Environmental Science and Pollution Research (2022) 29:66041–66067
https://doi.org/10.1007/s11356-022-22255-x

REVIEW ARTICLE

Risk management in sustainable supply chain: a knowledge map towards intellectual structure, logic diagram, and conceptual model

Liang Wang[1] · Yiming Cheng[1] · Zeyu Wang[2]

Received: 8 March 2022 / Accepted: 22 July 2022 / Published online: 1 August 2022

Abstract

The global spread of COVID-19, international trade protectionism, geopolitical conflicts, and climate change presents challenges and risks to sustainable supply chains (SSCs). In recent years, scholarly interest in sustainable supply chain risk management (SSCRM) has continued to rise. A helpful literature review is necessary to enable supply chain practitioners to apply empirical findings from academic research or conceptual frameworks to their operations to maintain the stability and competitiveness of sustainable supply chains. The knowledge map of SSCRM is explored in this study using both quantitative and qualitative analysis. A total of 793 articles were retrieved to reveal the knowledge map of SSCRM. Scientometric and context analysis are combined in quantitative analysis to identify the intellectual structure of risk management research related to SSC. Then, a critical review is conducted in qualitative analysis to summarize and analyze the motivations, strategies, approaches, and tools of SSCRM. Combining the quantitative and qualitative analysis results, a conceptual model is constructed for SSCRM from three aspects: (1) risk identification, (2) risk assessment, and (3) risk mitigating and responding. Finally, future research directions are suggested based on the conceptual model for guiding the theories and practice of SSCRM. This study can work as a roadmap for providing appropriate risk management policies and toolkits to SSC, which could advance theoretical thinking on how to mitigate SSC risks.

Keywords Sustainable supply chain · Risk management · Knowledge map · Intellectual structure · Logic diagram · Conceptual model

Introduction

Sustainable supply chain and risk management

Many corporations and organizations have acknowledged the need for sustainability in business as public awareness of environmental and social concerns has grown. So SSC emerges as the times require and becomes one of the hot issues in research. Especially in the context of the COVID-19 pandemic, the government has increased government spending, which has stimulated economic recovery and increased per capita GDP but has also brought environmental degradation, posing a considerable challenge to sustainability issues (Adebayo et al. 2022; Isik et al. 2022; Ongan et al. 2022; Sharif et al. 2019). However, there is no agreed-upon definition of SSC. Scholars from different schools and academic backgrounds have different understandings of SSC. According to Securing and Müller (2008), SSC is the management of natural resources, funds, and information by members of the supply chain to protect the interests of customers and shareholders by considering the three dimensions of sustainable development: economy, environment, and society. Carter and Rogers (2008) put the long-term interests into the supply chain. They characterized SSC as the company and its supply chain's long-term economic performance that can be improved by coordinating, integrating, and managing its key business processes while considering

Responsible Editor: Arshian Sharif

✉ Liang Wang
liangwang@dlmu.edu.cn

Yiming Cheng
chengyiming@dlmu.edu.cn

Zeyu Wang
wangzeyu@gzhu.edu.cn

[1] School of Maritime Economics and Management, Dalian Maritime University, Dalian 116026, China

[2] School of Management, Guangzhou University, Guangzhou 150001, China

the company's social, environmental, and financial goals. One of the most thorough definitions that included organizational flexibility for the introduction of risk in SSC was provided by Ahi and Searcy (2013). According to their research, SSC can create a cooperative and coordinated supply chain and effectively manage stuff, information, and capital flows related to procurement, production, distribution, and services by integrating economic, environmental, and social aspects, and increase the profitability, competitiveness, and resilience of businesses in the long and short term (Ahi and Searcy, 2013). Although these definitions are not identical, most of them combine environmental responsibility, social responsibility, and economic benefits with the supply chain, which is congruent with Elkington's notion of the "triple bottom line" presented in 1998 (Elkington 1998).

Evidence shows that enterprises suffer huge losses due to ignoring the supply chain's social responsibility, environmental problems, and economic impact. For example, multinational enterprises in Bangladesh's Rana Plaza building suffered significantly after the building's collapse, and the import volume of brand countries of origin related to the event decreased by about 40% in 2013 (Koenig and Poncet 2019). In 2015, 165 people were killed in the explosion of a dangerous goods warehouse of Ruihai company in Tianjin, China, causing a direct economic loss of RMB 6.866 billion (State Council of China 2016). Volkswagen's emissions cheating scandal in 2015 caused its market value to drop by a third in just 1 week (Rhodes 2016). In contrast to a standard supply chain, the risks associated with SSC include those posed by natural disasters like earthquakes and flooding. Improper management of natural disaster risks will also bring considerable losses to the company. For example, Toyota's output dropped by 40,000 automobiles in 2011 due to the earthquake and tsunami in Japan and the nuclear crisis that followed, costing the company $72 million per day in revenues (Pettit et al. 2013). The supply chain for computer and automobile makers was harmed by the 2011 floods in Thailand (Chopra and Sodhi 2014).

The high-risk supply chain is unstable and ineffective. Once interrupted, it will suffer huge losses. To retain the SSC's long-term strategic advantage, it is critical to reduce its risks and threats (Valinejad and Rahmani 2018). Environmental problems and social responsibility may lead to SSC risks. In terms of environmental problems, environmental pollution or waste of resources may damage the company's reputation. Damage to reputation may affect the company's profits and damage the brand's image. Low-carbon policies are also critical. Since the Paris Agreement, governments have made many efforts to reduce greenhouse gas emissions, but this has brought new risks to the supply chain of many industries. For example, tourism, agriculture, and transportation industries are closely related to carbon dioxide (Aziz et al. 2020; Isik et al. 2017; Sharif et al. 2020a). In terms of social responsibility, non-compliance with sustainability requirements may lead to consumer boycotts, labor disputes, costly legal proceedings, and other losses (Lee and Vachon 2016). In terms of economics, financial mechanisms targeting the economy can also lead to environmental and social issues, creating SSC risks (Sinha et al. 2021).

Previous literature on sustainable supply chain risk management

In fact, over the past few years, supply chain managers and academia have been increasingly concerned about SSCRM, as can be seen from the growing amount of studies recently published. As mentioned above, the triple bottom line concept integrates the three dimensions of environmental, social, and economic into the supply chain, defining three aspects of SSC (Seuring and Müller 2008). In particular, environmental regulations, global warming, climate change, and energy shortages affect the achievement of sustainability goals and pose many risks to the supply chain (Ali et al. 2021; Ho et al. 2015; Isik et al. 2021a, b; Shahzad et al. 2021). Achieving sustainability goals brings new risks to traditional supply chains, and studying these risks is essential. Some scholars have carried out research from an industry perspective. For example, Choirun et al. (2020) studied SSCRM in agriculture. Chowdhury and Quaddus (2021) studied SSC risks in the context and apparel industry. Different industries have their characteristics. For example, the leading SSC risks in the textile industry are the use of child labor and long working hours. Other scholars have developed risk identification, assessment, mitigation, and response research. For example, Abdel-Basset and Mohamed (2020) use the TOPSIS-CRITIC methodology to identify and assess SSC risks. Hsu et al. (2022) use the QFD-MCDM approach to mitigate SSC risks. Kusi-Sarpong et al. (2021) use big data to analyze critical risks to SSC. Most of these risks are triggered by pressure from external demands such as government, customers, and other stakeholders (Köksal et al. 2017). In response to these pressures, the word "risk management" is receiving increasing attention and a review of SSCRM is necessary.

Based on this, a search related to SSCRM found that only seven review papers were found, including Chiang et al. (2021); Koksal and Strahle (2021); Choirun et al. (2020); Bubicz et al. (2019); de Oliveira et al. (2019); Rafi-Ul-Shan et al. (2018); and Koeksal et al. (2017). The review by Chiang et al. (2021) focuses on the application of IT in SSC, with risk management not being the main objective of the review. Among several papers comparatively relevant to SSCRM, the major industries focus on fashion and agriculture (Choirun et al. 2020; Koksal and Strahle 2021; Rafi-Ul-Shan et al. 2018). The above three review articles do not conflict with the content of this review, which focuses on a particular industry in isolation. Bubicz et al. (2019)

and Koeksal et al. (2017) reviewed the social responsibility aspects of SSC, and the limitation of these two articles is that they review only one dimension of SSC. The paper by de Oliveira et al. (2019) is the closest attempt to this paper which discusses the impact of internal and external risk factors regarding environmental risks on a company's supply chain. However, their research is not on SSC, and the risks discussed are not exclusively SSC risks. These seven reviews only comb through the literature on one dimension of SSCRM or a few specific industries. They do not provide a comprehensive, objective, and systematic picture of the knowledge map of the field.

Research objects and purposes

Many studies of SSC have focused on risk, and risk management is essential to SSC management. However, the overall research in this area is still fragmented, and the literature review on SSCRM is scarce and incomplete. For example, the literature review by de Oliveira et al. (2019) focuses on SSC risks from an environmental perspective. The literature review by Choirun et al. (2020) analyses the risks of SSC in agriculture. Given today's environment of increased uncertainties such as epidemics, climate, and politics, it is crucial to summarize and review risk management for SSC. It is crucial to keep practitioners and interested readers abreast of the latest developments and management practices in SSCRM, which contribute to the development of SSC management. A literature review is a methodical, transparent, and repeatable method for discovering, assessing, and interpreting relevant literature that contributes to developing a trustworthy knowledge base by amassing existing information (Fisch and Block 2018). Ralston et al. (2017) argue that there is a need to review previous literature to help researchers study hotspots that are still to be studied accordingly. A helpful literature review allows supply chain practitioners to apply empirical findings or conceptual frameworks from academic research to their operations to maintain SSC's stability and competitiveness while enabling research scholars to shed more light on SSC.

Articles on SSCRM usually focus only on environmental issues, and some scholars lack a comprehensive understanding of SSCRM. At the same time, there is a wide range of research on SSCRM, covering a wide range of industries, with a wide variety of research methods and a lack of holistic analysis. Accordingly, this study aims to fill this gap. For a thorough knowledge of SSCRM, this research included scientometrics analysis and a thorough qualitative examination. Scientometrics research is the presentation of published articles from the standpoint of objectivity and quantitative (Zhou and Song 2021). The analysis's important outcome is the "intellectual structure," a scientometrics notion for visualizing the structural properties and study horizons. An intellectual structure can be used to establish a clear visual map that displays the intellectual structure in the subject of SSCRM in a complete, objective, and systematic manner. Establishing a knowledge map can effectively make up for the lack of current research. Despite its benefits, scientometric analysis cannot fully grasp the issue under investigation (Booth et al. 2021). Through quantitative analysis, the research framework of SSCRM can be established, and the knowledge structure of this field can be deeply analyzed. This study aims to help supply chain managers and academic researchers better understand the knowledge of SSCRM and increase emphasis on risk management. More specifically, it is to answer the following five questions.

RQ1: What is the intellectual structure of SSCRM?

RQ2: What are the risk types of SSCRM?

RQ3: How to apply risk management strategies in SSCRM?

RQ4: What are the main modeling approaches for SSCRM?

RQ5: What are the conceptual model and future research directions of SSCRM?

To answer the above questions, this paper intends to use a combination.

of qualitative and quantitative research as the basis for a qualitative discussion based on quantitative research. A quantitative analysis can answer RQ1. Scientometric analysis can visualize the knowledge structure of SSCRM and help researchers find topical issues for research and the classic literature in the field. By answering RQ2, RQ3, and RQ4 through a discussion of the quantitative results, the qualitative discussion allows for a more detailed analysis of the logical relationships demonstrated by these quantitative results and can help the researcher gain a quick and comprehensive understanding of the critical knowledge of SSCRM. It concludes with a conceptual model and future research directions, which can help supply chain managers and academic researchers better understand the risk factors, research methods, gaps, and impacts of SSCRM.

The remainder of this article is structured as follows: The research methodologies used for this study are discussed in the "Methodology" section. The intellectual structure of SSCRM is quantitatively identified and analyzed in the "Intellectual structure of risk management in sustainable supply chain" section. In the "Logic diagram of risk management in sustainable supply chain" section, a critical review is conducted in qualitative analysis to reveal the logic diagram of SSCRM. Then, the "Conceptual model and future research directions of risk management in sustainable supply chain" section proposes a conceptual model and potential research objectives. Finally, the "Conclusion" section summarizes the study findings.

Methodology

Research design

The knowledge of SSCRM is explored using a combination of quantitative and qualitative analysis approaches in this research. Figure 1 depicts the study framework for this study.

A literature review provides an in-depth description of existing papers in a field of study and is reproducible, illuminating, and explanatory (Chiang et al. 2021). The following steps are included in the research process for this article, as shown in Fig. 1.

Step 1—research scope: The main issue in step 1 is to clarify the review's scope and avoid ambiguity in the review. Firstly, identify the review process and research themes for this paper based on previous classic literature. The systematic literature review (SLR) approach increases the chances of finding the subject study and the study's reliability (de Oliveira et al. 2019). Seuring and Müller (2008), for example, conducted a four-step process of collecting materials, the descriptive analysis of those materials, the identification of categories, and the assessment of those materials in their literature review. de Oliveira et al. (2019) extend the research framework of risk management in supply chains by describing each study step in more details. In conjunction with the above papers, this study uses a four-step research process of research scoping, data collection, results analysis, conceptual modeling, and future research directions. Secondly, as defined in the "Introduction," the research scope of this paper is SSCRM. Finally, it was determined that the research criteria for this paper were all relevant articles in the database from 1996 to 2021 while excluding conference articles, reviews, and non-peer-reviewed articles.

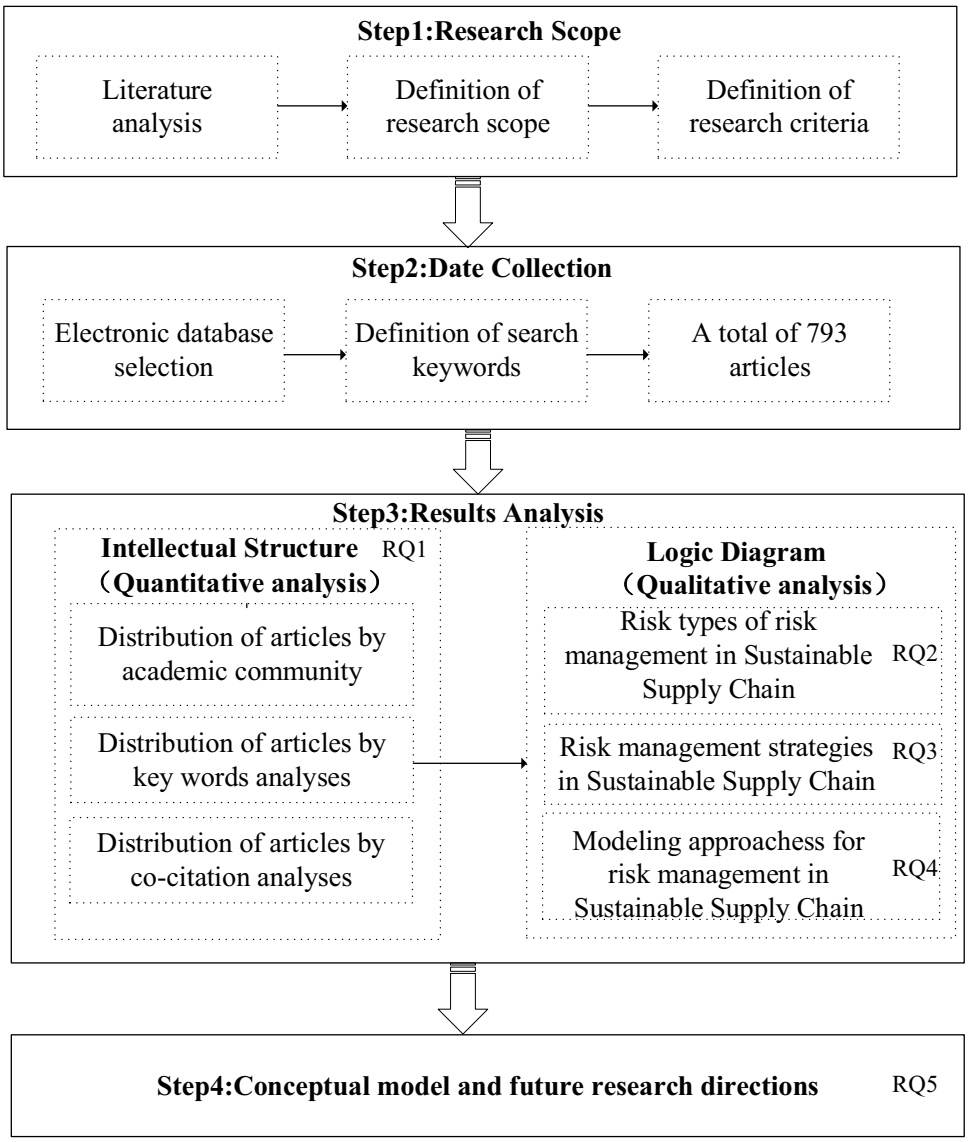


Fig. 1 The research framework of this study

Step 2—data collection: The second step is data collection, which begins with the selection of a suitable database; the database used for this study is the Web of Science. Web of Science is ideally suited to the analysis needs in this paper because it covers most of the quality literature and is the most reliable and commonly used database. The next is to select appropriate keywords. The detailed steps are shown in the "Research design" section. Finally, 793 articles were screened.

