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A Bibliometric Review of Two Decades' Research on Closed-Loop Supply Chain: 2001-2020

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ABSTRACT The closed-loop supply chain (CLSC) is generally regarded as an environmentally friendly approach that can help in reducing environmental impacts and achieving sustainable development of society and economics. In recent years, the popularity research of CLSC has been widely concerned by both business and academia practitioners. It is observed that most of the literatures have focused only on a particular journal or field; there is a distinct lack of comprehensive bibliometric review of two decades' research on CLSC. This study contributes in fulfilling this gap. A comprehensive bibliometric analysis was conducted based on 1,155 articles in Web of Science Core Collection Database from 2001 to 2020. In order to track research frontiers and hotspots, visualization software VOSviewer and CiteSpace are used for analysis. Initially, a descriptive analysis was carried out to identify the trends of number of publications, the leading journals, top authors and regions. A thematic cluster analysis was then carried out to identify the research domains. Subsequently, based on the analyses of co-keywords, dominant categories and co-citation, hot issues and research trends are summarized. ''game theory'', and ''remanufacturing'' are emerging research trends for CLSC. ''Dual channel'', ''quality'' and ''circular economy'' had become hot topics. This review also finds the landmark nodes and pivot nodes in the research of CLSC. Finally, some research gaps are revealed to shed light on future directions.

INDEX TERMS Bibliometric analysis, closed-loop supply chain, visualization analysis, VOSviewer, CiteSpace.

I. INTRODUCTION

Resource crisis and increasing environmental pollution are closely related to the sustainable development of the national economy and human beings' survival. Therefore, many enterprises have investigated the opportunities to develop a circular economy (CE). The focus of circular economy is the reuse, recycle, reduce of waste, changing the linear economy to a circular model, and the closed-loop supply chain (CLSC) perfectly fits this concept and can fulfil the achievement of CE. Kleindorfer, *et al.* [1] believe that closed-loop Supply chain management (CLSCM) is a major contributor to the realization of sustainable operations. Therefore, CLSC has also been considered as a sustainable supply chain [2]. The implementation of CLSC strategies enables enterprises to reduce negative impact of their business and use resources more efficiently [3].

The concept CLSCM is implemented in many countries. In terms of waste recycling, the United States enacted the ''Solid Waste Disposal Act'' in 1965 and it became the first country to determine the reusing of wastes in legal form. Based on the establishment and improvement of environmental protection and waste recycling regulations, Japan approved the ''Basic Law on Recycling Society in 2000. This year is called Japan's ''First Year of Recycling Society''. Since 13 February 2003, the Waste Electrical

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and Electronic Equipment (WEEE) directive (Directive 2002/96/EC) and the Restriction on the Use of Certain Hazardous Substances (ROHS) directive (Directive 2002/95 /EC) have become European laws. The regulation requires companies to take responsibility for collecting and recycling e-waste [4], [5]. The ''circular economy development legislation'' of China was promulgated relatively late and was implemented on January 1, 2009. Now, meeting the legal and regulation requirement and economic reasons are the strong driving forces that practitioners take CLSC into consideration [6].

The traditional supply chain is not responsible for end-of-life products. It only considers the process from the initial raw materials to the finished products delivered to the customer, which focus on a linear and one-way system [7]. The increasing popularity of environment requires enterprises to redesign their supply chain systems and explore new ways to coordinate both forward and reverse supply chains [5], [8], [9], so as to transform the existing supply chain systems into CLSC systems. Academic began to pay attention to the research in this field in the 1990s [10]–[14]. Guide and Van Wassenhove [6] defined the concept of CLSC from business-perspective: *''the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time.''* This definition has been evolved from merely integration of forward and reverse channel of supply chain, the result network will construct a CLSC. Due to the urgent need of sustainable development. Krikke, *et al.* [15] has organically combined the CLSC and return management. The processes of CLSC are no longer on production and distribution of products to end users [16]–[19].

Based on the new definitions of the CLSC revealing recent requirements and new situations, it is necessary to have a comprehensive bibliometric review to help researchers focus on future directions. The method of bibliometric has achieved good results in many fields, but there is still a big gap in the research of CLSC and its development trend by bibliometric. In the past, most researchers adopted the manual sorting way to analyze literature, and summarize the academic contribution and discipline development trend. In addition, they also had studied many issues of CLSCM from different perspectives, generally including the recovery and reuse of reverse logistics, CLSC structure design, CLSC operation, CLSC contract coordination, uncertainty issues, etc. Akçalı and Çetinkaya [20] reviewed the existing quantitative models for inventory and production planning in CLSC. According to demand and return process, deterministic and stochastic problems are categorized and the solution methodologies used in the article are provided.

Souza [21] presented a review and tutorial of the literature on closed-loop supply chains, and categorized the literature according to strategic, tactical and operational issues. The article, written in the form of a tutorial, introduces basic models with underlying assumptions for each topic.

