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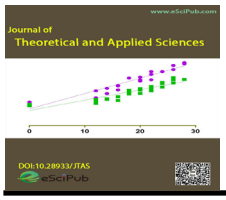

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A bibliometric analysis of research on Supply Chain Risk Management

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ABSTRACT

Analyze the knowledge structure and frontier research hotspots in the field of supply chain risk management research, and study the overall research trends in this field. Using the knowledge mapping software tools VOSviewer and Sci2 Tool, based on the articles published on the WoS core database from 1997 to 2018, systematic analysis of the development trend of supply chain risk management research. Come to the following conclusion: 1.Supply chain risk management research will become more and more “hot”; 2.Supply chain risk management research was mainly distributed in five areas:“quantitative model of supply chain risk management”, “Lean closed-loop supply chain”, “Supply uncertainty”and“Green Supply Chain” and “Equity risk”; 3.The three key words of “Sustainability”, “Emerging Economy”, “Big Data” and “Supply Chain Finance”will evolve into research hotspots in the field of supply chain risk management in the future. The research results reveal the research hotspots and frontier research topics in the field of supply chain risk management.

Key words: Bibliometric analysis; Supply chain risk management; VOSviewer; Sci2 Tool

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1. Introduction

Global supply chain is faced with increasingly complex and fragile challenges. Various emergencies, natural disasters, lead-times changes, exchange rate fluctuations and other uncertain factors impact the normal operation of supply chain more and more frequently [1]. Supply chain disruptions occur frequently. For example, the flood in Thailand in 2011 caused a supply chain crisis for computer manufacturers relying on hard drives and Japanese automobile manufacturers with factories in Thailand [2]. In April 2018, ZTE Corporation suffered from the us government's ban on the supply of sensitive products, leading to the failure of major business activities [3]. In the face of rising supply chain risks, few companies can take effective measures to control risks, resulting in supply chain disruption [4]. This global reality pain point drives supply chain risk management to become a rapidly heated research field, which is also confirmed by the rapid growth of relevant research papers.

Supply chain risk management is a multidisciplinary research and practice area involving supply chain management, enterprise risk management, business continuity and crisis management [5]. This requires researchers to master multidisciplinary knowledge and to work closely with interdisciplinary experts. The traditional research paradigm is difficult to clearly grasp the research landscape, main fields and overlapping forms in major fields, major countries and institutions, major journals and authors of papers, etc. It is particularly difficult to give the future research hotspots that researchers most want to know [6-8]. In view of this, this paper analyzes the supply chain risk management research situation for the first time, adopting a new research paradigm composed of bibliometrics, high-performance computer, complete database and information visualization technology, objectively reveals the research development status, and clarifies the frontier research direction. Provide researchers with high-value directional references.

2. Data sources and research methods

2.1 Data Sources

The data in this paper is derived from the authoritative Web of Science (WoS) core collection database. The search subject is “supply chain risk management”, the search time span is “1997-2018”, and the search document type is “ARTICLE”. A total of 2600 related articles are collected. The retrieved results are saved as "plain text" with "full record and referenced references". The database update time is February 22, 2019.

2.2 research method

In this paper, we use the bibliometric analysis method to analyze the distribution profile, quantity relationship and clustering of related literatures by using mathematical statistics methods, and use VOSviewer and Sci2 Tool analysis software. VOSviewer is a document knowledge unit visualization software based on similarity visualization technology developed by van Eck and Waltman in the Netherlands. It has unique advantages in knowledge mapping, especially clustering [9]. VOSviewer uses a visual mapping method to calculate and locate each topic in a two-dimensional map, so that the distance between the two projects reflects the similarity or relevance of the project as accurately as possible. Its layer label display technology enables dense network nodes to Clearly displayed through interaction, it is especially useful for analyzing large-scale data and building complex networks. The Sci2 Tool was developed by the research team of Borner and Boyack in the United States and is a modular tool set designed for scientific research [10]. Sci2 Tool embeds a variety of database functions, can load data sets in different formats, co-occurrence analysis, citation analysis, coupling analysis, burst detection analysis, etc. for scientometrics. This paper mainly uses the burst detection analysis in Sci2 Tool to construct a bar graph of keyword burst detection time.