Step 3—results analysis: Scientometric analysis is first carried out to establish intellectual structure, which can be used to create clear visual maps that give a complete, objective, and systematic picture of the knowledge structure of the SSCRM discipline. The intellectual structure includes academic community, keyword analyses, and co-citation analyses, and the quantitative analysis process is shown in the "Quantitative analysis approach" section. The three categories of risk type, model, and strategy were summarized through keyword co-occurrence of intellectual structure. The three categories are further discussed in detail through qualitative analysis to answer the three questions of SSC risk types, risk management strategies, and modeling approaches. The qualitative analysis method is shown in the "Qualitative analysis approach" section.

Step 4—conceptual model and future research directions: Finally, a conceptual model of SSCRM is developed based on the analysis in step 3. Future research directions are proposed, and the findings of this paper are discussed.

Data collection

The initial stage in this research's scientometrics journey is to choose a database to gather high-quality data. Similar to other prior scientometrics research (da Silva et al. 2020; de Oliveira et al. 2019; Rafi-Ul-Shan et al. 2018), in this work, data is collected using Web of Science's core collection database. Web of science covers most high-quality literature, which can fully meet the needs of scientometrics analysis.

The second stage is to get data from the chosen database and filter it for scientometric analysis. The appendix summarizes the keywords used by researchers in their study on SSCRM. Considering the extent to which these keywords are covered and the theme of this article, we try to take more keywords into account to ensure the comprehensiveness and reliability of the search. The summary of keywords selection criteria is shown in Table 1.

"BS" stands for the title of the article, "TS" stands for the subject, and "*" stands for fuzzy search. Because the search was done on April 2, 2021, the time from January 1, 1996, to April 2, 2021, was included in this research. Finally, 793 bibliographic records were obtained, and the number of articles per year is shown in Fig. 2.

Table 1 Keywords selection criteria

Keywords	KeyWords Plus	BS OR TS
sustainable	"sustainable" OR "sustainability" OR "green" OR "social" OR "ethic*"	BS
supply chain	"purchasing" OR "sourcing" OR "supply" OR "supply chain" OR "logistics" OR "logistical"	BS
risk	"risk*" OR "disaster" OR "hazards" OR "resilience" OR "unpredictable" OR "Robustness" OR "vulnerability" OR "uncertainty" OR "threat" OR "disruption" OR "disturbance" OR "crisis" OR "catastrophe" OR "peril" OR "hazard" OR "emergency" OR "resilience"	TS

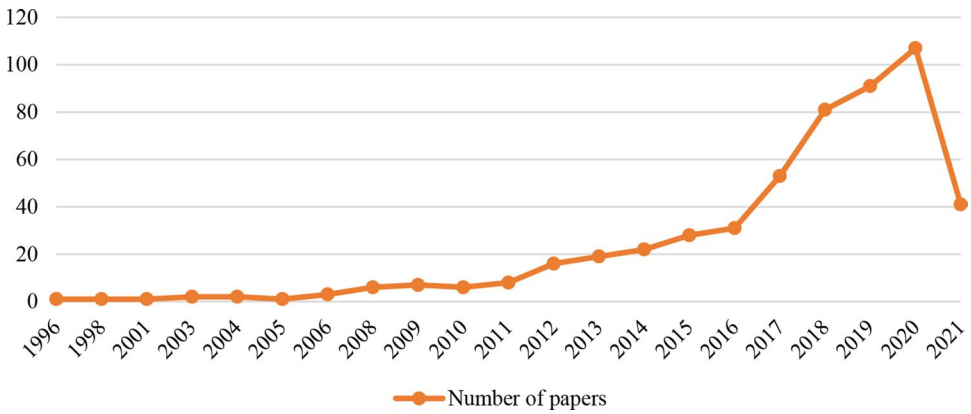


Fig. 2 Number of articles per year

Analysis approaches

Quantitative analysis approach

Using scientometrics analysis, we can get an overall understanding of the current research on SSCRM. Scientometrics analysis can be carried out through various software, including VOSviewer, Biblioshiny, CiteSpace, and Bibexcel. As a freshly designed software package based on the R environment, Biblioshiny is more adaptable, combining the visual features of numerous measuring tools (Shi et al. 2020). Biblioshiny is simple to operate and can provide a solid graphic visualization effect. A literature review by Shi et al. (2020) analyzed public–private partnerships in the construction industry using Biblioshiny. This paper uses both Biblioshiny and VOSviewer for the analysis. Biblioshiny has a richer form of data analysis, which is needed to build the intellectual structure of this paper. Through Biblioshiny academic community, keywords analyses, and co-citation analyses were carried out. Academic community analysis identifies the most relevant journals, the most influential institutions, and academics and their partnerships, which helps provide a quick overview of knowledge in SSCRM. Keywords are the most concise and essential description of an article by the author. Keyword analysis allows scholars to find popular themes and key research points in the field of study. The co-citation analysis allows scholars to sort out the research lineage between scholars and identify the more critical articles in the field of study. At the same time, this paper uses VOSviewer for keyword co-occurrence network and co-citation network analysis. The VOSviewer clustering algorithm is more mature than Biblioshiny, and the results are more reliable, forming an excellent complementary relationship with Biblioshiny.

Qualitative analysis approach

Qualitative analysis is carried out according to the keywords analysis of scientometrics. The articles were categorized according to the keyword co-occurrence network analysis results. The categories in SSCRM were summarized by reading the abstracts and keywords, a process that was done in a continuous process of construction, revision, testing, and iteration. Read further the articles in the categories with higher citations published in relatively recent years. Combined with keyword and citation analysis, find out essential articles in SSCRM, and read these articles. Three scholars defined and verified the above process to exclude the controversy defined by a single scholar.

Intellectual structure of risk management in sustainable supply chain

Academic community

Journal sources

Knowledge of the most relevant journals lets scholars know where to submit their research articles. In addition, it allows scholars to find articles related to SSCRM more quickly. The top 20 journals that published the most articles on SSCRM are shown in Fig. 3, which can be considered the most relevant in SSCRM. Journal of Cleaner Production, Sustainability, and International Journal of Production Economics are relatively more productive than the rest of the journal sources. The above analysis shows that the subjects of SSCRM mainly focus on environmental management and sustainability.

Country

Using Biblioshiny to analyze the countries of the article, we can find the most influential countries. The top 10 countries in the world have published the largest number of articles on SSCRM, as shown in Table 2. China has the largest number of published articles, with 183, much more than any other country, followed by the USA (132 articles) and Iran (104 articles).

Figure 4 shows the countries in which articles on SSCRM have been published. The depth of color is directly proportionate to the number of articles published. As shown in Fig. 4, 53 countries have published relevant studies, of which 15 countries have published more than ten articles. There are approximately 70% of countries with only 1–10 articles, which means there is still a lot of room for studying SSCRM in these countries.

Figure 5 shows the network of cooperative relations among countries. There are three apparent clusters in the whole cooperative network. Cluster # 1 comprises 21 countries, including China, the UK, France, the USA, and other countries, among which the UK, China, and the USA have the closest cooperation. Cluster # 2 comprises seven countries, including Iran, Denmark, Lithuania, and others. The strongest cooperation relationship of cluster 2 is between Iran and Denmark. Cluster # 3 consists of only five countries, the Netherlands, Poland, Belgium, and other Nordic countries. Meanwhile, there are some connections between clusters, among which cluster # 1 and cluster # 2 are more closely related.

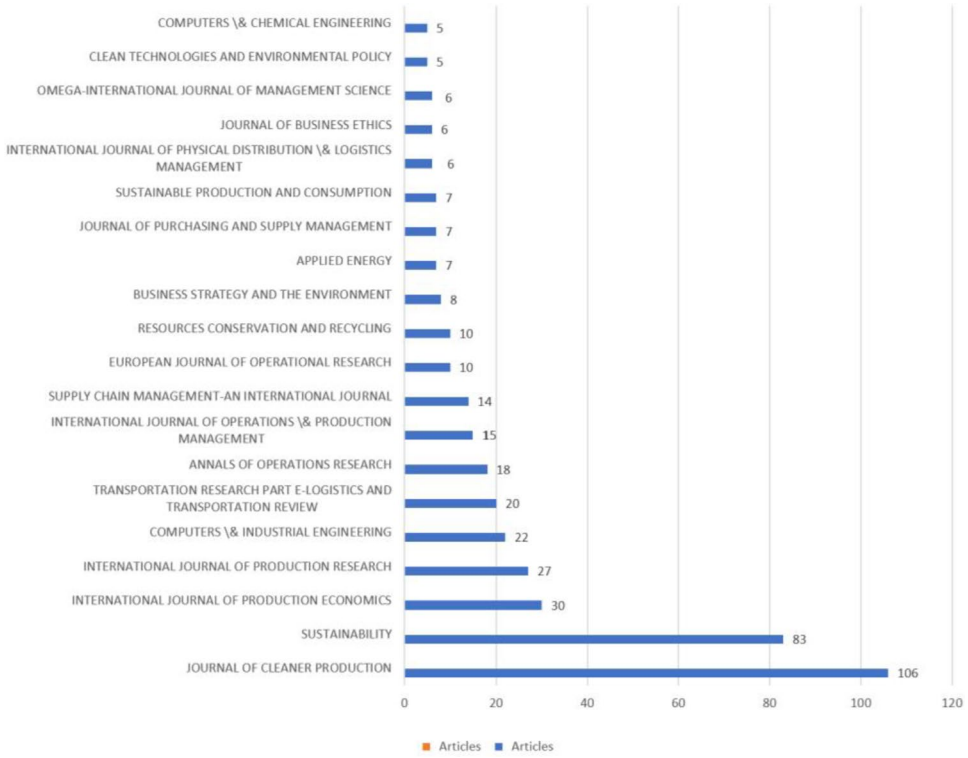


Fig. 3 Top 20 relevant journals

Table 2 Top 10 countries with the largest number of published articles

Country	NP	SCP	MCP	MCP_Ratio
China	183	125	52	0.2938
USA	132	68	26	0.2766
Iran	104	60	18	0.2308
UK	96	29	32	0.5246
India	57	32	9	0.2195
Germany	55	29	11	0.275
Canada	51	14	14	0.5
Australia	45	13	12	0.48
France	43	5	18	0.7826
Italy	33	14	8	0.3636

Institution

Table 3 lists the top 10 institutions that have published the most SSCRM-related publications. It is worth noting that Iranian research institutions are relatively active in SSCRM. The three research institutions that have published the most articles belong to Iran, namely, Iran University Science and Technology (36 articles), University of Tehran (24 articles), and Islamic Azad University (17 articles). This shows that Iran pays more attention to the research of SSCRM.

Figure 6 shows the main institutional cooperation groups that contribute to the research of SSCRM. There are seven obvious clusters, and the largest cluster is cluster # 1, which contains 12 institutions. Cluster # 1 centers on Iran University of Science and Technology, which publishes the largest number of articles and collaborates most with other institutions. Iranian universities' scientific relationship with the University of Tehran is the strongest, as shown by the thickness of the line connecting them. Islamic Azad University and University Southern Denmark are also in cluster # 1. Combined with Table 3, the top four institutions with the largest published articles are all in cluster # 1, so cluster # 1 should be the most influential cluster. There are ten institutions in the second-largest cluster #2. Lunghwa University of Science and Technology is the core institution in cluster #2 and is closely linked with Dalian University of Technology, Coventry University, and the University of Nottingham. Clusters #3–#7 also include several additional institutions' collaboration groups actively involved in the research of SSCRM. Cluster # 3, cluster # 5, and cluster # 6 are cooperative institutions mainly in China. Cluster # 4 is a cooperative institution dominated by the USA. There are also different degrees of cooperation among various clusters, while Fig. 6 indicates that Clusters #1, #2, and #3 cooperate most closely because of the dense links between them.

Scholar

The most prolific and influential authors are found in this article using Biblioshiny. Table 4 shows the top 20 authors

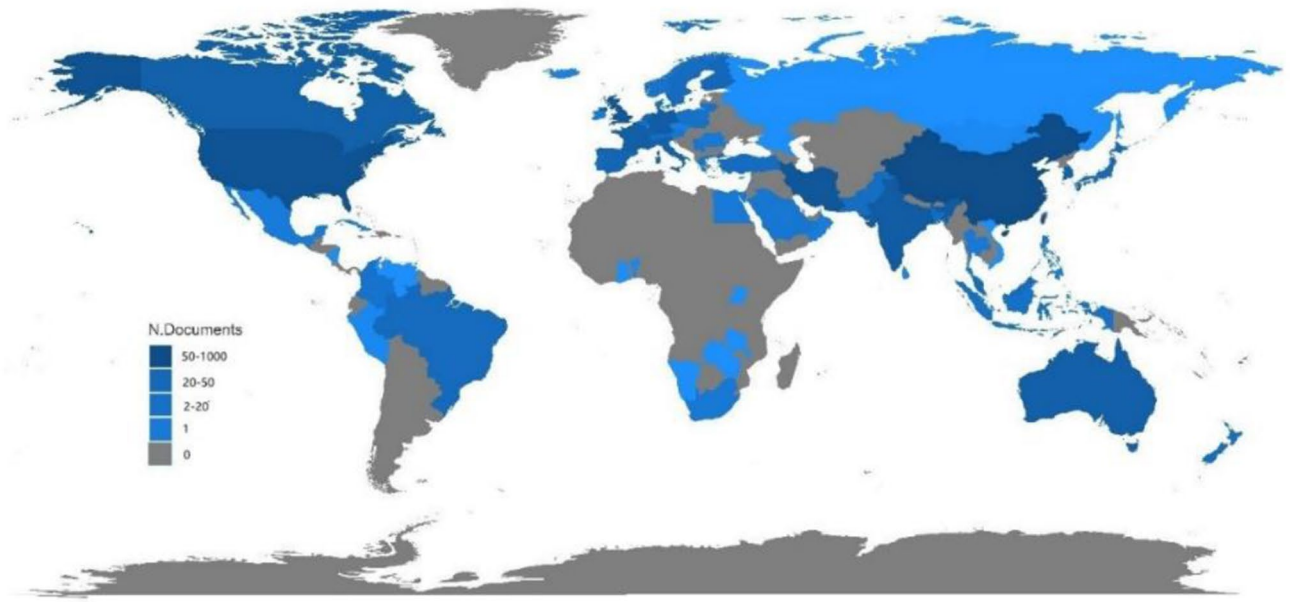


Fig. 4 Countries around the world published relevant articles

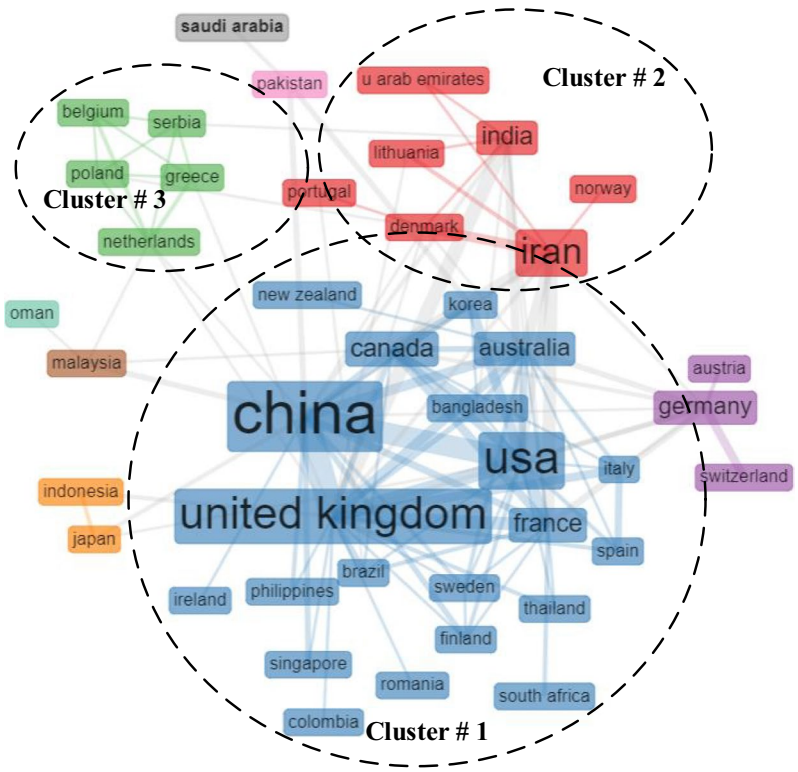


Fig. 5 Country collaboration network based on co-authorship

along with their number of articles (NP), the h-index, and the year of the first article (PY-start), as well as the total number of citations (TC).