From a methodological perspective, practice-driven classical operations research, empirical research, and behavioral research are needed to conduct more research. Govindan, *et al*. [22] conducted a comprehensive literature review of recently papers in reverse logistics and CLSC, a total of 382 papers published between January 2007 and March 2013 are selected. The greatest contribution of this review is that it analyzed and categorized to construct a useful foundation of past research. The gaps in literature are identified and completely discussed to clarify the future research opportunities. Another review is a recent one by Govindan and Soleimani [9], this paper tries to emphasize the primary role for the *Journal of Cleaner Production* (*JCP*) in the fields of RL and CLSC, 83 papers are selected and reviewed from 2001 to 2014. It clarified the main trends in reverse logistics and CLSC subjects and the evaluations revealed some suggested opportunities for new directions of research for the journal. Kazemi, *et al.* [23] conducted a thorough bibliometric and content analysis of 94 studies that were published in the *International Journal of Production of Research (IJPR)* from 2000 until July 2017. According to the contents of the sample papers, the papers were classified into two main categories: mathematical and non-mathematical models. It suggested that analyzing the impact of different managerial decisions on the performance of reverse logistics and closed-loop supply chain may be a fertile area of research. Islam and Huda [24] reviewed studies related to managing electric/electronic waste in a CLSC. Ghadimi, *et al.* [25] presented a sustainable supply chain modeling with a conventional literature review and therefore, they did not utilize any tools from bibliometric analysis (BA). Shekarian [26] presented one of the first in-depth studies to investigate factors influencing CLSCs. It concerned the investigation of the models which are designed based on the game theory. Ritola, *et al.* [27] illustrated the large variety and high potential of valuable information that can be attained from product returns and CLSC processes. Furthermore, a set of value-creating factors were uncovered by this study. The characteristics of earlier review/partial review studies are shown in Tab.1 together with the research of area, scope, year, and number of papers.

Although a number of bibliometric analysis has been published in recent years, the CLSC field is emerging rapidly with many more papers are emerging and not only in a few leading journals such as JCP and IJPR. To the best of our understanding, in the past 20 years, scholars did not use the corresponding bibliometric software to analyze the landmark nodes and pivot nodes in the research of closed-loop supply chain. This is necessary in order to demonstrate the evolution of CLSC literatures. Consequently, a comprehensive bibliometric analysis is an urgent needed to gain an overall picture of the research field. To fill this gap, we employed two kinds of bibliometric software, VOSviewer and CiteSpace, to conduct a comprehensive bibliometric review on papers published between 2001 and April 2020.

TABLE 1. Characteristics of earlier review/partial review studies.

Paper	Area	Scope	Year	Number of papers
Akçalı, Çetinkaya et al. (2009)	RL and CLSC	Network design models	Until 2008	22
Guide et al. (2009)	CLSCM	Evolution of the topic in the literature	NA	NA
Ilgin and Gupta (2010)	RL and CLSC	Environmentally conscious manufacturing and product recovery	1998 –2009	540
Akçalı and Cetinkaya (2011)	CLSC	Quantitative models for inventory and production planning	Until 2009	–
Carrasco-Gallego, et (2012)	CLSC	Case studies	Until 2010	10
San and Pujawan (2012)	CLSCM	Remanufacturing	2001–2012	88
Souza (2013)	CLSCM	Strategic and tactical issues	NA	NA
Stindt and Sahamie (2014)	CLSCM	Process industry	1984–2012	167
Govindan, et al. (2015)	RL& CLSCM	Whole area	2007–2013	382
Agrawal, et al. (2015)	CLSCM	Quantitative models of inventory	NA	NA
Jena and Sarmah (2016)	CLSCM	Acquisition management	2000–2014	92
Abbey and Guide (2017)	CLSCM	Strategic review	NA	NA
Govindan and Soleimani (2017)	RL&CLSCM	Based on publications in Journal of Cleaner Production	2001–2014	83
Diallo et al. (2017)	CLSC	Quality, reliability and maintenance issues.	1985-2016	NA
Kazemi, Modak & Govindan （2019）	CLSCM	International Journal of Production of Research	2000-2017	94
Antonio CarlosBraz （2018）	CLSC	the bullwhip effect in closed-loop supply chains	NA	133
Islam and Huda (2018)	RL&CLSC	Waste Electrical and Electronic Equipment (WEEE)	1999-2017	157
	CLSC	Sustainable supply chain	1975-2017	61
Ghadimi et al. (2019) Syed Asif Raza （2020）	RL&CLSCM	Whole area	2008-2019	333
Ehsan （2020）	CLSC	review of factors affecting closed-loop supply chain models	2004-2018	215
Ilkka et al. (2020)	CLSC	returned products in a closed-loop supply chain	2002–2020	59
This Study	CLSC	The whole area in CLSC	2001–2020	1155

Note: RL (reverse logistics); Not applicable (NA): this term is used to indicate that the paper does not explicitly state the number of papers collected and the time span of the review.

We explored the current state of the CLSC landscape, hot spots, evolutionary contexts, and future prospects with the visualization software of CiteSpace and VOSviewer. CiteSpace is a computer program developed by Chen [28] in Java, which is widely used in bibliometric analysis to detect and propose new trends and dynamics of development in a particular field. In our work, CiteSpace is used to identify and visualize the distribution characteristics of the discipline categories, cluster topic terms, and a reference cluster of timeline views.

VOSviewer is a free bibliometric measurement mapping tool, which was developed by van Eck and Waltman [29]. In our study, the VOSviewer is used to present mapping analysis of international collaboration, collaborative networks of key authors and density visualization of keywords. At the same time, the research path and knowledge clustering are determined. The research results of our work can help researchers better learn the research status in the field of CLSC and enable them to become familiar with the research domain in a short time. Furthermore, these findings can also provide enlightenment to scholars to find new ideas and directions for research. Finally, it will promote in-depth development of related research on CLSC and the ecological development of CLSC.

This paper intends to present a detailed bibliometric overview of CLSC, according to following research questions.

RQ1: *What are the main source journals and discipline distribution in a CLSC research?*

RQ2: *What are the distributions of research power with respect to countries, organizations, and authorship?*

RQ3: *What are the core research topics and their knowledge bases?*

RQ4: *What are the research landmark nodes and pivot nodes?*

RQ5: *What are the research hot spots and trends?*

The remainder of the paper is organized as follows: The data sources and research methodologies are presented in Section 2. Descriptive analysis is presented in Section 3. Co-Keyword and Subject Categories analysis are conducted in Section 4. In Section 5, Co-citation analysis is presented. Section 6 shows the analysis results of gaps in current research and potential research opportunities for the future. Finally, Section 7 concludes the whole research.