3. Bibliometric analysis

3.1 Number of papers and growth trends

The change in the number of academic papers in a subject is an important indicator of the development trend of the research field, and it is a reflection of the changes in the scope of subject knowledge. By drawing the number of documents that change over time and conducting multivariate statistical analysis, we can understand the research level and future development trends in a certain field. The specific situation is shown in Figure 1. Before 2002, there were few related documents, indicating that supply chain risk management is a new topic. There are few relevant research results in this

field, and a complete thesis system has not yet been formed. After 2002, supply chain risk management research entered a stage of rapid development. By 2011, the number of supply chain risk management papers has increased dramatically. By 2018, the number has reached 463, accounting for 17.8% of the total number of papers in the past 20 years. Obviously, supply chain risk management has become a hot research field.

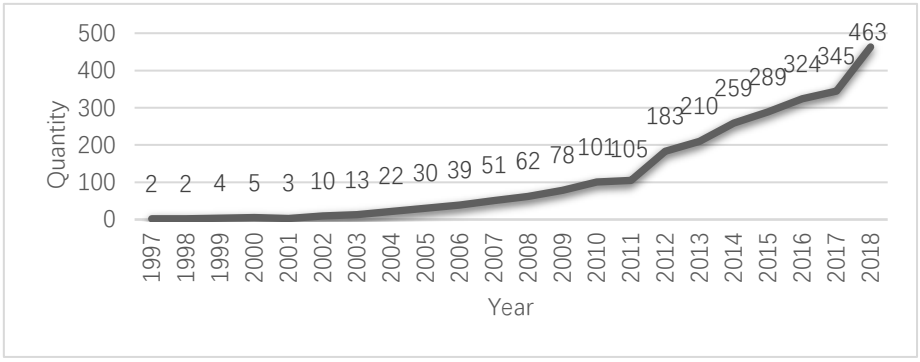

Fig.1. Supply chain risk management research papers

3.2 Quantitative analysis of major source journals

Table 1. Top 10 Journal Rankings

Ranking	Journal Title	SCI/SCIE	IF	Amount of paper	Cited	Research areas
1	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	SCIE	4.407	212	6532	Engineering, Operations Research and Management
2	INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH	SCI、SCIE	2.623	174	3209	Engineering, Operations Research and Management
3	EUROPEAN JOURNAL OF OPERATIONAL RESEARCH	SCIE	3.428	116	3893	Business and Economics, Operations Research and Management
4	JOURNAL OF CLEANER PRODUCTION	SCIE	5.561	62	975	Environmental Science and Ecology
5	SUSTAINABILITY	SCIE	2.075	53	141	Environmental Science and Ecology
6	TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW	SCIE	3.289	51	1089	Engineering, business and economics, transportation
7	SUPPLY CHAIN MANAGEMENT-AN INTERNATIONAL JOURNAL	SCI	3.833	50	927	Business and economics
8	COMPUTERS & INDUSTRIAL ENGI-	SCIE	3.195	47	583	Engineering, computer science

9	NEERING PRODUCTION PLANNING & CONTROL	SCIE	2.330	47	528	Engineering, Operations Research and Management
10	PRODUCTION AND OPERATIONS MANAGEMENT	SCIE	1.772	46	1829	Engineering, Operations Research and Management

2,600 papers were published in 569 journals covering engineering, transportation, computing, environmental ecology, business economics, and operations and management. Table 1 lists the top 10 journals in the field of supply chain risk management. According to the index database of the listed journals, most of the journals were included in SCIE (90%). From the number of papers published in journals, "INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS" published the most papers on supply chain risk management, with a total of 212 papers accounting for 8.15% of the papers. Followed by the "INTERNATIONAL JOURNAL OF PRODUCTION RESEARCH" journal, a total of 174 articles accounted for 6.69%. It is also worth noting that although there are not many publications in the two journals, the quotations are very high. They are the "TRANSPORTATION RESEARCH PART E-LOGISTICS AND TRANSPORTATION REVIEW" and the "PRODUCTION AND OPERATIONS MANAGEMENT" journals. 97 papers were cited 2918 times, and each of them was cited 30 times, indicating that the two journals published more excellent papers and higher quality. In general, the core journals of supply chain risk management research are interdisciplinary if they are not multidisciplinary. Explain that supply chain risk management is a multidisciplinary, interdisciplinary science with characteristics of engineering, management, economics, environment, and computer science.