Table 4 indicates that TSENG M. L. has the highest h-index and the largest number of published articles. Author Govindan K. has the highest total citations, almost twice as many as the second author, which indicates that the quality of Govindan K.'s articles is very high and influential. Regarding the h-index, Tseng M. L. and Govindan K. are the top two, followed by Liu Y., Pishvaee M. S., Cruz J. M.,

Table 3 Top 10 institutions with the largest number of published articles

Institution	NP
Iran Univ Sci and Technol	36
Univ Tehran	24
Islamic Azad Univ	17
Univ Southern Denmark	12
Lunghwa Univ Sci and Technol	11
Hong Kong Polytech Univ	11
Univ Connecticut	10
Coventry Univ	10
Univ Regina	9
Hanyang Univ	9

and Wu K. J. This demonstrates that these scholars have a greater influence than others.

Figure 7 displays the production of the top 20 writers over time. The color of the sphere in Fig. 7 is proportional to the total citations annually, and the volume of the sphere is proportional to the number of articles annually. Among these scholars, Liu Y. published five articles in 2018, the largest number of published articles among all researchers. In 2017, Govindan K.'s total citations per year (TC/Y) was 68.2, the highest among all researchers. Govindan K.'s total citations per year (TC/Y) in 2011 is 39.27, which shows that he is more influential than other scholars in these two years. Tseng M. L.'s total citations per year (TC/Y) in 2018 is 39.25, and Li Z.'s total citations per year (TC/Y) in 2016 is 32, reflecting that these scholars are more influential than others. Figure 7 also indicates that Chen X., Saheb H., Huang Y., Govindan K., and Liu Y. have published many articles in the last several years, suggesting that these scholars have paid great attention to the field of SSCRM in recent years.

Keyword analysis

Keyword frequency

The core and refinement of the research content is the keyword. In the subject of SSCRM, keyword analysis can aid in the identification of key research subjects as well as the representation of macro changes. The keywords are analyzed according to the time trend better to understand the changes in research subjects in different periods. First, the 24 years from 1996 to 2020 are divided into eight periods. Because of the small number of articles published from 1996 to 2006, the 10 years are combined as one time period for observation. The rest are divided into seven periods with a period of 2 years. Finally, as shown in Fig. 8, we get ten common keywords in SSC.

As shown in Fig. 8, the most frequent keyword is "management," which is easy to understand because most of the articles we collected are about supply chain management. The second most frequent keyword is "model," which shows that most articles on SSCRM use model analysis or

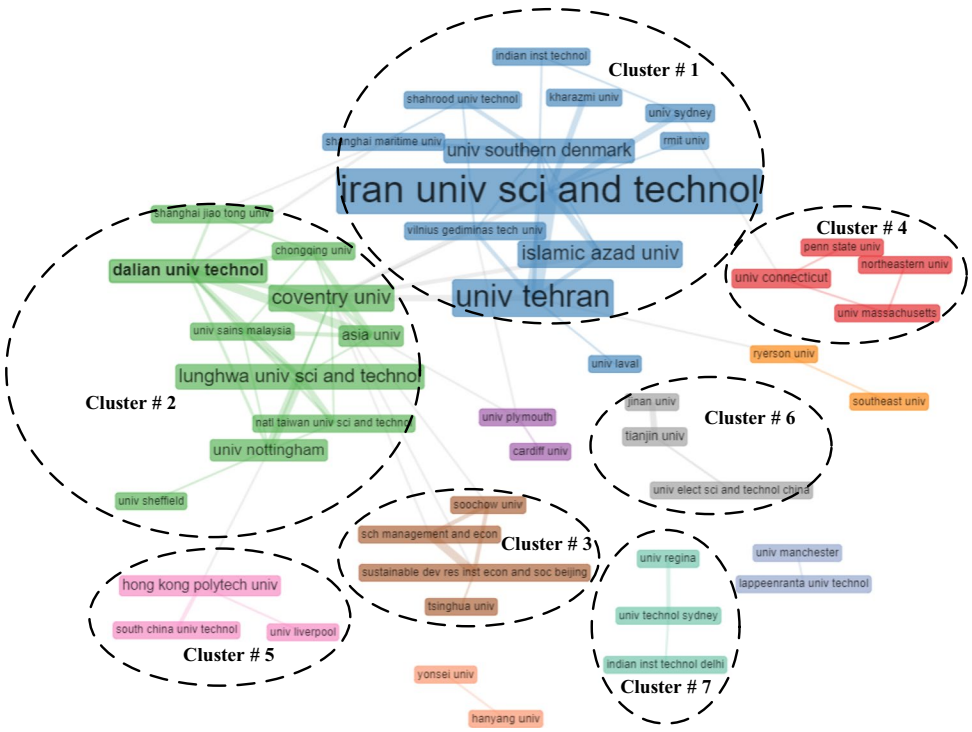


Fig. 6 Institution cooperation network

Table 4 Top 20 most influential authors

Author	h-index	TC	NP	PY-start
Tseng M. L	13	654	16	2014
Govindan K	9	1229	12	2011
Liu Y	6	214	10	2017
Pishvaee M. S	8	528	11	2012
Cruz J. M	8	580	8	2006
Wu K. J	7	321	8	2015
Zhang Y	6	116	8	2017
Busse C	7	316	7	2014
Li Y	4	108	7	2018
Sahebi H	2	9	7	2020
Zhang J	4	162	7	2014
Chen X	3	27	6	2018
Huang Y	4	75	6	2013
Jabbarzadeh A	5	192	6	2016
Li Z	4	226	6	2014
Lim M. K	4	177	6	2017
Mangla S. K	3	466	6	2015
Seuring S	5	248	6	2014
Cao C	4	136	5	2017
Chen Y	3	69	5	2015

use model to optimize the supply chain. "Risk" is the third most frequent keyword. Before 2015, the word "risk" did not appear many times, but after 2015, the growth rate was very high, indicating that risk has become a prominent subject in the latest years. More and more scholars are interested in risk management. The term "impact" is also prevalent and has shown a steady growth, which indicates that supply chain impact study has long been a focus for scholars. Finally, all the keywords show an upward trend, suggesting that the research on SSCRM has continued to increase in the latest years.

Co-occurrence keywords

Co-occurrence analysis can identify potential subjects in text data and reveal the logical structure of current research. Keyword co-occurrence analysis refers to the frequency of two or more keywords appearing in the same article. The cluster represents the direction of current research. As shown in Fig. 9, the co-occurrence map is divided into three clusters: red (22 items), green (13 items), and blue (9 items). The nodes in the network graph represent the keywords, and the nodes' size shows the keywords' frequency.

Red clustering is the largest of the three clusters, and the main keywords include "performance, impact, environmental management, corporate social responsibility, and framework." The related articles of this cluster tend to study the motivation of enterprises to implement SSC, as well as ways to lower the risk for enterprise supply chain through sustainability and analyze the advantages of implementing SSC. This research attempts to address the following questions: What are some barriers to implementing SSC? What impact do corporate social responsibility and reputation have on SSC? What benefits can green and SSC brings to enterprises. For example, Lee et al. (2013) and Valinejad and Rahmani (2018) studied the impact of reputation on corporate finance. Mulhall and Bryson (2014) investigated the risk of lack of social responsibility to SSC.

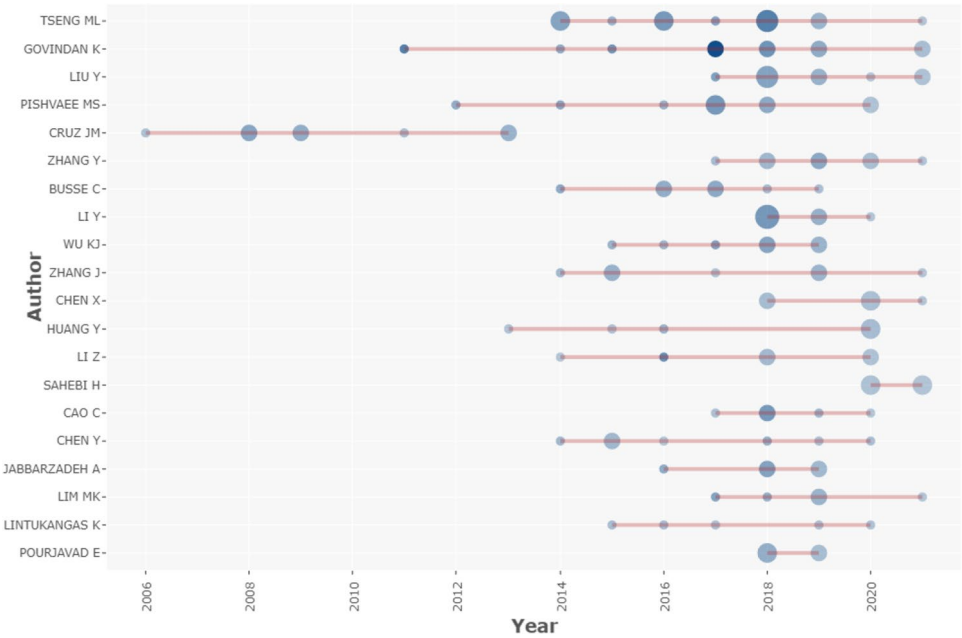


Fig. 7 Top 20 authors' productions over time

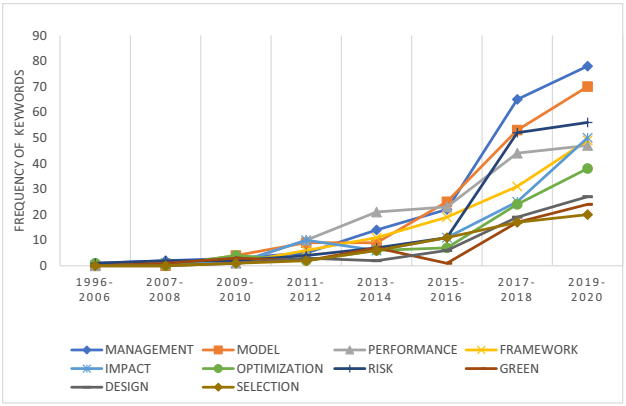


Fig. 8 The change of the top 10 keywords by frequency

The most common keywords in the green cluster are "management, model, optimization, programming approach, uncertainty, system." The "model" has more links with other keywords, with more than 40 keywords across the red and blue clusters. The related research focuses on establishing models to evaluate and optimize the SSC. The cluster also discusses the supply chain network design, algorithm optimization, and other issues. For example, Govindan et al. (2015) discussed how a closed-loop supply chain should be designed. Chaabane et al. (2012) studied SSC's network design.

The blue cluster contains the keywords "risk, innovation, coordination, decision." Related studies focus on strategies and solutions from a macro-perspective. Examples include global supply chain integration and green innovation, cooperative strategies in SSC, and the provision of socially responsible supply chain networks. For instance, Shete et al. (2020) studied the advantages of implementing green innovation. Wang et al. (2017) studied on fashion supply chain's cooperation strategy.

Evolution trends of research subjects

This section tries to analyze the subject evolution of SSCRM from 1996 to 2020 from a dynamic perspective. From the perspective of the number of articles, there were few studies on this subject before 2011. Therefore, 38 articles published in 15 years from 1996 to 2011 are considered one period for convenience of research. The following 9 years are divided into a small cycle every 3 years. Consequently, the whole study is divided into four consecutive sub-periods, 1996–2011, 2012–2014, 2015–2017, and 2018–2020. Figure 10 shows the amount of literature that was published within each period. The literature published in the first 15 years was very low, but the articles published in each subsequent period nearly doubled.

Figure 11 further analyzes the strategic diagrams of each period. Using Biblioshiny keyword-based subjects evolution analysis, highly relevant keywords are grouped into subject clusters, with high-frequency keywords appearing in the circle. There are four quadrants in Fig. 11, each representing a distinct type of subject matter. Each subject cluster

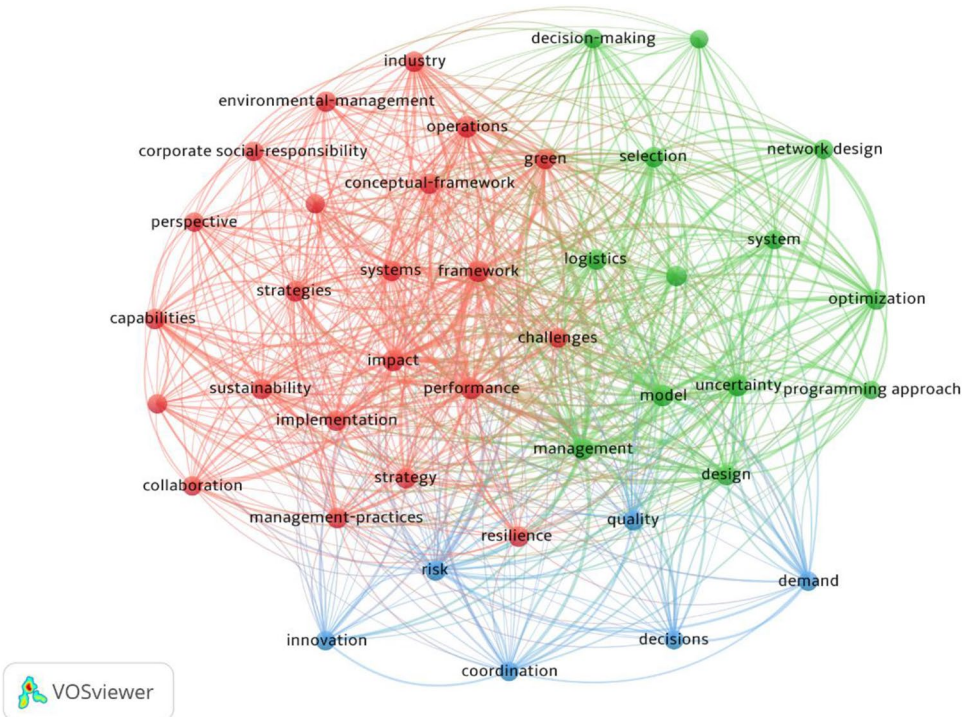


Fig. 9 Co-occurrence network of high-frequency keywords

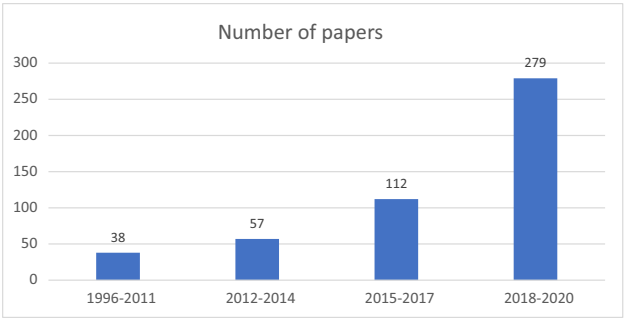


Fig. 10 Number of articles published in each period

is described in terms of two measures: centrality and density. The first quadrant's subjects have a high centrality and density, indicating that it is vital for developing SSCRM and a key component of many fundamental theories. Low centrality and high density suggest that the second quadrant subjects have strong internal links but are typically isolated points, which are of little importance to SSCRM. The third quadrant is the subjects of low center and low density, which indicates that these subjects are declining research frequency or emerging subjects, and the development of these subjects is relatively weak. The fourth quadrant is the subjects of high concentration and low density, which indicates that these subjects are fundamental to developing SSCRM but have not been thoroughly studied. The circle volume in Fig. 11 is proportional to the frequency of the keywords in each subject's name, which is shown in each circle.