II. DATA SOURCES ANDMETHODOLOGY

The data used in this study was from the core collection of Web of Science (WoS) on April 16, 2020. The Web of Science (WoS) is one of the important database platforms for obtaining global academic information, more than 20,000 authoritative and influential international academic journals are contained, covers natural science, engineering technology, social science, arts and Humanities and other disciplines. Wang and Waltman [30] compared the data coverage of WOS, Scopus and Google Scholar, respectively. The research results show that WoS outperforms the others because its journal classification system has much higher accuracy. In order to guarantee the quality of data collected from literature, we chose the core collection database of WOS, including SCI-Expansion, SSCI, CR-Expansion and IC. These are all sub databases of WoS. According to Bradford's Law in Bibliometrics, it provides more consistent and standardized literature than other databases, including paper titles, abstracts, keywords, article types, journals, year of publication, volume Number, page Number, and references. In addition, it also includes the references cited in the paper. Through a unique citation index, abrupt changes in nodes can be determined based on burst detection, which can help identify the changes in research directions. Users can use an article, a patent number, a conference document, a journal or a book as a search term to retrieve their cited situation, easily trace the origin and history of a research document or track its latest progress.

As different scholars use different terms to represent CLSC, we tried to use different keywords to search the literature. Data retrieval strategy is as follows: TS = ((''closed loop supply chain'') or (''closed loop supply chains'') or (''CLSC'') or ''CLSCs'')). All searches were done on the same day in order to prevent bias caused by daily updates of the database. According to the system boundary of the research content in our work, the search terms and strategies of CLSC research are shown in Fig. 1. Timespan = ''All years''; Language = ''English''; Where TS = Topic, which is the expression of search used for advanced retrieval in the WoS database. For instance, TS = (closed loop supply chain), means looking for a literature record that contains the term CLSC in the Topic field. The initial search resulted in 4,831, Article and review are chosen as the literature types. In the refine 2, 3,105 papers are remained. Next, according to the subject area, computer and manual filtering was carried out to delete the articles which failed to match the topic and as a way to control quality, 1,155 articles were finally obtained.

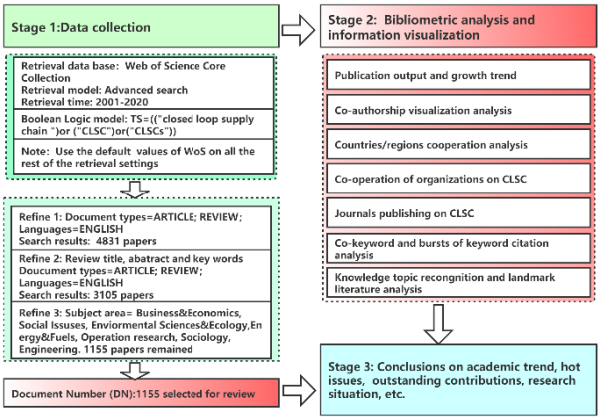

FIGURE 1. Research design of bibliometric analysis on CLSC research.

As shown in Figure 1, the four-step method proposed by van Eck and Waltman [29] has been used to identify the most influential research and examine research topics in bibliometric analysis.

III. ANALYSIS OF DEVELOPMENTS IN RESEARCH FIELDS

A. PUBLICATION OUTPUT AND GROWTH TREND

This section analyzes the whole trend of CLSC research according to the statistics of the published literature and the cited frequency in a given period. Fig. 2 shows the statistics of the number of published papers and the total number of citations in each year. It can be seen that the large growth of CLSC literature is after 2006, which is in line with what is the understanding of the business model research upsurge and the development of Internet technology at the end of the 20th century. In 2019, the number of published papers reached the highest level, 179 documents in total. From 3 in 2019 to 179 in 2019, the number of papers has increased almost 57 times in 17 years, which shows that in recent years, the number of papers is increasing a high degree of concern for CLSC. Figure 2 also reflects the rapid growth of citations in CLSC literature. The number of literature citied on CLSC is less than 5 for the year 2001, but in 2019, it reaches to 5,457.

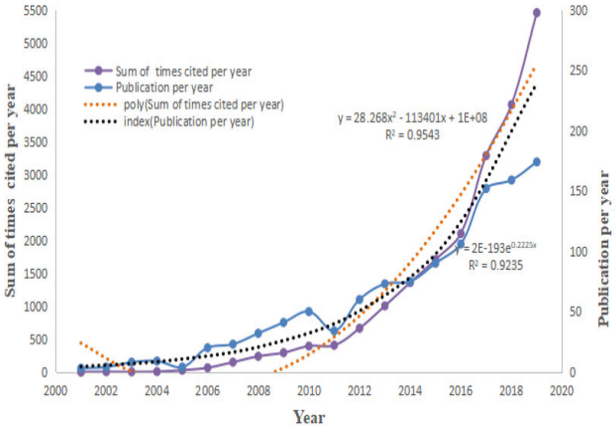

FIGURE 2. Annual publications and citations of CLSC.

TABLE 2. Top 15 journals and authors on CLSC based on the search results.