3.3 Quantitative analysis of the country/region in which the paper is produced

According to the search results, supply chain risk management research papers from 58 countries/regions, Table 1 lists the top 10 paper producing countries, a total of 2469 papers, accounting for 94.9% of the total published volume, North America, China and European developed countries / Most of the papers were published in the region. The United States is the most active country in supply chain risk management research. It has published 797 papers, accounting for 30.7% of the total published papers, and is in a dominant position. As one of the emerging scientific forces [11], China ranked second with 531 papers, accounting for 20.4%, and the United Kingdom ranked third with 269, accounting for 10.3%. Germany and Canada, ranked fourth and fifth, accounted for 6.0% and 5.8% respectively, while those ranked sixth and 10th, on average, accounted for 4.08%. These paper producing countries are either economically developed or at a high-speed development stage, and they attach more importance to supply chain risk management than other countries.

Table 2 .Top 10 countries/regions for supply chain risk management papers from 1997 to 2018

Ranking	country / region	Quantity	percentage	Cited times	Total correlation strength
1	United States	797	30.7%	20333	451
2	China	531	20.4%	7243	300
3	United Kingdom	269	10.3%	4712	251
4	Germany	157	6.0%	2704	124
5	Canada	150	5.8%	3111	139
6	Australia	128	4.9%	2912	100
7	Iran	118	4.5%	2126	65
8	Taiwan, China	113	4.3%	1635	49
9	India	110	4.2%	1753	83
10	France	96	3.7%	1559	103

VOSviewer uses bibliometric analysis to generate knowledge maps for major research countries in the field of supply chain risk management. Figure 2 shows the density heat map, which visually shows the research heat and correlation strength of the supply chain risk management country. The data in Figure 2 is shown as the label and the corresponding heat map area, the color of the area centered on the corresponding label, which depends on the number of papers published in that country. The larger the number, the redder the label color, the smaller the number, and the bluer the label color. Concentric circle labels indicate that these countries have a closer relationship, while non-concentric areas indicate a lower correlation strength. In this density map, the countries with larger nodes are located at the center of the block, namely the United States, China, and the United Kingdom. According to the statistics in Table 2, the number of papers published in the United States accounted for 30.7% of the total number of papers published, and the density shown on the map was the largest (and the most red), indicating that the United States is the international science center for supply chain risk management research. Although China's supply chain risk management research started late, with the increasing attention of enterprise managers to supply chain risk management, the number of papers has risen to the second place. The UK has been working on supply chain low carbonization and sustainability risk issues since the 21st century [12], and the number of research papers on supply chain risk management ranked third.

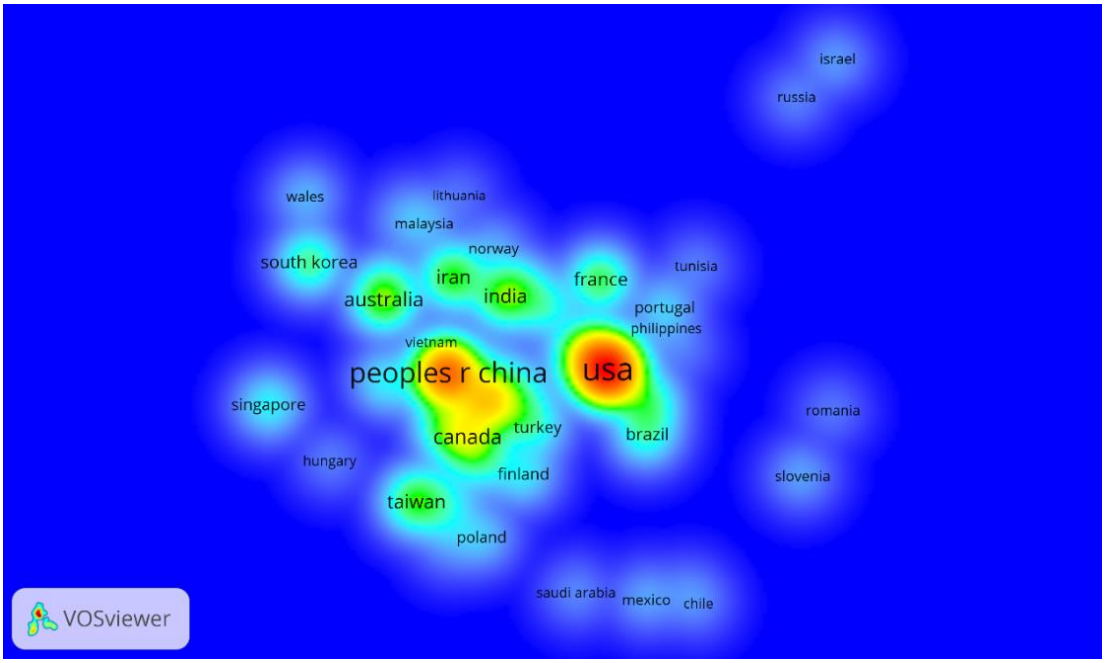

Fig. 2. focuses on the density of research in the field of supply chain risk management in countries/regions