Figure 12 shows that the number of subject clusters increases consistently from the first period to the period, indicating that SSCRM has developed into a complex and colorful research field covering diverse subjects. Therefore, it is necessary to create a Sankey diagram, depicted in Fig. 12, to study how subject clusters in Fig. 11 interact with one another in a longitudinal framework and identify their primary evolutionary trajectories. Each node in the Sankey chart represents a subject set that displays the most frequent keywords. The number of keywords in the associated subject determines the node's size. The flowing shows subject clusters' developmental orientation among nodes, and a group of subjects evolving in different sub-periods can be regarded as subject domains.

From the overall point of view, we can find that the number of links between subjects increases over time. In the four periods, the subject of risk management is divided into many subheadings, such as management → risk → risk → system, management → risk → risk → policy. The word "risk" appears in the second period, increases in frequency in the third period, and is divided into multiple subjects in the last

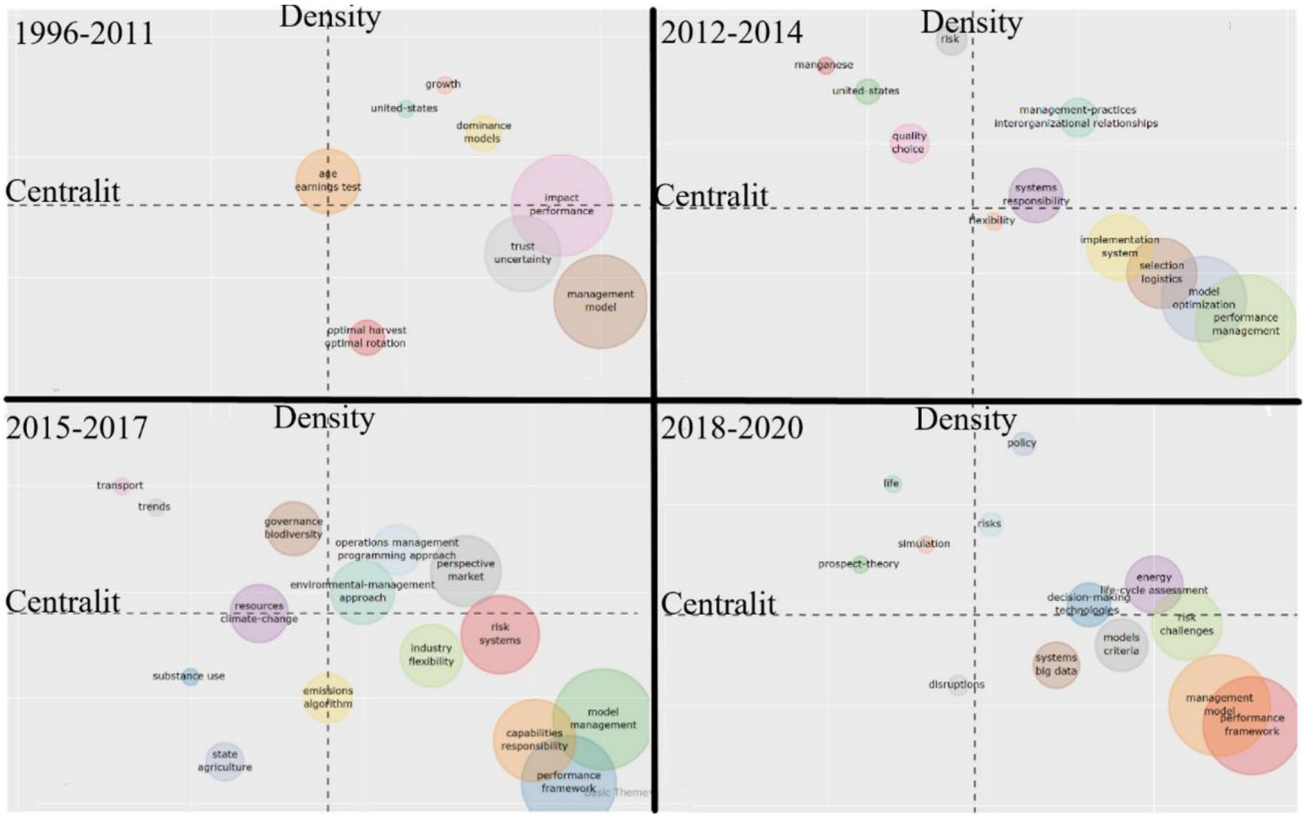


Fig. 11 Strategic diagrams of research (1996–2020)

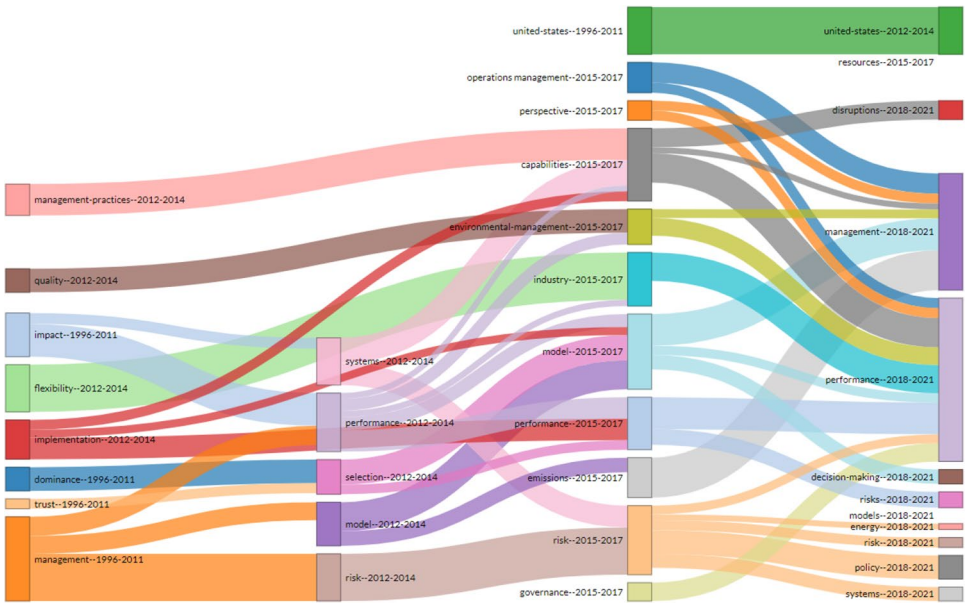


Fig. 12 Subjects' evolution at different periods

period. It can be seen from Fig. 12 that system risk, policy risk, and energy risk may be the key research subjects in this field. The subject of supply chain optimization begins to appear in the second period, evolving from the initial vocabulary of influence, implementation, and management to supply chain optimization and merging into the most frequent keywords in the last period. The evolutionary path shows that supply chain optimization has become increasingly important in SSCRM. It shows that the optimization problem has developed into a stable and mature subfield in SSCRM, and it has become increasingly significant to integrate with many other subjects.

Co-citation analysis

Static perspective

This article uses co-citation analytics to determine co-citation articles' frequency and investigate the citation connection in SSCRM from a static standpoint. Co-citation analysis can assist in identifying the most significant articles in the subjects of SSCRM. The co-citation network in SSCRM is drawn using VOSviewer software in this section, as illustrated in Fig. 13. A 20-citation threshold is used to create the co-citation network, and 78 nodes in the network are selected. Figure 13 depicts every node as an article, with the volume of each node corresponding to the number of citations in each published article. The nodes' co-citation relationship is shown by the lines connecting them and the same color reflecting comparable topics in these articles. There are three different clusters in the network: the red cluster, the blue cluster, and the green cluster. There are 32 nodes in the red cluster, 30 in the green cluster, and 16 in the blue cluster.

We can gain a basic idea of the three clusters' content by looking at the titles and abstracts of all the articles in each cluster. The co-citation network's blue cluster is the tiniest. From the subjects of this cluster, we can see that it focuses on the network design and optimization of the supply chain, such as supply chain network design (Chaabane et al. 2012; Eskandarpour et al. 2015; Pagell and Wu 2009), closed-loop supply chain, and reverse logistics supply chain (Govindan et al. 2015; Pishvaee et al. 2010). The co-citation network's blue cluster is the biggest. This cluster contains literature reviews as well as the core theory studies of the supply chain, such as the conceptual framework for SSC management (Pishvaee et al. 2010, Seuring and Müller 2008), theory of SSC management (Gold et al. 2010; Pagell and Wu 2009), and the evolution and future direction of SSC management (Gold et al. 2010). Green cluster is relatively early research representing the management practice. For example, consider the collaborative role of environmental management as well as supply chain efficiency (Vachon and Klassen 2008).

Dynamic perspective

The study of SSCRM may benefit from a dynamic perspective provided by historical citation analysis. Biblioshiny is used to generate the historical citation network of SSCRM. The citation connection among the first 25 cited articles, as shown in Fig. 14, demonstrates the development of key literature study focus in the field of SSCRM. Each node in this network represents a single article, and their connections indicate their citation relationship.

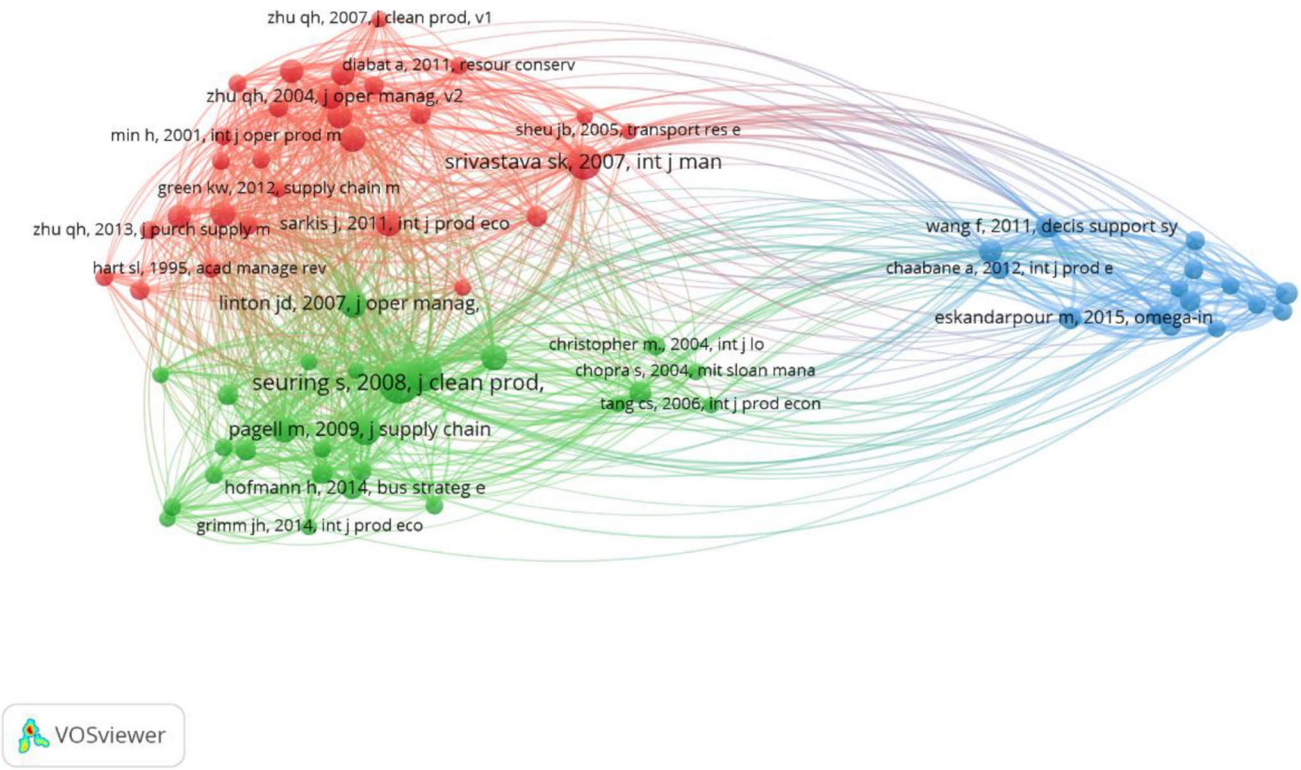
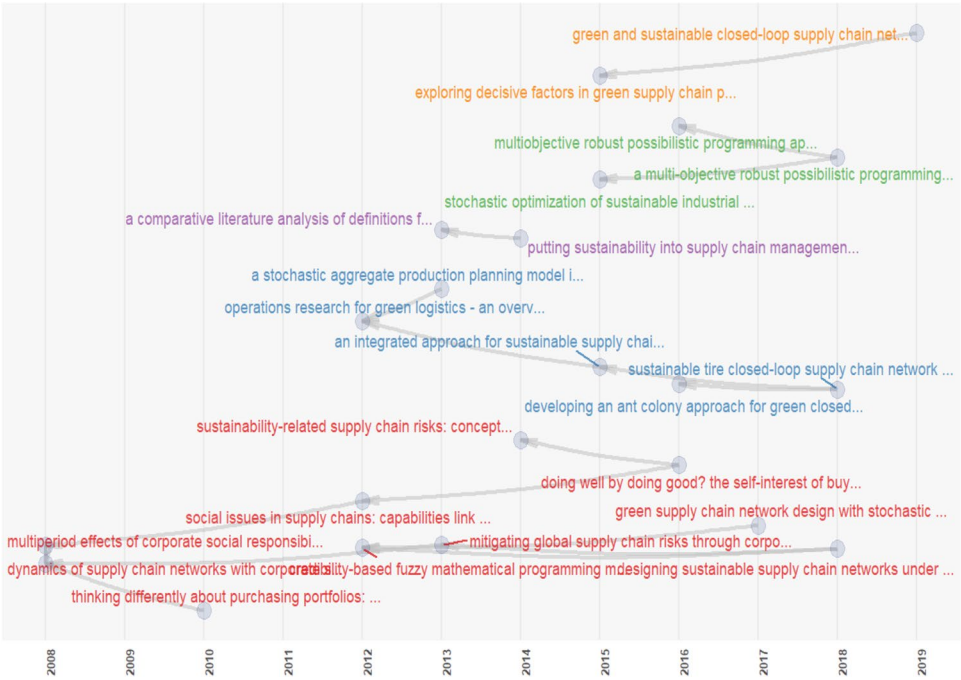


Fig. 13 Co-citation network of cited references

Fig. 14 Historical citation network



Examining the complete text of these 25 important articles will aid in our understanding of the development of SSCRM study emphasis.

The blue sub-network comprises five nodes. The sub-network studies the design of SSC operating networks. Such as, the operation of green logistics was studied (Dekker et al.

2012). Sahebjamnia et al. (2018) studied the network design of a sustainable tire closed-loop supply chain. Zohal and Soleimani (2016) studied the network design of the gold industry's green closed-loop supply chain.

The red sub-network is linked by 13 nodes. The sub-network studies social responsibility. The earliest articles of this subnetwork are Cruz and Wakolbinger (2008), and Cruz (2008). Cruz and Wakolbinger (2008) studied the effect of corporate social responsibility on the risk associated with supply chain networks. Three articles in the historical citation form a citation relationship with this article. Klassen and Vereecke (2012) study supply chain social problems by linking responsibility, social management ability, risk, and performance. Multaharju et al. (2017) integrated social, ecological, and moral issues into SSC. Cruz's article has six nodes, mainly studying how to reduce the impact of SSC risk. For example, Cruz (2013) studied how to reduce the global supply chain risk through corporate social responsibility. Cruz (2008) analyzed the supply chain network with social responsibility.