NO.	Journal	PC	Author	PC
1	Journal of Cleaner Production	93	Gupta, Surendra M.	19
2	International Journal of Production Research	63	Govindan, Kannan	17
3	International Journal of Production Economics	57	Van Wassenhove	16
4	Sustainability	55	Barbosa-Povoa, AP	15
5	European Journal of Operational Research	36	Paksoy, Turan	13
6	Computers and Industrial Engineering	34	Tavakkoli-Moghaddam, R	13
7	Transportation Research Part E Logistics and Transportation Review	22	De Giovanni, Pietro	12
8	Applied Mathematical Modelling	18	Guide, V. Daniel R., Jr.	12
9	Mathematical Problems in Engineering	17	Giri, B. C.	11
10	International Journal of Advanced Manufacturing Technology	15	Ozceylan, Eren	11
11	Computer Aided Chemical Engineering	13	Soleimani, Hamed	10
12	Journal of Manufacturing Systems	13	Wei, Jie	10
13	Computers & Chemical Engineering	12	Zeballos, L. J.	10
14	Resources, Conservation and Recycling	11	Yang Yu-xiang	9
15	Production and Operations Management	10	Amin, Saman assanzadeh	9

Abbreviations: PC= publication count

TABLE 3. Information of the top 10 productive countries and organizations.

NO.	Country/ Territory	PC	Organization	PC
1	China	472	University of Tehran	38
2	USA	159	Pennsylvania Commonwealth System of Higher Education	29
3	Iran	140	HuaZhong University of Science and Technology	28
4	India	85	Islamic Azad University	27
5	France	68	University of Southern Denmark	24
6	Canada	57	Indian Institute of Technology System	23
7	UK	47	Pennsylvania State University	23
8	Germany	43	University of Lisbon	23
9	Turkey	39	Northeastern University	21
10	Taiwan	38	Chinese Academy of Sciences	18

Among the samples of literature, the most cited literature is ''Reverse logistics and CLSC: a comprehensive review to explore the future'' [22]. The curve also suggests that the research level of CLSC shows an exponential growth trend, and its influence in academic circles continues to increase in recent years.

Fig. 2 illustrates the cumulative progress from 2001 to 2020. Interestingly, none of the reviewed publications was published in 2002. By utilizing a nonlinear fit ($R^2 = 0.9235$) of publications, the number of predicted publications in 2020 is calculated as 186. It is also estimated that the number of scientific articles on CLSC research will grow rapidly in the near future. Fig. 2 shows the distribution of articles over the years. According to Fig. 2, the number of publications has been exploded, almost geometrical growth, and reached its peak in 2019. In addition, about 50 percent of articles were published within the past five years, which indicates that the field of CLSC is growing more popularity and suggests the essential of timely review of the research field. Statistics shows that 161 journals were published in the field, among which about 38% of the articles were published in the first 15 journals. Tab. 2 lists top 15 journals that have published the highest number of papers in this field. Journal of Cleaner Production (JCP), International Journal of Production Research (IJPR) and International Journal of Production Economics (IJPE) are the journals that have made the most contributions to CLSCM research in terms of the number of published papers.

It is worth noting, among the 1,155 publications, which organizations and countries made outstanding contributions. Thus, the top 10 organizations and countries were displayed in Tab. 3 and Fig. 3. China, America and Iran were the highest number of contributions to the field of CLSC, accounted

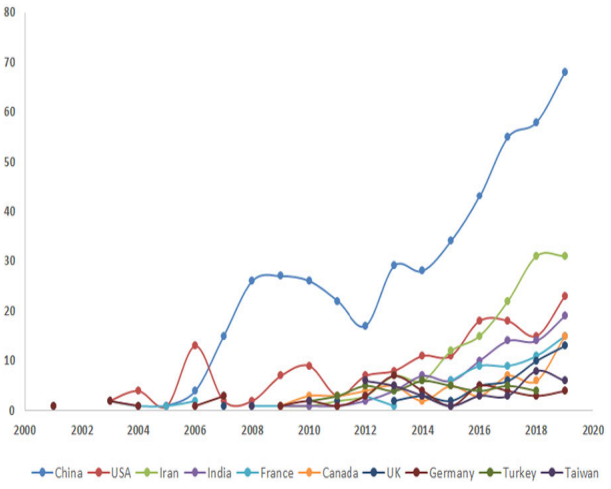

FIGURE 3. Number of articles issued in each country/ territory per year.