3.4 Quantitative analysis of literature

The co-citation analysis of the literature reflects the relationship between the two cited documents and summarizes the literature cited in other papers. The more times two documents are cited simultaneously, the greater the similarity between them can be considered [13]. Therefore, through the co-citation analysis of the literature, important knowledge in the research field can be found efficiently and conveniently from a large number of cited documents. In addition, the relevance and development process of the literature can be analyzed and explored. In the 2,600 papers on supply chain risk management, 82,573 references were used, and VOSviewer was used to generate a clustered network map that was cited in the supply chain risk management literature. In view of the visualization ef-

fect, important references should be included in the knowledge. In the map, the setting must be quoted at least 20 times in 2,600 papers, and in the 82,573 references, a total of 395 articles satisfy the threshold.

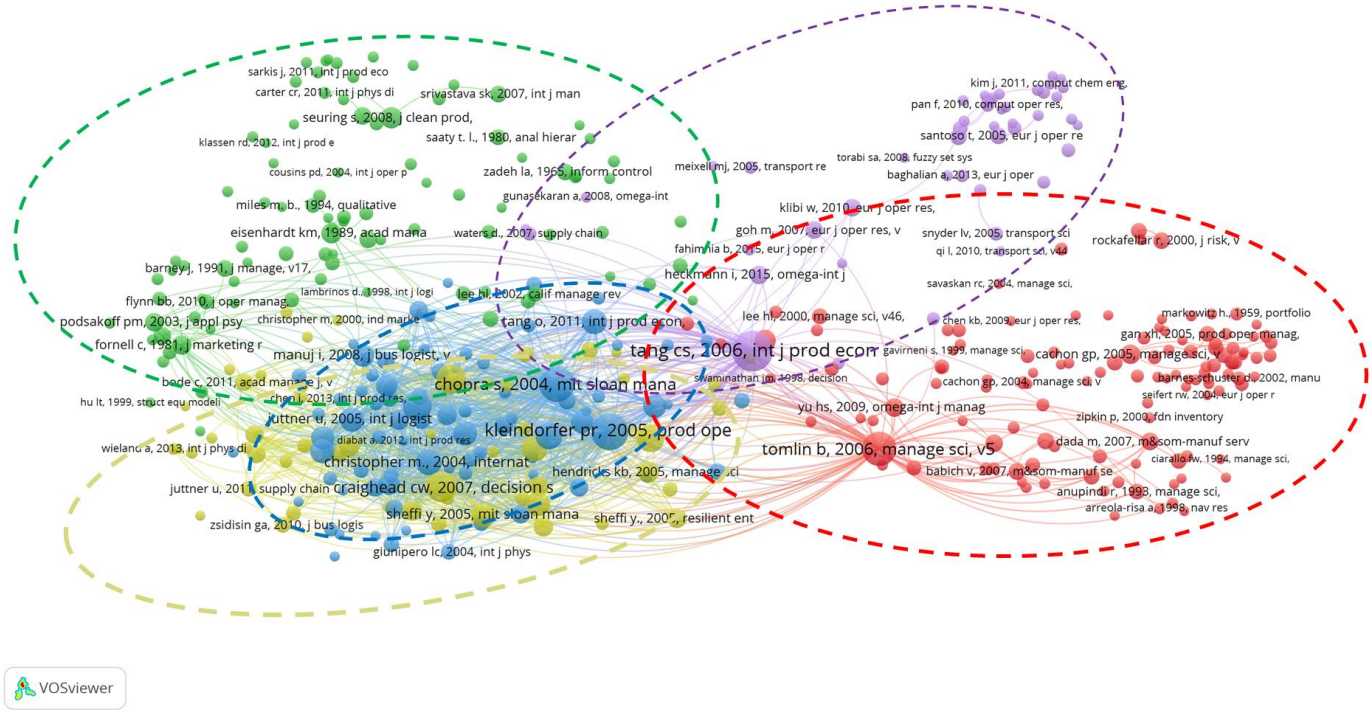

Fig. 3. Literature co-cited analysis network diagram

As shown in Figure 3, the knowledge map is divided into five clusters of different colors in the generated cluster network graph. These clusters are related to the number of nodes and weights in the VOSviewer and the strength of the association between the nodes [14]. The size of the circle represents the number of citations, ie, the larger the circle, the more times the supply chain risk management published paper is cited. The smaller the distance between the two labels, the stronger the association between them and the higher the similarity. In these papers, circles of the same color represent similar themes. The co-cited graphs show how the references to supply chain risk management papers are clustered together and clearly illustrate five different clusters, each of which represents a hot area of supply chain risk management research. There is a certain overlap between the five clusters, indicating that there is a cross-disciplinary study between the various research fields in this multidisciplinary research field. According to the title and keyword review of the representative papers in the five groups, an appropriate label can be assigned to each cluster cluster, and the analysis results are shown in Table 3.

Table 3.5 papers with the most cited five clusters

Author	Paper title	Source journal	Representative field (color)
Tang, Christopher S.	Perspectives in supply chain risk management	INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS	Risk quantitative model (purple)
Kleindorfer, PR	Sustainable operations management	PRODUCTION AND OPERATIONS MANAGEMENT	Lean closed loop supply chain (blue)

Tomlin, Brian	On the value of mitigation and contingency strategies for managing supply chain disruption risks	MANAGEMENT SCIENCE	Supply chain uncertainty (red)
Seuring, Stefan	From a literature review to a conceptual framework for sustainable supply chain management	JOURNAL OF CLEANER PRODUCTION	Green supply chain (green)
Hendricks, KB	An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and equity risk of the firm	PRODUCTION AND OPERATIONS MANAGEMENT	Stock risk (yellow)