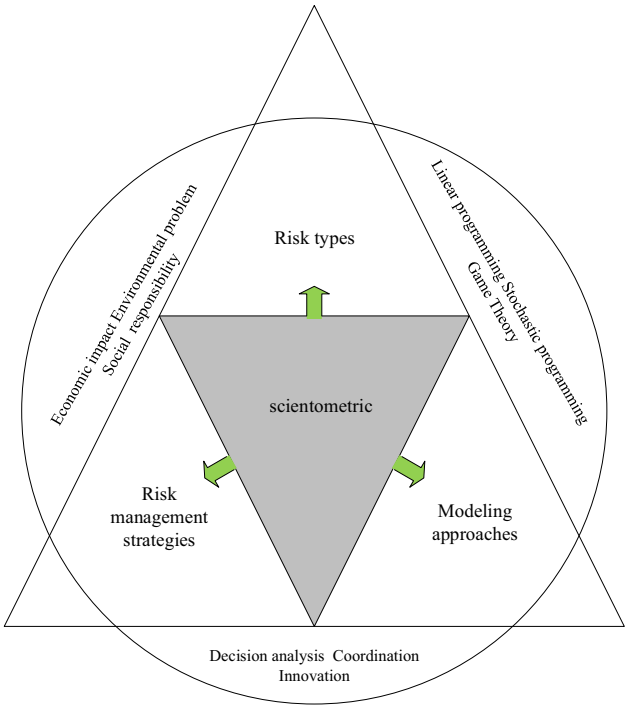


Fig. 15 Logic diagram of risk management in sustainable supply chain

Logic diagram of risk management in sustainable supply chain

According to the scientometric analysis results in the "Intellectual structure of risk management in sustainable supply chain" section, a critical review was conducted in that section to summarize the risk types, strategies, and modeling approach of SSCRM. The logic diagram of critical review for SSCRM is depicted in Fig. 15.

Risk types of risk management in sustainable supply chain

With the development of modern communication technology, information is becoming more and more transparent. Failure to pay attention to and implement appropriate sustainability strategies can easily lead to risks in the supply chain, such as consumer boycotts, costly legal proceedings, and a decline in corporate reputation. Common risks as shown in Table 5.

Social responsibility

Carroll et al. (2018) believe corporate social responsibility includes economic, legal, moral, and charitable expectations. As shown in Table 5, the most mentioned risks are those caused by violation of local laws, business ethics, and dangerous working environments. Compliance with local laws is the most basic requirement for enterprises in the supply chain. The studies of SSCRM are mainly related to environmental regulations. For example, Zhao et al. (2013) used game theory to study enterprises' strategic choice of carbon emissions under different government legal policies. In recent years, environmental protection–related laws have become increasingly important. The government may punish or even shut down enterprises with severe pollution. Especially in developing countries, governments tend to adopt stricter new energy policies and environmental regulations (Godil et al. 2020; Khan et al. 2020; Sharif et al. 2021). Many enterprises and organizations have put greenhouse gas emission targets into the company's important consideration (Syed et al. 2019). Institutional uncertainty is one of the main risks to SSC (Kelling et al. 2021). The behaviors against business ethics mainly refer to corruption, bribery, child labor, price manipulation, fraud patent infringement, etc. When the media reports the scandals of these companies, it will bring huge risks to the supply chain (Mulhall and Bryson 2014). The most direct impact is the damage to corporate reputation, which may affect the efficiency of enterprises.

Workplace safety and comfort may also help decrease risk and increase productivity in SSC. The work safety of workers, especially in the construction industry and large logistics service providers, has been paid attention to (Deng et al. 2019). The assessment of workplace safety and comfort includes job satisfaction, motivation, creativity, participation, sense of responsibility, and work-life balance. Focusing on the company's short-term interests and ignoring

Table 5 Typical sustainable supply chain risks

Category	Risk factor	Reference
Economic risk	Reputational risk	Alikhani et al. (2019), Mani et al. (2017), Rostamzadeh et al. (2018), Song et al. (2017), Sutrisno et al. (2019), Torres-Ruiz and Ravindran (2018)
	Inflation and currency exchange rates	Alikhani et al. (2019), Rostamzadeh et al. (2018), Song et al. (2017)
	Energy price volatility	Alikhani et al. (2019), Rostamzadeh et al. (2018), Shankar et al. (2018), Song et al. (2017), Torres-Ruiz and Ravindran (2018)
Environmental risk	natural disasters	Alikhani et al. (2019), Mani et al. (2017), Rostamzadeh et al. (2018), Song et al. (2017)
	Environmental pollution risk	Lim and Phillips (2008), Reinerth et al. (2019), Rostamzadeh et al. (2018), Song et al. (2017), Sutrisno et al. (2019), Torres-Ruiz and Ravindran (2018)
	Inefficient use of resources	Mani et al. (2017), Reinerth et al. (2019), Song et al. (2017)
Social risk	Collaborative risk	Alikhani et al. (2019), Sutrisno et al. (2019)
	Political risk	Alikhani et al. (2019), Hofmann et al. (2014), Rostamzadeh et al. (2018), Sutrisno et al. (2019)
	Dangerous working environment	Hofmann et al. (2014), Mani et al. (2017), Reinerth et al. (2019), Rostamzadeh et al. (2018), Shankar et al. (2018), Song et al. (2017), Torres-Ruiz and Ravindran (2018)
	Law risk	Alikhani et al. (2019), Hofmann et al. (2014), Lim and Phillips (2008), Reinerth et al. (2019), Rostamzadeh et al. (2018), Shankar et al. (2018), Torres-Ruiz and Ravindran (2018)
	Violation of business ethics	Hofmann et al. (2014), Lim and Phillips (2008), Reinerth et al. (2019), Rostamzadeh et al. (2018), Shankar et al. (2018), Song et al. (2017), Torres-Ruiz and Ravindran (2018)
	Violation of human rights	Lim and Phillips (2008), Reinerth et al. (2019), Song et al. (2017), Torres-Ruiz and Ravindran (2018)
	Corruption risk	Reinerth et al. (2019), Shankar et al. (2018), Sutrisno et al. (2019)
	Cultural risk	Alikhani et al. (2019), Rostamzadeh et al. (2018), Sutrisno et al. (2019)
other	Lack of sustainable knowledge	Rostamzadeh et al. (2018), Shankar et al. (2018)
	Innovation risk	Shankar et al. (2018), Sutrisno et al. (2019)

employees' mental and psychological problems will reduce the creativity of employees and the quality of work and even cause safety accidents that threaten the stability of the supply chain (Kurniawan et al. 2019).

Environmental problem

The environmental problems mainly include natural disasters, environmental pollution, and inefficient use of resources. Environmental pollution refers to water, soil, and air pollution, including the emission of greenhouse gases, ozone-depleting substances, and other harmful substances. Environmental problems are a global issue. Many countries have formulated or are preparing to enact greenhouse gas emissions and environmental protection laws. If they ignore environmental problems, they may be condemned by the public and punished by the government. Valinejad and Rahmani (2018) pointed out in the case of telecom companies that greenhouse gas emissions and electromagnetic radiation will bring many health problems to people and bring considerable risks to the management of the supply chain. Environmental problems are particularly important in the textile industry, because many chemicals used in the textile manufacturing process are toxic and cause pollution to air, water, and soil, and these contaminations are one of the important risks for SSC in the textile industry (Raian et al. 2022).

Environmental pollution, greenhouse gas emissions, natural disasters, non-compliance with sustainable development laws, and other environmental risks have gradually become the most prominent SSC risk (Giannakis and Papadopoulos 2016). Natural disasters refer to hurricanes, floods, storms, earthquakes, and other disasters. These risks do not often occur, but once occurred, they will bring huge harm to the whole supply chain. Through an empirical questionnaire, Ahmad and Afzal (2021) demonstrated that the impact of natural disasters on the social and environmental aspects of SSC is significant. According to Xin et al. (2020) findings, the losses caused by natural disasters will rise from $11.8 billion in 2006 to $110 billion in 2011. Meanwhile, once a severe natural disaster occurs, it may lead to the shutdown of the supply chain, which may bring great losses to the upstream and downstream enterprises.

Economic impact

Reputation is an essential invisible asset of a company. If the company's reputation and trust are damaged, customers may no longer buy its products. Meanwhile, a good reputation helps negotiate with suppliers and the government to obtain better human resources and more capital resources. An enterprise's reputation is directly related to its financial performance (Lee et al. 2013). It is important to note that poor management of the supply chain's downstream and upstream firms will also lead to serious reputational and even economic losses. For example, some media criticized child labor and conflict minerals in Apple and Microsoft's upstream cobalt supply chain. Suppliers' poor management may also significantly impact the company's performance (Busse et al. 2017; Lee et al. 2013). Through MCDM's empirical approach, Alshehri et al. (2022) considered that economic impact was one of the three major risks affecting the SSC of Saudi Arabia's manufacturing industry.

Risk management strategies in sustainable supply chain

Decision analysis

In SSCRM, demand decision analysis is a significant issue. The strategies for demand uncertainty decisions include demand estimation, risk transfer, collaborative, and mathematical modeling. Using the model to estimate the demand reasonably to reduce SSC risk is essential. For example, hydrogen is vital new energy, but the construction of hydrogen infrastructure is costly and requires a lot of investment, so the failure to assess the demand for hydrogen will bring considerable risks to the SSC (Dagdougui 2012). Dayhim et al. (2014) developed a spatial aggregation model to assess hydrogen demand. Building infrastructure based on demand can significantly reduce the risk of hydrogen SSC. Tavana et al. (2021) used fuzzy set theory to control the adverse effects of demand uncertainty on SSC. Yet, other businesses, such as the fashion industry, make it impossible to forecast demand. The producer and retailer sign a buyback contract in the fashion SSC to mitigate the risk posed by the retailer's demand unpredictability.

A collaborative supply chain is also a measure to solve demand uncertainty. The risk of SSC induced by demand unpredictability may be handled from an overall viewpoint by evaluating the benefits of each node of the closed-loop supply chain (Sazvar et al. 2021). Mathematical modeling is another essential tool for dealing with demand uncertainty. Under the context of limited historical data, powerful models can tackle the issue of demand uncertainty. Jabbarzadeh et al. (2019) used the drug supply chain data to analyze the green supply chain planning, which reduced the impact of demand uncertainty. Establishing a flexible supply chain with an effective information sharing mechanism and more autonomy can alleviate the demand uncertainty to a certain extent.

Coordination and innovation

Collaboration and innovation are essential strategies to reduce the risk of SSC. Collaboration can lead to faster communication and sharing of critical information, which can lead to better SSCRM (Kaur et al. 2022). In an empirical study of supply chain resilience, 32% of respondents said they worked more closely with suppliers to mitigate SSC risks (Eggert and Hartmann 2022). Many studies employ wholesale pricing contracts, revenue sharing contracts, repurchase contracts, etc. to achieve supply chain cooperation. In the fashion SSC, the manufacturer and the retailer sign a buy-back contract to solve the risk caused by the demand uncertainty of the retailer. Contracts can be more flexible in coordinating the distribution of profits among supply chain members and mitigate the effects of uncertainty (Cai et al. 2022). Retailers in the clothing industry always hold many unsold products at the end of the sales season, which is one of the major risks of SSC, but a repurchase strategy can reduce the risk to retailers (Wang et al. 2017). Revenue sharing contracts can be used to reduce the risk of demand interruption in SSC. A perfect revenue-sharing contract that matches the fluctuation of market demand will improve the emergency response-ability of the supply chain in an emergency (Yan et al. 2020). Strengthening supply chain coordination improves the supply network's capacity to withstand risks, hence boosting the supply chain's economic, environmental, and social benefits.

The supply and demand markets are getting more competitive in the complicated and changing external environment. Collaborative supply chain innovation progressively displaces individual company innovation and has become the lifeblood of contemporary organizations' survival and success (Shan et al. 2020). The innovation of the supply chain includes supply chain technology and supply chain management. In supply chain innovation, green innovation is particularly important. The COVID-19 pandemic has made SSC more vulnerable to disruption, increasing green innovation's importance (Ayyildiz 2021). Green innovation employs novel techniques to lessen the harmful environmental effect of the manufacturing process. Green innovation involves reducing the discharge of hazardous substances during manufacturing, consumption of energy, waste recovery, waste utilization, and consumption of raw materials (Chen et al. 2006). Green innovation can make enterprises obtain a better public image and reduce the risk of SSC caused by the environment, policy, and reputation. The innovation of SSC has many sustainable advantages, such as reducing

waste, improving environmental performance, and enhancing market social image (Shete et al. 2020). Especially in underdeveloped countries with social corruption and concentrated wealth, collaborative innovation of the supply chain is particularly important. Al Asbahi et al. (2020) evaluated the renewable energy sector in Yemen through a TOPSIS empirical approach, showing the importance of implementing green innovation, especially in SMEs.

Modeling approaches for risk management in sustainable supply chain

We reviewed the SSCRM modeling approaches to understand the SSCRM research comprehensively. The specific research modeling approaches are shown in Table 6.

Game theory

The game theory generally deals with risks in two ways. One method includes risk factors into a game theory model to determine the best business strategy. The other is to study the competition and cooperation of different companies in the supply chain and share and reduce risks through cooperation. Game theory effectively studies SSCRM, especially when multiple supply chain members have conflicting goals. Zhao et al. (2012) use game theory to explore how to mitigate the environmental risks of SSC and study the strategies that companies should adopt under cost and benefit, government punishment, and incentive policies. Zou et al. (2018) studied the optimal decision of a supplier and two retailers under different price strategies and used revenue-sharing contracts to avoid risks. Recently, game theory is often used to study SSCRM research involving the government. For example, Tong and Li (2018) studied the impact of government subsidies on SSC.

Linear programming

Multi-objective optimization, goal programming, and mixed-integer linear programming are the most often used linear programming modeling approaches in SSCRM. Linear programming studies the mathematical theory and approach to the extreme value problem of linear objective function under linear constraints (Dantzig 2016). Linear programming is widely used in SSC modeling to maximize goals, such as minimizing total costs, reducing environmental pollutants, and maximizing social benefits (Pourjavad and Mayorga 2018; Pourjavad and Mayorga 2019). A mixed-integer linear programming model is a variation of a linear programming model in which specific parameters must be integers (Dantzig 2016). The mixed-integer linear programming model is mainly used for supply chain design issues and the location of facilities. For example, Ahranjani et al. (2020) studied the design of a sustainable bioethanol supply chain that may be disrupted. The multi-objective optimization model is another approach that deals with conflicts between objectives by establishing multiple linear functions (Evans 1984). Goal programming is a branch of multi-objective optimization that deals with many, often competing for goals (Evans 1984). In the SSCRM model, profit maximization is not the only focus. Risk minimization and sustainability are usually set as optimization goals. For example, Bal and Satoglu (2018) considered the triple goals of economy, society, and environment.

Table 6 Main modeling approaches

Approaches	Example articles
Game theory	Tong and Li (2018); Zhao et al. (2012); Zou et al. (2018)
Goal programming	Bal and Satoglu (2018)
Multi-objective linear programming	Cruz (2013); Hasani et al. (2021); Zhen et al. (2019)
Mixed-integer linear programming	Golpira et al. (2017); Sahebjamnia et al. (2018); Zahiri et al. (2017); Ahranjani et al. (2020)
Nonlinear programming	Rahimi et al. (2019); Sherif et al. (2021)
Stochastic programming	Fathollahi-Fard et al. (2018); Fazli-Khalaf et al. (2017); Tsao et al. (2018); Yu and Khan (2021)
Experts and decision-making trial and evaluation laboratory	Ivanov (2018); Song et al. (2017); Wu et al. (2015)
Failure mode and effects analysis	Giannakis and Papadopoulos (2016); Valinejad and Rahmani (2018)
Fuzzy importance and performance analysis	Islam et al. (2018)
Analytic hierarchy process	Bappy et al. (2019); Gold and Awasthi (2015); Mangla et al. (2015); Shete et al. (2020); Wang et al. (2012)
Structural equation	(Chu et al. 2017)
Life cycle assessment	Chaabane et al. (2012); Kolotzek et al. (2018)
Best and worst method	Zhang et al. (2020)
Technique for order preference by similarity to an ideal solution	Rostamzadeh et al. (2018)

Stochastic programming

Stochastic programming is a common approach in SSCRM. Stochastic programming usually deals with uncertain situations that seek to model risks mainly in air pollution, supply chain disruption, fires, and earthquakes. Stochastic programming has many applications in SSCRM. The following is a description of representative examples. Design an SSC network under uncertain circumstances to reduce social, environmental, and economic risks (Tsao et al. 2018). Research the location of distribution centers and carbon emissions in a three-tier supply chain comprised of factories, distribution centers, and retailers to reduce risks and enhance supply chain stability (Yu and Khan 2021). Two-stage stochastic programming models have been used in SSCRM to enable sequential choices under supply and demand uncertainty realizations. For example, Fathollahi-Fard et al. (2018) build a closed-loop supply chain while addressing economic and social objectives using a two-stage stochastic programming approach. In other examples, the uncertainty and fuzzy parameters are included in the optimization model. Over the issue scope, information concerning fuzzy parameters is often inadequate or unusable. In SSCRM, what is uncertain is often environmental factors. For example, parameter uncertainty and interrupt strikes are added to the model (Fazli-Khalaf et al. 2017).