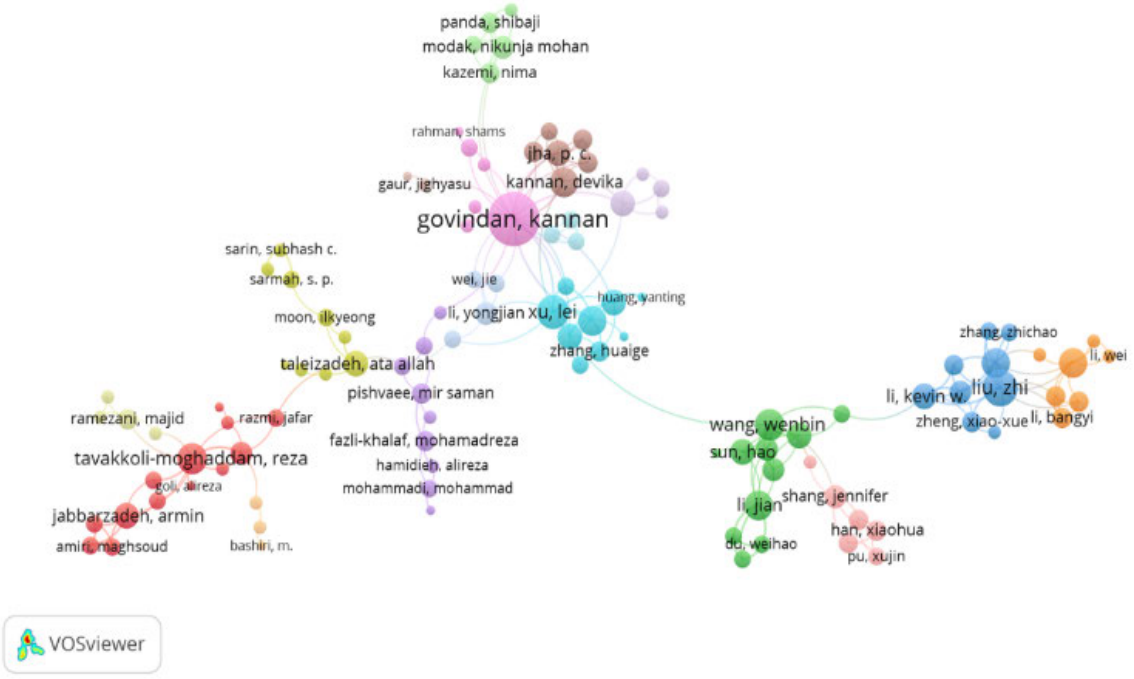

FIGURE 4. Overlay visualization was based on author link-weights.

for about 66.7% of the total publications. From the perspective of global geographic distribution, the top ten countries/ regions with more published articles are from Asia (China, Iran, India, Taiwan and Turkey), Europe (UK, Germany and France) and North America (US and Canada). Obviously, Asian countries have been more successful in articles published, but the first two authors among top ten who contributed to the field of CLSC are from the United States, and the third one is from France, as shown in Tab.2. It indicates that the economically developed European and American countries have been at the forefront of research in this field. Some Asian countries, especially China, are rapidly rising and catching up in this field.

B. CO-AUTHORSHIP VISUALIZATION ANALYSES

By utilizing the function module of the co-authorship visualization of VOSviewer, the cooperation patterns of authors, publishing organizations and countries on CLSC are different auth analyzed. Based on 1,155 papers published by 2,236 ors, the collaborative network of authors in the field of CLSC research is visualized in Fig.4.lly, From Statistical point of view, 47.88% of the authors (n = 553/1, 155) wrote two publications on CLSC, 18.27% (n = 211/1, 155) wrote at least three publications, 0.09% (n = 112/1, 155) wrote four publications, and 0.06% (n = 65/1, 155) had five publications or more. When the data of author is created based on the co-author Map, the threshold is set to 2 to facilitate finding well-known authors who have published on CLSC topics (n = 553). The result suggests that some of the 553 authors are not related to other authors in the network. Only 110 items were analyzed.

Analysis of author collaboration makes us learn its level and visualize the current research status. The exchange of experts between different fields can promote the development of this specific field. Because the number of publications is also an important indicator, Tab. 3 gives a ranking based on this. In Fig. 4, each node stands for an author, while the size of the node denotes the number of their publications. According to the default clustering method, the color of the node indicates the group which the contributor belongs to, and we can see 17 different colored clusters. Lines represent the cooperative relationship among authors, and the wider the line, the stronger the cooperative relationship. In these clusters, main academic relationships and outstanding researchers can be found. For example, the strong chain researchers ''Govindan, Kannan'', ''Fahimnia, behnam'', ''Mina, hassan'', and ''Rahman, shams'' were grouped in a cluster in purple color. The top researchers in the network were ''Wang,Zongjun'', Govindan,Kannan'',''Zhao,Jing'',''Soleimani,Hamed.'', ''Pishvaee, mirsaman'',Liu,Zhi'',''Modak, nikunja mohan'', ''Taleizadeh, atc allah'', ''Tavakkoli-moghaddam reza''.

Tab. 4 shows that the top 10 co-authorship with strong correlation made huge contributions to the publications after 2015. To a certain extent, this indicates that CLSC research has maintained a vigorous development trend.

C. ANALYSIS OF NATIONAL/REGIONAL COOPERATION

1) VISUALIZATION ANALYSIS OF CO-AUTHORSHIP BASED ON COUNTRIES/REGIONS

According to the bibliographic data obtained from the core collection of the WoS, the visualization map of co-authorship network based on countries was created using VOSviewer.

TABLE 4. The top 10 strong co-authorship linked document-productive authors.

	Authours	Documents	Citation	Link Strength	Year
	Govindan, Kannan	16	1193	33	2014
2	Gupta, Surendra M.	16	576	14	2014
3	Paksoy, Turan	13	407	23	2013
4	De Giovanni, Pietro	12	320	7	2014
5	Giri, B. C.	11	241	10	2015
6	Ozceylan, Eren	10	395	14	2017
7	Soleimani, Hamed	10	1085	14	2016
8	Van Wassenhove, Luk N.	10	956	10	2015
9	Huang,min	9	250	9	2013
10	Guide, V. Daniel R., Jr.	9	1231	7	2014

The minimum document threshold of a country is set at 10. 55 countries out of 99 were listed as visualization items. In Fig. 5, the size of circle denotes the number of documents, and the bigger the circle is, the more documents there are. Seven different colors are used to distinguish the seven scientific camps of research on CLSC. China (n=472), South Africa, Singapore, the Taiwan region of China and Indonesia co-authored a lot, while USA (n = 159), France, UK, Germany, Hungary, Australia, Russia, Hungary, Northern Ireland and Poland are closely associated with CLSC research collaboration. The third team colored in red countries/regions has extensive cooperation in Iran (n = 140), Argentina, Portugal, Canada, Qatar, Belgium, Malaysia and other countries and regions. As can be seen from the density visualization of Fig.6, collaboration in CLSC research is leading in the United States, China, United Kingdom, Spain, Italy and Australia.