In the purple clustering, the classic document with the largest number of co-citations (the largest circle on the graph) is Tang, Christopher S (2006) in *Perspectives in supply chain risk management* published in "*INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS*". This paper was cited 324 times, with a correlation strength of 389, which is the most cited paper in all the cited papers, indicating that this paper is one of the most important references in the field of supply chain risk management. In this article, Tang, Christopher S believes that outsourcing manufacturing and product diversification are effective for compan- ies to obtain cost advantages and market share in a stable environment, but they may make the supply chain more vulnerable to uncertain economic cycles and consumption. Demand and the damage caused by natural and man- made disasters. In this regard, he reviewed various quantitative models proposed by resea- rchers in the field of supply chain risk manage- ment, and linked various supply chain risk management (SCRM) strategies examined in the research literature to actual situations, for later researchers. Research in this important area plays a useful role.

Among the blue clusters, the document with the highest number of co-citations is *Sustainable operations management* published by Kleindorfer, PR (2005) in "*PRODUCTION AND OPERATIONS MANAGEMENT*". A total of 267 times were cited, with a total correlation strength of 370, indicating that this paper has an important position in the co-citation network structure. In this paper, Kleindorfer, PR believes that the company is facing increasing pressure, which requires them to pay more attention to the products and services provided by the company and the impact of the deployed processes on the environment and resources, and to reconcile corporate profits. The relationship between humans and the earth. The challenges generated in this process include combining environmental, health and safety issues with green product design and green operations and a closed-loop supply chain. These ideas from Kleindorfer, PR have had a profound impact on the field of sustainable management.

In the red clustering, the document with the highest number of citations is Tomlin, Brian (2006) *on the value of mitigation and contingency strategies for managing supply chain disruption risks* published in "*MANAGEMENT SCIENCE*", a total of 232 times, The total correlation strength is 232. In the daily business activities of the enterprise, uncertainty is once synonymous with risk because the uncertainty of the supplier or the uncertainty of the market environment is the most common predisposing factor in the supply chain risk of the enterprise. In this paper, Tomlin, Brian argues that the percentage of suppliers' uptime and the nature of supply disruptions are key determinants of the best strategy. Within a certain percentage of uptime, as supply disruptions become less frequent but longer, reducing purchases is increasingly favored than reducing inventory. In addition, a hybrid mitigation strategy (purchasing and holding inventory from a reliable supplier) is the optimal solution if the company circumvents the desired risk under conditions of unreliable supplier capacity.