Other modeling approaches

Main modeling approaches also include decision-making trial and evaluation laboratory (DEMATEL) (Song et al. 2017) failure mode and effects analysis (FMEA) (Giannakis and Papadopoulos 2016), analytic hierarchy process (AHP) (Wang et al. 2012), life cycle assessment (LCA) (Bairamzadeh et al. 2016), best and worst method (BWM) (Zhang et al. 2020), the technique for order preference by similarity to an ideal solution (TOPSIS) (Rostamzadeh et al. 2018), and so on. LCA is the most commonly used assessment approach, which can assess the environmental problem of each stage of the product life cycle. Bairamzadeh et al. (2016) utilized LCA to investigate the ethanol supply chain design. The advantage of the DEMATEL approach is the visual analysis which provides an intuitive analysis through the four quadrants of driving factors, autonomy, independence, and core issues to help decision-makers identify their interactions and provide intuitive judgment (Wu et al., 2015). Song et al. (2017) used the DEMATEL approach to determine the key risk factors of SSC management.

Conceptual model and future research directions of risk management in sustainable supply chain

Conceptual model

Some businesses believe risk management is unnecessary, and they continue to overlook risk management's capacity to provide a competitive edge (Kwak et al. 2018). As shown in Fig. 16, we try to establish a conceptual model to help practitioners better establish an SSCRM system and promote the development of SSCRM.

According to the scientometric and context analysis in the "Intellectual structure of risk management in sustainable supply chain" and "Logic diagram of risk management in sustainable supply chain" sections, we further propose a conceptual model for SSCRM. As shown in Fig. 16, the conceptual model of SSCRM is divided into three parts: risk assessment, risk identification, and risk-mitigating and responding. Next, we divide the conceptual model into three propositions according to the three parts.

Proposition 1. Risk identification *El Baz and Ruel* (2021) *demonstrate that risk identification plays a vital role in supply chain resilience and robustness through an empirical method of structural equations. According to Hofmann et al.* (2014), *the difference between traditional and SSC is whether the firm reacts to the supply chain's environment. Traditional supply chain companies will ignore these SSC risks, which will lead to the reaction of stakeholders, and the supply chain enterprises will bear the consequences. The "Risk types of risk management in sustainable supply chain" section of the article identifies the critical risk factors that affect the SSC. The triple bottom line classification divides them into environmental, social, and economic risks. Among these risks, the research on environment-related risks is more than that on social and economic aspects* (*Bubicz et al.* 2019). *It is worth noting that enterprises in different countries, economies, and climate regions have different risk exposures, the intensity of stakeholder pressure, and different industries required by law in the region, which may lead to different views and effects on the SSCRM. For example, Isik et al.* (2019*a*), *Isık et al.* (2019*b*), *and Isik et al.* (2021*a*, *b*) *proved through empirical research methods that the consumption of fossil energy and renewable energy in regions with different GDP levels had different environmental impacts, which should be developed in different environmental policies.*

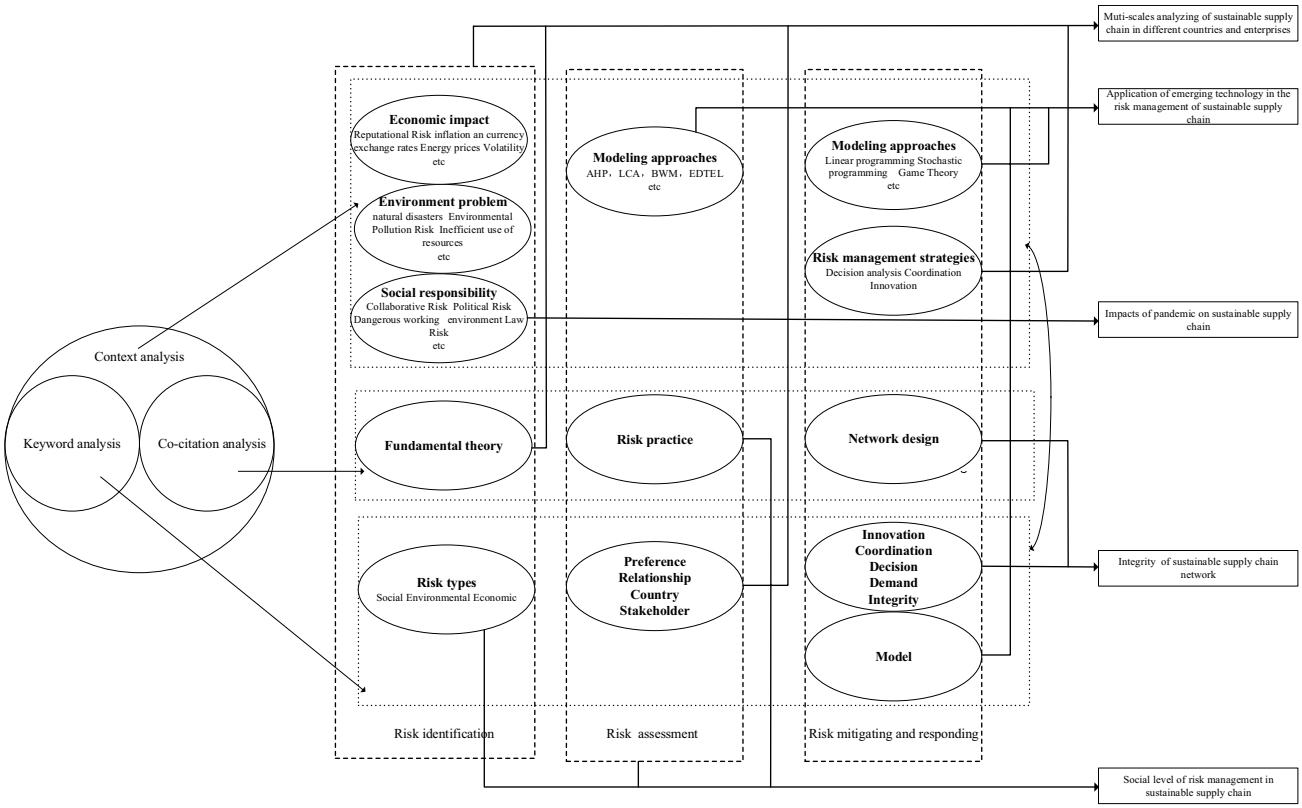


Fig. 16 Conceptual model of risk management in sustainable supply chain

Proposition 2. Risk assessment *According to Giannakis and Papadopoulos* (2016), *risk identification*, *risk assessment*, *and risk supervision and control are the three components of a sustainable risk practice strategy. Risk assessment aims to determine the likelihood of a risk occurring and the consequences that may arise. Risk assessments are the basis of SSCRM. Among risk assessment modeling approaches*, *AHP*, *TOPSIS*, *and DEMATEL are more commonly used in risk assessment. The advantages of these approaches are relatively mature and easy to use. Multiple approaches are often used for risk identification and assessment. For example*, *Giannakis and Papadopoulos* (2016) *use FMEA and correlation analysis to evaluate the risk factors of SSC. It is worth noting that there are many problems in applying environmental research approaches directly to the research on the society and economy dimensions of SSCRM. The innovation of research approaches should be developed considering the social and economic needs of SSCRM.*

Proposition 3. Risk mitigating and responding *The last part is to consider the strategy to mitigate SSC risk. This part is divided into supply chain network optimization and SSC strategy. The first part focuses on quantitative research to reduce the risk from the design of the supply chain. The second part focuses on the contract*, *and innovative approaches to supply chain risk reduction. We review the main modeling approaches of SSCRM. We divide the models into linear programming*, *the stochastic programming model*, *and the game theory. Goal programming*, *multi-objective optimization*, *and mixed-integer linear programming are some of the linear programming-based optimization approaches used in SSCRM modeling. Linear programming is widely used in SSC modeling to maximize goals*, *such as minimizing total costs*, *reducing environmental pollutants*, *and maximizing social benefits. Most of the supply chain models of SSCRM are multi-objective linear models*, *and the modeling approaches often used consider an economic and environmental objectives. Many articles contain uncertain data and have done intensive calculations to find the best solution. But in practice*, *obtaining high-quality solutions in a limited time is more conducive to establishing a sustainable risk management system.*

Future research directions

Based on the review of existing research, this article puts forward the following problems that may need further research.

Impacts of the pandemic on sustainable supply chain

The outbreak of coronavirus (COVID-19) shows that the epidemic will cause severe damage to the global SSC. There is a gap in the study on the pandemic's influence on the SSC. To curb the spread of the virus, most governments have taken containment measures to varying degrees, such as border blockade and stricter quarantine measures (Bai et al. 2020). This makes the supply chain established under the condition of maximum efficiency suffer significant economic losses due to various uncertainties. The national manufacturers association of the USA surveyed the impact of COVID-19 among its 558 US member companies and found that more than 78% of its members expected that its financial impact would be severe due to the uncertainty of its business caused by the pandemic (da Silva et al. 2020). On the other hand, too concentrated supplier procurement also affects the supply chain's resilience (Ivanov 2018). Wuhan, for example, is a significant car parts manufacturing hub that supplies vital components to global automakers, including Toyota, GM, and Volkswagen (Choirun et al. 2020). Enterprises highly dependent on Wuhan as an essential supplier will face the risk of significant supply in the early stage of the COVID-19 epidemic. In the face of the severe damage caused by the epidemic, SSC needs to strengthen its resilience, including increasing its viability (Ivanov and Dolgui 2020). Additionally, COVID-19 has significantly influenced the economy, tourism, and oil prices (Isik et al. 2020; Sharif et al. 2020b). Ahmad et al. (2021) discuss the prevention of COVID-19 from a psychological perspective, suggesting that there should be greater awareness and more active policies to reduce the impact of COVID-19 (Ahmad et al. 2021). The traditional understanding of supply chain risk and elasticity is very limited in dealing with the long-term global pandemic interference, and new approaches or improvements to existing approaches are needed (Queiroz et al. 2020).

Integrity of sustainable supply chain network

Due to the integrity of the SSC network, the upstream and downstream supply chains will interact with each other. Internal and external integration of supply chains helps to strengthen supply chain resilience (Tarigan et al. 2021). To raise the flexibility of the SSC, it is required to strengthen the flexibility between the supply chain's upstream and downstream members and consider the priority of each supply chain node (Zavala-Alcivar et al. 2020). In the future, we can investigate and evaluate the supply chain network's weak areas in terms of process type and node vulnerability to reduce the potential of the supply chain network's chain reaction. Meanwhile, strengthening the cooperation between supply chain members to make information more transparent will help enhance the trust between enterprises and improve their reputation. Strengthening the cooperation of supply chain members will also help improve the company's ability to resist risks and help reduce the impact of unexpected outages caused by the supplier's possible use of suspicious products.

Social level of risk management in sustainable supply chain

In today's economic climate, every organization's long-term success should be measured in terms of profits and its contribution to the future of mankind and the planet (Bubicz et al. 2019). Meanwhile, due to the strain from environmental agencies, trade unions, consumers, and non-governmental organizations, more and more companies are committed to sustainable development and corporate social responsibility strategies. We have observed that the number of sustainability-related articles has increased exponentially in recent years, but most research only covers the environmental aspect. The number of social level articles has only increased rapidly in recent years, and there are still many gaps in social level research. In terms of research approaches, researchers mainly apply the traditional environmental problem assessment approaches to analyze social sustainability (Cunha et al. 2019). However, the social level is far from the conventional environmental level. Many social problems are not easy to assess and quantify, and the stakeholders involved are more complex. We need more breakthroughs in the research approach and possibly a shift in supply chain models to make them more sustainable.

Application of emerging technology in the risk management of sustainable supply chain

Communication and information technology play a significant role in reducing the SSCRM. The increasing use of emerging technology tools can enhance supply chain transparency and effectively solve the problems related to non-compliance with the code of conduct. The research on the use of technology needs to be deepened. For example, blockchain technology implementation can improve supply chain social sustainability and reduce SSC risks (Chaudhuri et al. 2021). Blockchain can increase trust and integrity, establish new cultural norms and redesign new business processes, and blockchain technology is likely to contribute to sustainable development goals (Hughes et al. 2019). Big data can be used to analyze, predict, and manage the social and environmental risks that disrupt the supply chain (Mani et al. 2017; Zhao and Ding 2010). Artificial intelligence can improve supply chain resilience through better monitoring and analysis of supply chain data (Jung et al. 2021). Meanwhile, artificial intelligence, data mining, and Internet of things can alleviate the risk of SSC by improving information transparency and the rapid response to emergencies.

New information technology can integrate all stakeholders to build a sustainable and tough collaborative supply chain network.

Multi-scales analysis of sustainable supply chain in different countries and enterprises

Most of the published articles on social sustainable development focus on supply chains in developed countries because their economic stability enables them to deal with environmental and social issues (Bubicz et al. 2019). Most of the challenges that firms confront regarding social sustainability in this era of supply chain globalization are mostly connected to their internal stakeholders in the supply chains of developing nations. Therefore, we should pay attention to social sustainability research in underdeveloped countries. However, most of the enterprises in these countries are small or medium-sized companies, of which the composition of the SSC is quite different from that of large companies. Further research on SSCRM of small and medium-sized companies is needed.

Conclusion

This article describes the knowledge map of SSCRM based on a thorough literature review of 793 articles. A conceptual model of SSCRM was developed through a detailed discussion of the intellectual structure and logic diagrams. The article suggests future directions of SSC management according to the shortcomings of existing research. An essential contribution of this paper is the systematization of knowledge on SSCRM, which will help supply chain managers and academics better understand the latest developments in SSCRM and helps academics to understand the topical research on SSCRM. It may also stimulate more research by scholars in the field of SSCRM. To our knowledge, no other papers provide a conceptual model for SSCRM. Many articles have been written on SSCRM, and this model brings together ideas from previous research. The presentation of the conceptual model improves the understanding of the latest knowledge in SSCRM and contributes to the development of the field. At the same time, the findings of this study offer answers to the following five questions.

On the first question, RQ1: What is the intellectual structure of SSRCM? Scientometric analysis has shown that SSCRM has received increasing attention in recent years, with publication figures for the last 3 years already exceeding the number of articles published in the past combined, indicating that the research field is growing at a high rate and that there are many issues to be addressed. The amount of SSRCM papers published in Journal of Cleaner Production, Sustainability was much higher than in other journals in a statistical survey of related journals. The analysis of scholars found that Govindan K. had the highest total number of citations, with almost twice as many citations as the second-ranked author, and that most of his articles were published in the last 5 years, which indicates that Govindan K.'s articles are of high quality and influential. The fact that China has the most publications is not unexpected. Interestingly Iran is in third place in terms of the number of publications, while the top three universities in the ranking of the most published are all Iranian schools. Iran is also active in institutional cooperation networks. An analysis of country and institutional cooperation networks shows that Iran and Denmark cooperate more closely.

The key elements of SSCRM were determined using keyword and citation analysis. Based on keyword frequency variation analysis, keyword co-occurrence networks, strategy diagrams, and subject evolution are used to identify research themes hidden beneath the data. Analyzing the temporal trends in keyword frequency reveals outstanding research potential around the themes of models, frameworks, and impact. Based on the analysis of the identification of topics, we have identified some topical issues such as "performance and framework," "management and model," 'energy and life-cycle assessment," "big data and systems," and "model and criteria." In addition, the citation analysis has identified two more prominent sub-areas. One is network design for SSC, such as network design of reverse logistics and closed-loop logistics. Another is the social responsibility aspect of SSC.