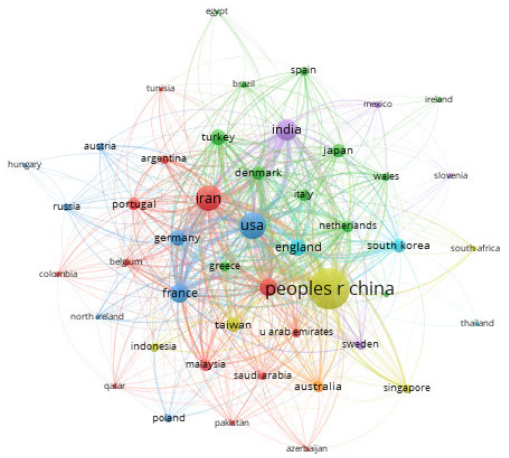

FIGURE 5. Network visualization based on document-weights.

2) VISUALIZATION ANALYSIS OF CITATIONS BASED ON COUNTRIES/REGIONS

The citation analysis can be construed as two authors simultaneously cited by a third author, in which case, these two

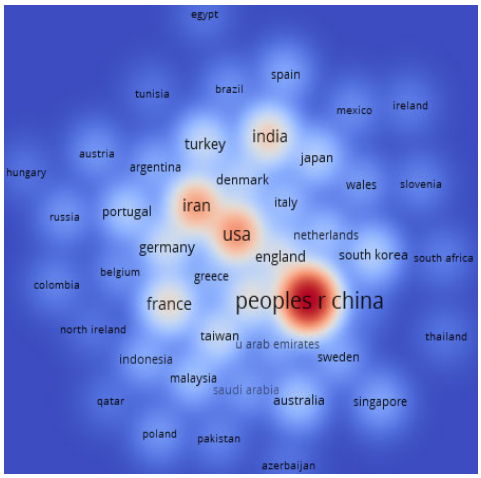

FIGURE 6. Density visualization based on document-weights.

authors are considered having a co-citation relationship. The VOSviewer software is used to create co-citation visualization map of country/region (Fig.7). In the mapping process, the minimum document threshold for a country is set at 2. regions with higher density of co-authors also have The above figures indicate that the two leading countries in CLSC research had very different attitude toward an open intellectual environment. USA held a more collaborative attitude, and the U.S. scholars were more willing to share their experiences in the field of CLSC. According to the density visualization map based on citation-weights as shown in Fig.8, the leading countries/regions in CLSC research are as follows: USA, France, China, Iran, Netherlands, Denmark, etc. By comparing Figure 7 and Fig. 8, we can draw the rough conclusions that even though academic collaboration is reflected by the network patterns of both co-authorship and co-citation relationship, there are still some distinctive differences. Besides, the countries or a strong co-citation regime. To further supplement the content in Table 1, the cooperation characteristics of main countries/regions are shown in Table 5. In the co-citation visualization map in Fig. 7, USA (7,402 citations) has a wider cooperative network in 7 clusters. By contrast, China (3678 citations) maintains close cooperation with only few members. The density visualization map based on citation weights is shown in Fig. 8. The leading countries/regions include USA, France, China, Iran, Netherlands, Denmark.

D. CO-OPERATION OF ORGANIZATIONS ON CLSC

In Fig. 9, when the minimum of documents of an organization is set as 5, 101 representative organizations were grouped into thirteen clusters, which is indicated by thirteen colors. The size of node/circle stands for the number of publications, and the line between two nodes represents the academic link between two organizations, and the shorter the line is, the stronger the link. Therefore, it could be found that the cooperation networks among organizations are relatively dispersed, so this paper only analyzes the top five cooperative networks with the largest number of cooperative

TABLE 5. The cooperation characteristics of main countries/regions.

	Countries/Regions	Links	Link Strength	Documents	AC	APY
1	China	42	4196	472	3678	2014
2	USA	44	3742	159	7402	2013
3	Iran	43	2981	140	3448	2016
4	India	39	2072	85	1526	2016
5	France	41	2256	68	4280	2015
6	Canada	40	1487	57	1500	2015
7	UK	40	1219	47	976	2016
8	Turkey	40	1010	39	1415	2014
9	Taiwan	30	543	38	560	2015
10	Denmark	43	1512	28	1834	2016

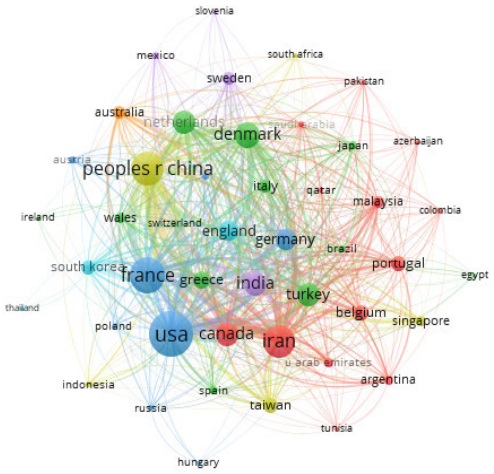

FIGURE 7. Co-citation visualization map of countries/regions.

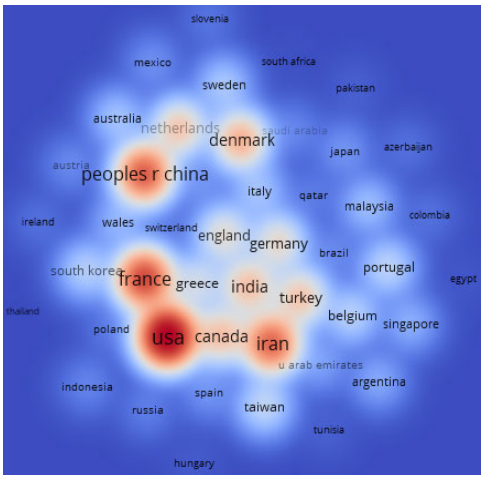

FIGURE 8. Density visualization map based on citation-weights.

members. The red cluster includes the highest member (11) of organizations conducting research on CLSC. In this red cluster, Shanghai Maritime University took the lead in both publication number and the total links.

