likely to gain active recognition. Therefore, the issues of enhancing enthusiasm among green producers, increasing sales to achieve supply chain resource sharing and improving supply chain efficiency also require in-depth research.

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