Among the green clustering, Seuring is the most frequently cited document. Stefan (2008) published in "*JOURNAL OF CLEANER PRODUCTION*" of *From a literature review to a conceptual framework for sustainable supply chain*

management.A total of 90 citations with a total correlation strength of 847.Interest in sustainable supply chain management has surged in recent years, both in academia and in the business world, as environmental awarene- ss has grown.This can be seen from the number of related papers published, especially in some special journals.In this sustainable supply chain on behalf of the paper, it first analyzes the 191 papers published from 1994 to 2007, provides a literature review about sustainable supply chain management, second, Seuring, Stefan, we propose a conceptual framework, the study of this field are summariz- ed, and then puts forward two kinds of different strategies: (1) the risk of supplier management and performance, and (2) the sustainable product of supply chain management.Obviously, in 2008, for the boundary, this paper studies in the field of sustainable supply chain manage- ment plays a key role, which forms a connect- ing link between the preceding and business practitioners and academics have found this review useful, because it not only learn from the past research results and summarizes the main research direction in this field, further discusses the specific features of sustainable supply chain and the limitations of existing research, which will stimulate further green supply chain research.

In blue clustering, the most frequently cited document is Hendricks, KB (2005) published in "*PRODUCTION AND OPERATIONS MANAGEMENT*", *An empirical analysis of the effect of supply chain disruptions on long-run stock price performance and Equity risk of the firm*. A total of 152 times were cited, with a total correlation strength of 2,800. When the enterprise supply chain is interrupted, the most intuitive manifestion of the poor performance of the company is the stock price. This paper uses the 827 supply chain interruption announcements issued during the period of 1989-2000 as a sample to study the supply chain disruption to the stock price. Long-term impact and stock risk impact. Studies have shown that the average abnormal stock return rate of companies that have experienced supply chain disruption is close to -40%, and companies will not recover quickly from the negative impact of the disruption. The company's stock risk has also increased signif- icantly around the announcement date. Supply chain disruption will affect the company's stock price, and corporate stock price and credit evaluation may also lead to disruption of the supply chain. With the development and appli- cation of supply chain financial services, more and more researchers will pay attention to stoc- k risk research. field.

3.5 Burst Detection Analysis——Analysis of Supply Chain Risk Management Research Trends

The Burst Detection Algorithm (BDA) was first proposed by Kleinberg to identify keywords with high-density features in documents by the density of keyword frequency changes [15]. BDA can be used to detect sudden increase in the frequency of use of keywords in a research field. It can be applied to keywords such as authors, references, journals, countries, institutions, keywords, etc., when performing surprise detection analysis on author keywords. The burst weight, burst start and burst end year of each burst keyword can be obtained to analyze the change of research trend in the supply chain risk management field.

In the Sci2 Tool software, a time bar graph is used to represent the time distribution of the burst keywords, especially the time span indicating the burst keywords. This article imports the data downloaded from WoS into the Sci2 Tool and performs burst detection. Since the WoS database can only download 500 records at a time, the 2600 records are manually integrated before importing the data. The tool used in this article is the text editing software notepad.) and save as isi format. Since the burst detection algorithm is case sensitive, the fields to be analyzed must be normalized before running the algorithm. In this paper, the "Lowercase, Tokenize, Stem, and Stopword Text" in the data preprocessing column of the Sci2 Tool software is used. The item doubles the uppercase and lowercase words of 2600 pieces of data and deletes the stop words such as "of" and "in". The data is pre-processed and then re-imported into the software for burst keyword detection analysis. The parameters are set as follows: Gamma=1, Density Scaling=2.0, Bursting States=1, Bursting Length=1. Through the keyword burst detection analysis of 2600 records of data, 20 keywords are obtained, and the specific time distribution of the burst keywords is shown in Fig. 5 and Table 4.

Table 4 .1997-2018 keyword burst detection distribution table

Time Distribution	Word	Level	Weight	Length	Start	End
2000-2008	genetic algorithms	1	3.575633	14	2000	2013
	e-procurement	1	4.181103	9	2002	2010
	electronic commerce	1	4.0773	10	2002	2011
	electronic marketplace	1	3.743016	10	2003	2012
	vendor managed inventory	1	5.096179	7	2004	2010
	multiple criteria decision making	1	4.149897	6	2004	2009
	radio frequency identification (RFID)	1	4.578618	8	2005	2012
	policy development	1	4.432407	3	2005	2007
	scheduling	1	4.467442	4	2005	2008
	information management	1	3.806081	3	2006	2008
	product recall	1	3.381648	6	2006	2011
2009-2016	Inventory control	1	5.955364	6	2008	2013
	cost	1	3.430339	1	2012	2012
	conditional value-at-risk	1	4.15695	2	2013	2014
	responsibility	1	3.238564	1	2015	2015
	structural equation model (SEM)	1	3.810541	2	2015	2016
2017-2018	sustainable	1	14.30549	2	2017	2018
	emerging economies	1	3.222605	2	2017	2018
	big data	1	4.50225	2	2017	2018
	supply chain finance	1	3.311123	1	2018	2018