The green cluster (upper left) in Fig. 9 is the second largest cluster with 8 organizations, including Tsinghua University, Tianjin University, China Jiliang University, Iowa State University, and so on. Among them, Tsinghua University has the most publications. The purple (upper left) cluster in Fig. 9 is the third largest with 7 members, University of Windsor and Northeastern University is a key member with 32 articles. The nattier blue (lower right) cluster in Fig. 9 is the fifth largest cluster, and University of Tehran, with 38 publications, is the most productive member in this cluster in terms of number of publications. Besides that, Huazhong University of Science & Technology and University of Southern Denmark are the key members in terms of publication production. By combining this information with the visualization map of organization link density as shown in Fig. 10, it can be inferred that the cooperation among organizations in Europe was much stronger than that of China. The co-operation of organizations is mostly within its own country.

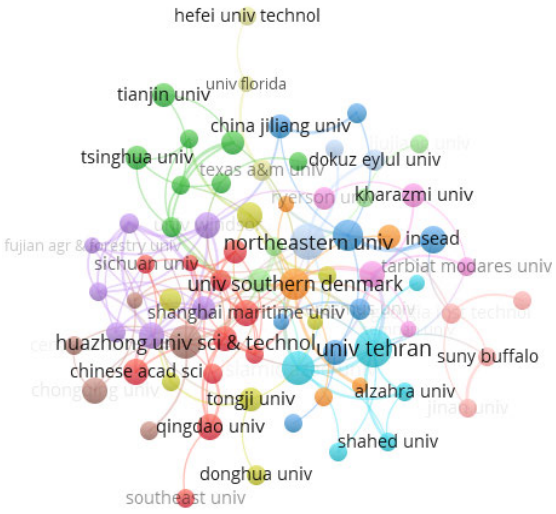

FIGURE 9. Organizational network visualization map based on document-weights.

IV. CO-KEYWORD AND BURSTS OF KEYWORD CITIATION ANALYSIS

A. KEY WORDS CO-OCCURRENCE

Keywords reflect the main content of a literature, and they are usually presented as nouns or phrases. The co-occurrence of any two terms refers to their presence in the same scientific publication. This study involved a total of 2,128 keywords. In order to reveal the thematic areas in closed-looped supply chain, the co-occurrence of research keywords was analyzed using VOSviewer. To demonstrate the co-occurrence of keywords, the co-occurrence threshold of keywords was set as 8, and 61 items were introduced into visualization (Fig. 11 and Fig. 12).

As it was indicated by different colors in Fig.11, the keywords are clearly categorized into eight major clusters. The size of circle indicates the occurrences of keywords. The larger the circle is, the more keywords are selected in

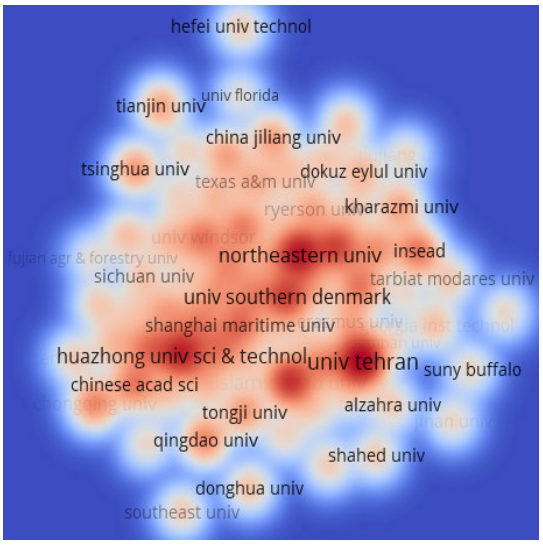

FIGURE 10. Density visualization map of organizations based on total link-weights.

FIGURE 11. Co-keyword network visualization.

the CLSC publication. Publications on the same topic are shownby the circles with the same color cluster. Each circle represents a subdomain of the CLSC domain. According to Fig.11, CLSC, reverse logistics, and remanufacturing are three main clusters/keywords used most frequently in CLSC.

Through the analysis of the main node circle, the 8 main clusters can be assigned by appropriate labels.

Specifically, as it was shown in red color (cluster 1), keywords such as network design, robust optimization, genetic algorithm, supplier selection, supply chain, etc., were obviously related to the topic of ''uncertainty''. Cluster 2 (in green color) represents the characterization of CLSC, which involves studies on Inventory, game theory, coordination, pricing strategy, dual-channel, Stakelberg game, fuzzy theory. Among these keywords, ''remanufacturing'' is the largest node. Next, in the nattier blue (Cluster 3, upper right), keywords like circular economy, bullwhip effect, sustainability, reuse, reverse supply chain, simulation, case

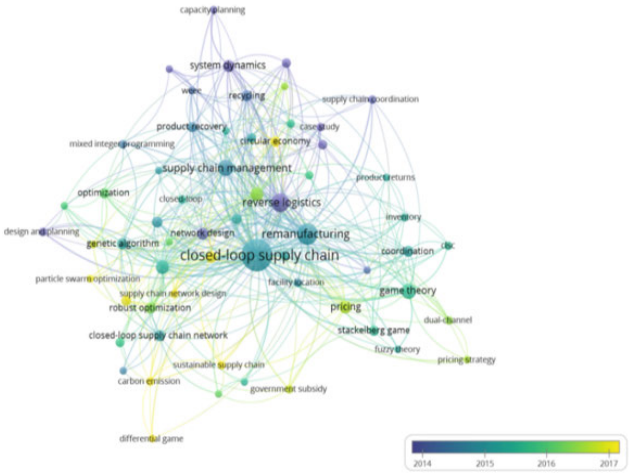

FIGURE 12. Co-keyword network overlay visualization.