On the second question, RQ2: What are the risk types of SSCRM? This paper identifies 16 SSC risks, of which legal violations, unsafe working environment, environmental pollution, and reputational damage, are the more crucial SSC risks. Scholars have paid more attention to environmental risk factors in SSC and less attention to social and economic aspects. Research on the impact of social risk factors on SSC is still not comprehensive. Social risk factors such as international politicization, social unrest, and business ethics have a more pronounced and direct impact on supply chain disruptions than environmental risk factors. They can even be deadlier and more immediate for companies. The current world economic landscape is changing profoundly, and supply chain managers and academics should re-identify and reassess the importance of social aspects of sustainable risk factors to avoid the risks to which they may be exposed. The literature of de Oliveira et al. (2019) identifies risk factors for SSC in the form of a review that ignores the risk factor of an "unsafe working environment." Many researchers often overlook this risk factor, and a good working environment can avoid many unnecessary risks to SSC. In identifying environmental risk factors, we have found that the risk factor of "natural disasters" has received increasing attention from scholars in recent years.

On the third question, RQ3: How to apply risk management strategies in SSCRM? Considering SSCRM from a holistic perspective is essential and should fully recognize the impact relationships between upstream and downstream companies in the SSC. Koksal and Strahle (2021) argues that complex global SSC is prone to information asymmetries and that there is a power imbalance in implementing social standards in multi-layered SSC. Risk assessment of focal companies in SSC is essential. Using risk-sharing strategies and risk-sharing contracts between companies up and down the SSC is a proven SSCRM strategy. Green innovation and demand forecasting in the SSC are also critical, as demand forecasts that deviate significantly from reality can lead to companies placing orders unexpectedly. In the past years, the emergence of big data analytics, as well as artificial intelligence systems, has provided promise for reliable demand forecasting. Green innovation can make enterprises obtain a better public image and reduce the risk of SSC caused by environment, policy, and reputation.

On the fourth question, RQ4: What are the modeling approaches for risk management in SSC? As described in the "Modeling approaches for risk management in sustainable supply chain section, modeling approaches include linear programming, stochastic programming model, and game theory. Although SSCRM issues have their unique peculiarities compared to other forms of supply chain management, the underlying mathematical techniques of risk modeling are relatively similar. In the SSCRM model, linear programming and stochastic programming are the most common modeling approaches. In SSC network design problems, stochastic programming models can largely resolve uncertainty. It is worth noting that the social dimension's risk factors are more complex than the environmental dimension, and there are many problems with applying environmental research methods directly to the social dimension, which requires innovation in research methods. Most papers consider only a single dimension and rarely consider the issue of SSC risk comprehensively in all three dimensions.

On the fifth question, RQ5: What are the conceptual model and future research directions of SSCRM? Rafi-Ul-Shan et al. (2018) suggest that no study has yet proposed an SSCRM framework. As shown in Fig. 16, we have attempted to develop a conceptual model to help practitioners better establish sustainable risk management systems and facilitate the development of the SSCRM field. Future researchers may consider looking for SSCRM research questions based on this framework. Notable for future research directions studies is the COVID-19 pandemics on SSC. COVID-19 pandemic significantly influences oil prices, travel, and the economy as one of the systemic risks (Sharif et al. 2020b). Attention should be paid to the transmission of risk. Supply chain managers and academics should be more careful in assessing the risks posed to SSC by epidemics, politics, reverse globalization, and resource crises. One aspect of SSC strategy worth investigating is the holistic nature of SSC networks. The trend of supply chain integration is deepening, and the interaction between upstream and downstream SSC has become greater. Future research can consider SSCRM from the priority and vulnerability of supply chain nodes. The role of new technologies in SSCRM is increasingly recognized. In particular, the application of blockchain, big data, artificial intelligence, and other technologies in SSC has seen rapid growth in the number of papers in this area.

This article has some limitations, one of which is the number of articles included in this study. Web of science provides extensive coverage for academic literature, but it cannot cover all peer-reviewed articles and may omit some articles. Another limitation is related to the keywords used. Different keywords may produce different results. We refer to keywords frequently used in several reviews to maximize the subjects' coverage and change the risk-related keywords to subject search. While ensuring a comprehensive search, articles of weak relevance will inevitably appear, which may slightly impact the study results.

Author contribution Liang Wang analyzed the intellectual structure, constructed the conceptual model, and contributed to writing the manuscript. Yiming Cheng and Zeyu Wang performed the analysis methods and performed the scientometrics analysis. All authors read and approved the final manuscript.

Funding This study was supported by the Social Science Planning Fund of Liaoning Province (No. L20BGL056).

Data availability The data used to support the findings of this study are available from the corresponding author upon request.

Declarations

Ethics approval Not applicable.

Consent to participate Not applicable.

Consent for publication Not applicable.

Competing interests The authors declare no competing interests.

References

Abdel-Basset M, Mohamed R (2020) A novel plithogenic TOPSIS-CRITIC model for sustainable supply chain risk management. J Clean Prod 247:119586

Adebayo TS, Rjoub H, Akadiri SS, Oladipupo SD, Sharif A, Adeshola I (2022) The role of economic complexity in the environmental Kuznets curve of MINT economies: evidence from method of moments quantile regression. Environ Sci Pollut Res 29:24248–24260

Ahi P, Searcy C (2013) A comparative literature analysis of definitions for green and sustainable supply chain management. J Clean Prod 52:329–341

Ahmad D, Afzal M (2021) Flood hazards, human displacement and food insecurity in rural riverine areas of Punjab, Pakistan: policy implications. Environ Sci Pollut Res 28:10125–10139

Ahmad M, Akhtar N, Jabeen G, Irfan M, Khalid Anser M, Wu H, Isik C (2021) Intention-based critical factors affecting willingness to adopt novel coronavirus prevention in Pakistan: implications for future pandemics. Int J Environ Res Public Health 18:6167

Ahranjani PM, Ghaderi SF, Azadeh A, Babazadeh R (2020) Robust design of a sustainable and resilient bioethanol supply chain under operational and disruption risks. Clean Technol Environ Policy 22:119–151

Al Asbahi AAMH, Fang Z, Chandio ZA, Tunio MK, Ahmed J, Abbas M (2020) Assessing barriers and solutions for Yemen energy crisis to adopt green and sustainable practices: a fuzzy multi-criteria analysis. Environ Sci Pollut Res 27:36765–36781

Ali S, Yan Q, Sajjad Hussain M, Irfan M, Ahmad M, Razzaq A, Dagar V, Isik C (2021) Evaluating green technology strategies for the sustainable development of solar power projects: evidence from Pakistan. Sustainability 13:12997

Alikhani R, Torabi SA, Altay N (2019) Strategic supplier selection under sustainability and risk criteria. Int J Prod Econ 208:69–82

Alshehri SMA, Jun WX, Shah SAA, Solangi YA (2022) Analysis of core risk factors and potential policy options for sustainable supply chain: an MCDM analysis of Saudi Arabia's manufacturing industry. Environ Sci Pollut Res 29:25360–25390

Ayyildiz E (2021) Interval valued intuitionistic fuzzy analytic hierarchy process-based green supply chain resilience evaluation methodology in post COVID-19 era. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-021-16972-y

Aziz N, Sharif A, Raza A, Rong K (2020) Revisiting the role of forestry, agriculture, and renewable energy in testing environment Kuznets curve in Pakistan: evidence from Quantile ARDL approach. Environ Sci Pollut Res 27:10115–10128

Bai QG, Xu JT, Chauhan SS (2020) Effects of sustainability investment and risk aversion on a two-stage supply chain coordination under a carbon tax policy. Comput Ind Eng 142:106324

Bairamzadeh S, Pishvaee MS, Saidi-Mehrabad M (2016) Multiobjective robust possibilistic programming approach to sustainable bioethanol supply chain design under multiple uncertainties. Ind Eng Chem Res 55:237–256

Bal A, Satoglu SI (2018) A goal programming model for sustainable reverse logistics operations planning and an application. J Clean Prod 201:1081–1091

Bappy MM, Ali SM, Kabir G, Paul SK (2019) Supply chain sustainability assessment with Dempster-Shafer evidence theory: implications in cleaner production. J Clean Prod 237:117771

Booth A, Sutton A, Clowes M, Martyn-St James M (2021) Systematic approaches to a successful literature review. SAGE Publications Ltd

Bubicz ME, Barbosa-Povoa A, Carvalho A (2019) Incorporating social aspects in sustainable supply chains: trends and future directions. J Clean Prod 237:117500

Busse C, Schleper MC, Weilenmann J, Wagner SM (2017) Extending the supply chain visibility boundary: Utilizing stakeholders for identifying supply chain sustainability risks. Int J Phys Distrib Logist Manag 47:18–40

Cai J, Lin H, Hu X, Ping M (2022) Green supply chain game model and contract design: risk neutrality vs. risk aversion. Environ Sci Pollut Res. https://doi.org/10.1007/s11356-022-18804-z

Carroll AB, Brown JA, Buchholtz AK (2018) Business and society: ethics, sustainability, and stakeholder management. Cengage Learning, Boston

Carter CR, Rogers DS (2008) A framework of sustainable supply chain management: moving toward new theory. Int J Phys Distrib Logist Manag 38:360–387

Chaabane A, Ramudhin A, Paquet M (2012) Design of sustainable supply chains under the emission trading scheme. Int J Prod Econ 135:37–49

Chaudhuri A, Bhatia MS, Kayikci Y, Fernandes KJ, Fosso-Wamba S (2021) Improving social sustainability and reducing supply chain risks through blockchain implementation: role of outcome and behavioural mechanisms. Ann Oper Res. https://doi.org/10.1007/s10479-021-04307-6

Chen YS, Lai SB, Wen CT (2006) The influence of green innovation performance on corporate advantage in Taiwan. J Bus Ethics 67:331–339

Chiang C-T, Kou T-C, Koo T-L (2021) A systematic literature review of the IT-based supply chain management system: towards a sustainable supply chain management model. Sustainability 13:2547

Choirun A, Santoso I, Astuti R (2020) Sustainability risk management in the agri-food supply chain: literature review. In: Suhartini S et al. (Editors), 3rd International Conference on Green Agro-Industry and Bioeconomy. IOP Conference Series-Earth and Environmental Science. Iop Publishing Ltd, Bristol 475:01250

Chopr S, Sodhi M (2014) Reducing the risk of supply chain disruptions. MIT Sloan Manag Rev 55:72–80

Chowdhury MMH, Quaddus MA (2021) Supply chain sustainability practices and governance for mitigating sustainability risk and improving market performance: a dynamic capability perspective. J Clean Prod 278:123521

Chu SH, Yang H, Lee M, Park S (2017) The impact of institutional pressures on green supply chain management and firm performance: top management roles and social capital. Sustainability 9:764

Cruz JM (2008) Dynamics of supply chain networks with corporate social responsibility through integrated environmental decision-making. Eur J Oper Res 184:1005–1031

Cruz JM (2013) Mitigating global supply chain risks through corporate social responsibility. Int J Prod Res 51:3995–4010

Cruz JM, Wakolbinger T (2008) Multiperiod effects of corporate social responsibility on supply chain networks, transaction costs, emissions, and risk. Int J Prod Econ 116:61–74

Cunha L, Ceryno P, Leiras A (2019) Social supply chain risk management: a taxonomy, a framework and a research agenda. J Clean Prod 220:1101–1110

da Silva EM, Ramos MO, Alexander A, Jabbour CJC (2020) A systematic review of empirical and normative decision analysis of sustainability-related supplier risk management. J Clean Prod 244:118808

Dagdougui H (2012) Models, methods and approaches for the planning and design of the future hydrogen supply chain. Int J Hydrogen Energy 37:5318–5327

Dantzig G (2016) Linear programming and extensions. Princeton University Press, Princeton University Press, Princeton, N.J.

Dayhim M, Jafari MA, Mazurek M (2014) Planning sustainable hydrogen supply chain infrastructure with uncertain demand. Int J Hydrogen Energy 39:6789–6801

de Oliveira FN, Leiras A, Ceryno P (2019) Environmental risk management in supply chains: a taxonomy, a framework and future research avenues. J Clean Prod 232:1257–1271

Dekker R, Bloemhof J, Mallidis I (2012) Operations Research for green logistics - an overview of aspects, issues, contributions and challenges. Eur J Oper Res 219:671–679

Deng XQ, Yang XM, Zhang Y, Li YS, Lu Z (2019) Risk propagation mechanisms and risk management strategies for a sustainable perishable products supply chain. Comput Ind Eng 135:1175–1187

Eggert J, Hartmann J (2022) Sustainable supply chain management - a key to resilience in the global pandemic. Supply Chain Manag. https://doi.org/10.1108/SCM-10-2021-0463

El Baz J, Ruel S (2021) Can supply chain risk management practices mitigate the disruption impacts on supply chains' resilience and robustness? Evidence from an empirical survey in a COVID-19 outbreak era. Int J Prod Econ 233:107972

Elkington J (1998) Partnerships from cannibals with forks: the triple bottom line of 21st-century business. Environ Qual Manag 8:37–51

Eskandarpour M, Dejax P, Miemczyk J, Peton O (2015) Sustainable supply chain network design: an optimization-oriented review. Omega-Int J Manag Sci 54:11–32

Evans GW (1984) An overview of techniques for solving multiobjective mathematical programs. Manage Sci 30:1268–1282

Fathollahi-Fard AM, Hajiaghaei-Keshteli M, Mirjalili S (2018) Multi-objective stochastic closed-loop supply chain network design with social considerations. Appl Soft Comput 71:505–525

Fazli-Khalaf M, Mirzazadeh A, Pishvaee MS (2017) A robust fuzzy stochastic programming model for the design of a reliable green closed-loop supply chain network. Hum Ecol Risk Assess 23:2119–2149

Fisch C, Block J (2018) Six tips for your (systematic) literature review in business and management research. Manag Rev Q 68:103–106

Giannakis M, Papadopoulos T (2016) Supply chain sustainability: a risk management approach. Int J Prod Econ 171:455–470

Godil DI, Sharif A, Agha H, Jermsittiparsert K (2020) The dynamic nonlinear influence of ICT, financial development, and institutional quality on CO2 emission in Pakistan: new insights from QARDL approach. Environ Sci Pollut Res 27:24190–24200

Gold S, Awasthi A (2015) Sustainable global supplier selection extended towards sustainability risks from (1+n)th tier suppliers using fuzzy AHP based approach. Ifac Papersonline 48:966–971

Gold S, Seuring S, Beske P (2010) Sustainable supply chain management and inter-organizational resources: a literature review. Corp Soc Responsib Environ Manag 17:230–245

Golpira H, Najafi E, Zandieh M, Sadi-Nezhad S (2017) Robust bi-level optimization for green opportunistic supply chain network design problem against uncertainty and environmental. Comput Ind Eng 107:301–312

Govindan K, Soleimani H, Kannan D (2015) Reverse logistics and closed-loop supply chain: a comprehensive review to explore the future. Eur J Oper Res 240:603–626

Hasani A, Mokhtari H, Fattahi M (2021) A multi-objective optimization approach for green and resilient supply chain network design: a real-life case study. J Clean Prod 278:123199

Ho W, Zheng T, Yildiz H, Talluri S (2015) Supply chain risk management: a literature review. Int J Prod Res 53:5031–5069

Hofmann H, Busse C, Bode C, Henke M (2014) Sustainability-related supply chain risks: conceptualization and management. Bus Strateg Environ 23:160–172

Hsu C-H, Yu R-Y, Chang A-Y, Liu W-L, Sun A-C (2022) Applying integrated QFD-MCDM approach to strengthen supply chain agility for mitigating sustainable risks. Mathematics 10:552

Hughes L, Dwivedi YK, Misra SK, Rana NP, Raghavan V, Akella V (2019) Blockchain research, practice and policy: applications, benefits, limitations, emerging research themes and research agenda. Int J Inf Manage 49:114–129

Isik C, Kasimati E, Ongan S (2017) Analyzing the causalities between economic growth, financial development, international trade, tourism expenditure and/on the CO2 emissions in Greece. Energy Sources Part B-Econ Plann Policy 12:665–673

Isik C, Ongan S, Özdemir D (2019) The economic growth/development and environmental degradation: evidence from the US state-level EKC hypothesis. Environ Sci Pollut Res 26:30772–30781