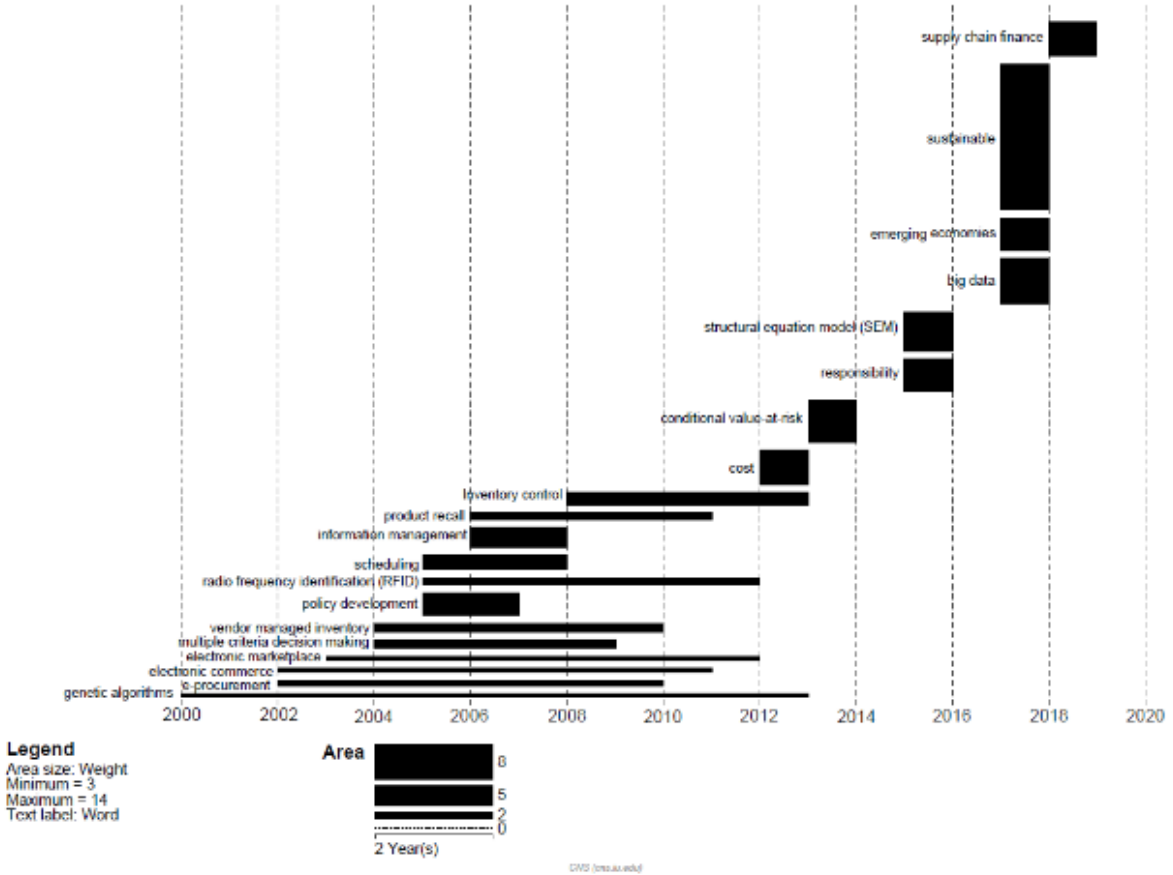

Fig. 4.1997-2018 keyword burst detection analysis time bar chart

As can be seen from Fig. 4, the left side of each bar is the burst keyword represented by it, the length of the bar represents the duration of the burst, and the width of the traverse represents the burst weight of the keyword. Through keyword burst detection analysis, we can more accurately grasp the development trend of this field. Now we have summarized the staged research hotspots in this field as follows:

In 2000-2008, the earliest emergent keywords appeared in 2000, indicating that the supply chain risk management research began to develop rapidly after 2000, and gradually became a research hotspot at that time, and formed a variety of research. A large number of sudden keywords (11 in total, accounting for 55%), such as genetic algorithm, e-procure- ment, policy environment, e-commerce, etc. From the perspective of sudden keywords, in the early research activities, supply chain risk management research covers a wide range, but it is worth noting that the “electronic” root appears many times, indicating that Internet technology and electronic information technolo- gy are on the supply chain at this stage. The impact of risk management research was a hot topic at the time. For example, under the Vendor Managed Inventory (VMI) program, RFID technology is used to reduce supply chain risk levels [16].