Isik C, Sirakaya-Turk E, Ongan S (2020) Testing the efficacy of the economic policy uncertainty index on tourism demand in USMCA: theory and evidence. Tour Econ 26:1344–1357

Isik C, Ahmad M, Ongan S, Ozdemir D, Irfan M, Alvarado R (2021a) Convergence analysis of the ecological footprint: theory and empirical evidence from the USMCA countries. Environ Sci Pollut Res 28:32648–32659

Isik C, Ongan S, Ozdemir D, Ahmad M, Irfan M, Alvarado R, Ongan A (2021b) The increases and decreases of the environment Kuznets curve (EKC) for 8 OECD countries. Environ Sci Pollut Res 28:28535–28543

Isik C, Ongan S, Bulut U, Karakaya S, Irfan M, Alvarado R, Ahmad M, Rehman A (2022) Reinvestigating the Environmental Kuznets Curve (EKC) hypothesis by a composite model constructed on the Armey curve hypothesis with government spending for the US States. Environ Sci Pollut Res 29:16472–16483

Isık C, Ongan S, Özdemir D (2019) Testing the EKC hypothesis for ten US states: an application of heterogeneous panel estimation method. Environ Sci Pollut Res 26:10846–10853

Islam MS, Tseng M-L, Karia N, Lee C-H (2018) Assessing green supply chain practices in Bangladesh using fuzzy importance and performance approach. Resour Conserv Recycl 131:134–145

Ivanov D (2018) Revealing interfaces of supply chain resilience and sustainability: a simulation study. Int J Prod Res 56:3507–3523

Ivanov D, Dolgui A (2020) Viability of intertwined supply networks: extending the supply chain resilience angles towards survivability. a position paper motivated by COVID-19 outbreak. Int J Prod Res 58:2904–2915

Jabbarzadeh A, Haughton M, Pourmehdi F (2019) A robust optimization model for efficient and green supply chain planning with postponement strategy. Int J Prod Econ 214:266–283

Jung J, Maeda M, Chang A, Bhandari M, Ashapure A, Landivar-Bowles J (2021) The potential of remote sensing and artificial intelligence as tools to improve the resilience of agriculture production systems. Curr Opin Biotechnol 70:15–22

Kaur A, Kumar A, Luthra S (2022) Business continuity through customer engagement in sustainable supply chain management: outlining the enablers to manage disruption. Environ Sci Pollut Res 29:14999–15017

Kelling NK, Sauer PC, Gold S, Seuring S (2021) The role of institutional uncertainty for social sustainability of companies and supply chains. J Bus Ethics 173:813–833

Khan SAR, Yu Z, Sharif A, Golpîra H (2020) Determinants of economic growth and environmental sustainability in South Asian association for regional cooperation: evidence from panel ARDL. Environ Sci Pollut Res 27:45675–45687

Klassen RD, Vereecke A (2012) Social issues in supply chains: capabilities link responsibility, risk (opportunity), and performance. Int J Prod Econ 140:103–115

Koenig P, Poncet S (2019) Social responsibility scandals and trade. World Dev 124:104640

Köksal D, Strähle J, Müller M, Freise M (2017) Social sustainable supply chain management in the textile and apparel industry-a literature review. Sustainability 9:100

Koksal D, Strahle J (2021) Social sustainability in fashion supply chains-understanding social standard implementation failures in Vietnam and Indonesia Using Agency Theory. Sustainability 13:2159

Kolotzek C, Helbig C, Thorenz A, Reller A, Tuma A (2018) A company-oriented model for the assessment of raw material supply risks, environmental impact and social implications. J Clean Prod 176:566–580

Kurniawan M, Santoso I, Kamal MA (2019) Risk management of shallot supply chain using failure mode effect analysis and analytic network process (case study in Batu, East Java). In: Suhartini S et al. (Editors), International Conference on Green Agro-Industry

and Bioeconomy. IOP Conference Series-Earth and Environmental Science. Iop Publishing Ltd, Bristol 230:012055
Kusi-Sarpong S, Orji IJ, Gupta H, Kunc M (2021) Risks associated with the implementation of big data analytics in sustainable supply chains. Omega-Int J Manag Sci 105:102502
Kwak DW, Seo YJ, Mason R (2018) Investigating the relationship between supply chain innovation, risk management capabilities and competitive advantage in global supply chains. Int J Oper Prod Manage 38:2–21
Lee K-H, Vachon S (2016) Supply chain sustainability risk, business value and sustainability: an integrated supply network perspective. Palgrave Macmillan UK, London, pp 245–280
Lee PKC, Lau AKW, Cheng TCE (2013) Employee rights protection and financial performance. J Bus Res 66:1861–1869
Lim SJ, Phillips J (2008) Embedding CSR values: the global footwear industry's evolving governance structure. J Bus Ethics 81:143–156
Mangla SK, Kumar P, Barua MK (2015) Risk analysis in green supply chain using fuzzy AHP approach: a case study. Resour Conserv Recycl 104:375–390
Mani V, Delgado C, Hazen BT, Patel P (2017) Mitigating supply chain risk via sustainability using big data analytics: evidence from the manufacturing supply chain. Sustainability 9:608
Mulhall RA, Bryson JR (2014) Energy price risk and the sustainability of demand side supply chains. Appl Energy 123:327–334
Multaharju S, Lintukangas K, Hallikas J, Kahkonen AK (2017) Sustainability-related risk management in buying logistics services an exploratory cross-case analysis. Int J Logist Manag 28:1351–1367
Ongan S, Isik C, Bulut U, Karakaya S, Alvarado R, Irfan M, Ahmad M, Rehman A, Hussain I (2022) Retesting the EKC hypothesis through transmission of the ARMEY curve model: an alternative composite model approach with theory and policy implications for NAFTA countries. Environ Sci Pollut Res 29:46587–46599
Pagell M, Wu ZH (2009) Building a more complete theory of sustainable supply chain management using case studies of 10 exemplars. J Supply Chain Manag 45:37–56
Pettit TJ, Croxton KL, Fiksel J (2013) Ensuring supply chain resilience: development and implementation of an assessment tool. J Bus Logist 34:46–76
Pishvaee MS, Kianfar K, Karimi B (2010) Reverse logistics network design using simulated annealing. Int J Adv Manuf Technol 47:269–281
Pourjavad E, Mayorga RV (2018) Optimization of a sustainable closed loop supply chain network design under uncertainty using multi-objective evolutionary algorithms. Adv Prod Eng Manag 13:216–228
Pourjavad E, Mayorga RV (2019) Multi-objective fuzzy programming of closed-loop supply chain considering sustainable measures. Int J Fuzzy Syst 21:655–673
Queiroz MM, Ivanov D, Dolgui A, Wamba SF (2020) Impacts of epidemic outbreaks on supply chains: mapping a research agenda amid the COVID-19 pandemic through a structured literature review. Ann Oper Res. https://doi.org/10.1007/s10479-020-03685-7
Rafi-Ul-Shan PM, Grant DB, Perry P, Ahmed S (2018) Relationship between sustainability and risk management in fashion supply chains: a systematic literature review. Int J Retail Distrib Manag 46:466–486
Rahimi M, Ghezavati V, Asadi F (2019) A stochastic risk-averse sustainable supply chain network design problem with quantity discount considering multiple sources of uncertainty. Comput Ind Eng 130:430–449
Raian S, Ali SM, Sarker MR, Sankaranarayanan B, Kabir G, Paul SK, Chakrabortty RK (2022) Assessing sustainability risks in the supply chain of the textile industry under uncertainty. Resour Conserv Recycl 177:105975
Ralston PM, Richey RG, Grawe SJ (2017) The past and future of supply chain collaboration: a literature synthesis and call for research. Int J Logist Manag 28:508–530
Reinerth D, Busse C, Wagner SM (2019) Using country sustainability risk to inform sustainable supply chain management: a design science study. J Bus Logist 40:241–264
Rhodes C (2016) Democratic business ethics: Volkswagen's emissions scandal and the disruption of corporate sovereignty. Organ Stud 37:1501–1518
Rostamzadeh R, Keshavarz Ghorabaee M, Govindan K, Esmaeili A, Nobar HBK (2018) Evaluation of sustainable supply chain risk management using an integrated fuzzy TOPSIS- CRITIC approach. J Clean Prod 175:651–669
Sahebjamnia N, Fathollahi-Fard AM, Hajiaghaei-Keshteli M (2018) Sustainable tire closed-loop supply chain network design: hybrid metaheuristic algorithms for large-scale networks. J Clean Prod 196:273–296
Sazvar Z, Zokaee M, Tavakkoli-Moghaddam R, Salari SA-S, Nayeri S (2021) Designing a sustainable closed-loop pharmaceutical supply chain in a competitive market considering demand uncertainty, manufacturer's brand and waste management. Ann Oper Res. https://doi.org/10.1007/s10479-021-03961-0
Seuring S, Müller M (2008) From a literature review to a conceptual framework for sustainable supply chain management. J Clean Prod 16:1699–1710
Shahzad U, Radulescu M, Rahim S, Isik C, Yousaf Z, Ionescu SA (2021) Do environment-related policy instruments and technologies facilitate renewable energy generation? Exploring the Contextual Evidence from Developed Economies. Energies 14:690
Shan HM, Li Y, Shi J (2020) Influence of supply chain collaborative innovation on sustainable development of supply chain: a study on Chinese enterprises. Sustainability 12:2978
Shankar R, Choudhary D, Jharkharia S (2018) An integrated risk assessment model: a case of sustainable freight transportation systems. Transport Res Part D-Transport Environ 63:662–676
Sharif A, Afshan S, Qureshi MA (2019) Idolization and ramification between globalization and ecological footprints: evidence from quantile-on-quantile approach. Environ Sci Pollut Res 26:11191–11211
Sharif A, Afshan S, Chrea S, Amel A, Khan SAR (2020a) The role of tourism, transportation and globalization in testing environmental Kuznets curve in Malaysia: new insights from quantile ARDL approach. Environ Sci Pollut Res 27:25494–25509
Sharif A, Aloui C, Yarovaya L (2020b) COVID-19 pandemic, oil prices, stock market, geopolitical risk and policy uncertainty nexus in the US economy: fresh evidence from the wavelet-based approach. Int Rev Financ Anal 70:101496
Sharif A, Bhattacharya M, Afshan S, Shahbaz M (2021) Disaggregated renewable energy sources in mitigating CO2 emissions: new evidence from the USA using quantile regressions. Environ Sci Pollut Res 28:57582–57601
Sherif SU, Asokan P, Sasikumar P, Mathiyazhagan K, Jerald J (2021) Integrated optimization of transportation, inventory and vehicle routing with simultaneous pickup and delivery in two-echelon green supply chain network. J Clean Prod 287:125434
Shete PC, Ansari ZN, Kant R (2020) A Pythagorean fuzzy AHP approach and its application to evaluate the enablers of sustainable supply chain innovation. Sustain Prod Consump 23:77–93
Shi JG, Duan KF, Wu GD, Zhang R, Feng XW (2020) Comprehensive metrological and content analysis of the public-private partnerships (PPPs) research field: a new bibliometric journey. Scientometrics 124:2145–2184
Sinha A, Mishra S, Sharif A, Yarovaya L (2021) Does green financing help to improve environmental & social responsibility?

Designing SDG framework through advanced quantile modelling. J Environ Manage 292:112751
Song WY, Ming XG, Liu HC (2017) Identifying critical risk factors of sustainable supply chain management: a rough strength-relation analysis method. J Clean Prod 143:100–115
State Council of China (2016) Investigation report on the special serious fire and explosion accident in the "8.12" Ruihai Company Dangerous Goods Warehouse in Tianjin Port (In Chinese). http://www.gov.cn/xinwen/2016-02/05/content_5039785.htm
Sutrisno A, Kumar V, Handayani D, Arief RK, Virdhian S, Punuhsingon C (2019) A classification and framework for measuring sustainability supply chain risk indices in small and medium enterprises. In: Anwar M et al. (Editors), 4th International Conference on Industrial, Mechanical, Electrical, and Chemical Engineering. AIP Conference Proceedings. Amer Inst Physics, Melville 2097:030001
Syed MW, Li JZ, Junaid M, Ye X, Ziaullah M (2019) An Empirical examination of sustainable supply chain risk and integration practices: a performance-based evidence from Pakistan. Sustainability 11:5334
Tarigan ZJH, Siagian H, Jie F (2021) Impact of internal integration, supply chain partnership, supply chain agility, and supply chain resilience on sustainable advantage. Sustainability 13:5460
Tavana M, Tohidi H, Alimohammadi M, Lesansalmasi R (2021) A location-inventory-routing model for green supply chains with low-carbon emissions under uncertainty. Environ Sci Pollut Res 28:50636–50648
Tong Y, Li Y (2018) External Intervention or Internal Coordination? Incentives to Promote Sustainable Development through Green Supply Chains. Sustainability 10:2857
Torres-Ruiz A, Ravindran AR (2018) Multiple criteria framework for the sustainability risk assessment of a supplier portfolio. J Clean Prod 172:4478–4493
Tsao Y-C, Vo-Van T, Lu J-C, Yu V (2018) Designing sustainable supply chain networks under uncertain environments: Fuzzy multi-objective programming. J Clean Prod 174:1550–1565
Vachon S, Klassen RD (2008) Environmental management and manufacturing performance: The role of collaboration in the supply chain. Int J Prod Econ 111:299–315
Valinejad F, Rahmani D (2018) Sustainability risk management in the supply chain of telecommunication companies: A case study. J Clean Prod 203:53–67
Wang X, Chan HK, Yee RWY, Diaz-Rainey I (2012) A two-stage fuzzy-AHP model for risk assessment of implementing green initiatives in the fashion supply chain. Int J Prod Econ 135:595–606
Wang F, Zhuo XP, Niu BZ (2017) Sustainability analysis and buy-back coordination in a fashion supply chain with price competition and demand uncertainty. Sustainability 9:25
Wu KJ, Liao CJ, Tseng ML, Chiu ASF (2015) Exploring decisive factors in green supply chain practices under uncertainty. Int J Prod Econ 159:147–157
Xin C, Chen X, Chen HF, Chen SR, Zhang MQ (2020) Green product supply chain coordination under demand uncertainty. IEEE Access 8:25877–25891
Yan B, Chen XX, Yuan Q, Zhou XT (2020) Sustainability in fresh agricultural product supply chain based on radio frequency identification under an emergency. CEJOR 28:1343–1361
Yu Z, Khan SAR (2021) Green supply chain network optimization under random and fuzzy environment. Int J Fuzzy Syst 24:1170–1181
Zahiri B, Zhuang J, Mohammadi M (2017) Toward an integrated sustainable-resilient supply chain: A pharmaceutical case study. Transport Res E-Log 103:109–142
Zavala-Alcivar A, Verdecho M-J, Alfaro-Saiz J-J (2020) A conceptual framework to manage resilience and increase sustainability in the supply chain. Sustainability 12:6300
Zhang X, Sun B, Chen X, Chu X, Yang J (2020) An approach to evaluating sustainable supply chain risk management based on BWM and linguistic value soft set theory. Journal of Intelligent & Fuzzy Systems 39:4369–4382
Zhao R, Neighbour G, Han J, McGuire M, Deutz P (2012) Using game theory to describe strategy selection for environmental risk and carbon emissions reduction in the green supply chain. J Loss Prev Process Ind 25:927–936
Zhao L, Huo BF, Sun LY, Zhao XD (2013) The impact of supply chain risk on supply chain integration and company performance: a global investigation. Supply Chain Manag 18:115–131
Zhao J, Ding S (2010) Information sharing in construction supply chain, key engineering materials. Trans Tech Publ, pp. 249–253
Zhen L, Huang LF, Wang WC (2019) Green and sustainable closed-loop supply chain network design under uncertainty. J Clean Prod 227:1195–1209
Zhou C, Song W (2021) Digitalization as a way forward: A bibliometric analysis of 20 Years of servitization research. J Clean Prod 300:126943
Zohal M, Soleimani H (2016) Developing an ant colony approach for green closed-loop supply chain network design: a case study in gold industry. J Clean Prod 133:314–337
Zou H, Qin J, Yang P, Dai B (2018) A coordinated revenue-sharing model for a sustainable closed-loop supply chain. Sustainability 10:3198