In 2009-2016, the number of sudden keywords decreased by 6 compared with 2000-2008, but the burst weights were more balanced. The results show that the research network of supply chain risk management has gradually expanded and more research branches have been produced. It can be seen from Figure 5 that the main research trends in this period focus on inventory control, cost, conditional risk value, information asymmetry, etc. . It shows that after the previous stage of research and development, supply chain risk management research begins to reduce the risk while considering the cost factor, and the research shows that the conditional risk value (CVaR) measurement model can effectively improve the risk management level of the supply chain [17].

In 2017-2018, in the keyword burst detection chart, there are four keywords with high burst weights in the supply chain risk management research, namely “sustainability”, “emerging economy” and “big data”. And “supply chain finance”, the biggest weight of sudden “sustainability” (burst weight: 14.3), in fact, a few years ago, European researchers began to be sustainable in the context of sustainable development. Sexual supply chain manageme- nt research [18], but the increasingly fierce and ever-changing business environment has brought huge challenges to enterprises. They urgently need a sustainable supply chain to actively and flexibly deal with uncertainties and ensure The company's normal operations [19], so "sustainability" will likely become a research hotspot again. Also worth noting is the key word “supply chain finance” that began in 2018. In recent years, the development of the Internet has provided new channels and opportunities for SME financing. Financial institutions will transfer materialized capital in the context of big data. Turning into online data, they need more effective risk prediction methods, and supply chain finance as the core driving force of supply chain development, is crucial to solve the financing difficulties of many small and medium enterprises in the upstream and downstream of the supply chain [20], supply Chain finance will become a hot issue in the theoretical and practical circles.

4. Conclusion

This paper focuses on the subject and frontier research of supply chain risk management research, adopts the knowledge mapping analysis method based on scientometrics, and uses VOSviewer and Sci2 Tool tools to publish quantitative analysis from journal papers and countries/regions. The analysis of supply chain risk management is analyzed by burst analysis and other aspects. The main conclusions are as follows:

(1) The rapid growth of the number of papers

indicates that supply chain risk management research has developed rapidly in the global academic community. According to the distribution of papers in various countries, the United States, China and the United Kingdom are among the best, indicating that these countries are the development centers and active areas of supply chain risk management science. In terms of source journals, the journals of" *INTERNATIONAL JOURNAL OF PRODUCTION ECONOMICS*", "*INTERNATIONAL ESTATE OF PRODUCTION RESEARCH*", and "*EUROPEAN JOURNAL OF OPERATIONAL RESEARCH*" are supply chains, both in terms of the number of papers published in journals and the number of journal articles cited. An authoritative journal in the field of risk management research is an important platform for publishing and exchanging research results.

(2) Through the establishment of literature co-citation clustering network map, extract the knowledge base of supply chain risk management research, insight into the development of theory and method, and highlight the results of supply chain risk management research in recent years. The five classics with the highest citation frequency are concentrated in the “Quantitative Model of Supply Chain Risk Management”, “Lean Closed-loop Supply Chain”, “Supply Uncertainty”, “Green Supply Chain” and “Stock Risk”. Several clusters are the core research hotspots of supply chain risk management. The authors of these five papers (Tang, Christopher S, Kleindorfer, PR, Tomlin, Brian, Seuring, Stefan, Hendricks, KB) are research experts with outstanding contributions in the field of supply chain risk management research.

(3) Using the burst detection analysis in Sci2 Tool to explore the research trend of supply chain risk management, and find that the four keywords “sustainability”, “emerging economy”, “big data” and “supply chain finance” will evolve into The frontier of research in the field of supply chain risk management. In addition, it can be found that the main keyword durations appearing in the research trend are sudden in two stages, such as “genetic algorithm”, “product recycling”, “information management”, “policy environment”. It is an important part of supply chain risk management research.

In the next step, we will focus on the growth analysis and prediction of sudden keyword keywords in the research field of supply chain risk management, and provide researchers with more reliable frontier research trends.

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