study, etc., concentrated on the aspect of ''circular economy''. In the lime-green cluster (Cluster 4, upper left), keywords, like capacity planning, system dynamics, recycling, WEEE (Waste Electrical and Electronic Equipment), supply chain coordination, etc., were associated with the coordination topics of supply chain. The central purple cluster (Cluster 5) consisted of keywords like optimization, mixed integer linear programming, design and planning, genetic algorithm, etc., which were more concerned with ''product recovery''. Cluster 6 (in clear blue color) focuses on the sustainable supply chain, which was related to government subsidy, product design, etc. Meanwhile, cluster 7 (in orange color) is related to the reverse logistics with the keywords of facility location, inventory management, etc. The last light purple cluster in the bottom of Fig.11 (Cluster 8) gathered keywords like remanufacturing, sustainability, carbon emission, and so on, had frequently been linked to ''differential game''.

In Fig. 12, the colors are used to indicate the time-varying characteristic of keyword occurrences from 2014 (in dark purple) to 2017 (in yellow). In almost every sub-domain of CLSC research, some keywords appear more frequently than others, such as circular economy, sustainability, multi-objective optimization, supply chain network design, robust optimization, sustainable supply design, and so on.

The keywords ''CLSC'' and ''remanufacturing'' has the strongest strength. Relative strength and topic similarity are reflected by the distance between these two keywords.

Specifically speaking, according to Fig. 12 (green color, cluster 2), keywords such as game theory, remanufacturing, inventory, coordination, dual-channel, pricing (strategy), Stackelberg-game and fuzzy theory are apparently relevant to the topic in Figure 12; Table 6 lists the information of links and total link strength for the top 10 keywords with highest occurrences.

In Tab. 6, a link represents a co-occurrence connection between two keywords. In accordance with the manual of VOSviewer, a positive numerical value represents a strength of each link. The bigger this value is, the stronger the

TABLE 6. The link and total link strength of the top 10 occurrence keywords.

	Key-words	Clus-ter	Links	Link Strength	Occurr-ences	Year
1	CLSC	2	55	723	657	2014
2	Remanufacturing	2	48	301	182	2014
3	Reverse logistics	7	32	176	119	2013
4	Supply chain management	4	35	112	77	2014
5	Game theory	2	20	103	64	2015
6	Sustainability	3	33	90	48	2016
7	Uncertainty	1	28	90	50	2015
8	Pricing	2	20	67	38	2016
9	System dynamics	4	19	64	34	2013
10	Network design	1	20	58	30	2014

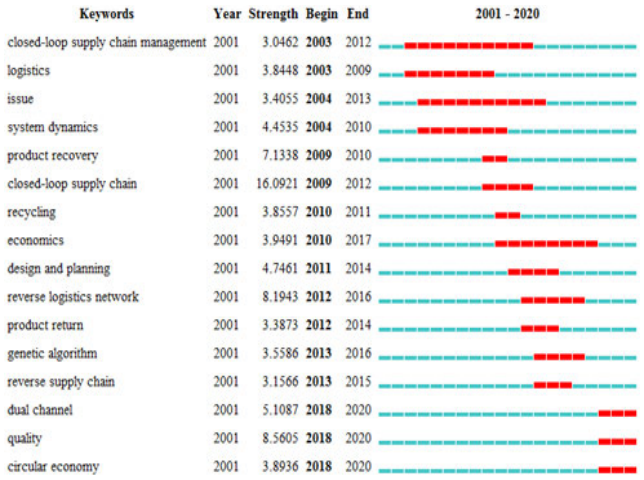

FIGURE 13. Top 16 keywords with the strongest citation bursts.

connection. Total link strength represents the number of publications, where two keywords appear simultaneously. We can see the research hotspot by looking at Tab. 6, which is focused on sustainability, uncertainty, and pricing.

B. BURSTS OF KEYWORD CITIATION

Bursts of keyword citation refer to a sharp increase in the citation of a certain keyword. Burst detection [31] is an effective analytical method to find the keywords of special concern to the relevant scientific communities in a certain time period utilizing CiteSpace software to analyze the emergence of keywords. As is shown in Fig. 13, the red part is the time period when citation outbreak occurs, and the green bar indicates the keywords with less citation. The topics and approaches that received the most and the least attention over the past few years were identified. The top 10 emerging strengths are CLSC, quality, reverse logistics network, product recovery, dual- channel, design and planning, system dynamics, economics, circular economy, and logistics. Among them, ''CLSC management'' was the first keyword proposed in 2003. After 2009, the keywords with the strongest citation bursts can be categorized into four stages. They were recycling, economics, design, and planning (2010-2017), reverse logistics, product recovery, genetic algorithm, reverse supply chain (2012-2016), dual-channel, quality, and circular economy are emergent words appearing in 2018–2020. Combined with the evolutionary path of emergent words of the literature keyword, multiple branches of CLSC research develop simultaneously. The emergence of new keywords with the strongest citation burst has occurred since 2009, and the emergence of new keywords with low citation frequency of the keyword ''circular economy'' between 2012 and 2020 may imply that ''CLSC'' is becoming an independent research topic.

V. CO-CITATION ANALYSIS

The co-citation analysis concentrates on the contribution and role of specific literature, while the cluster analysis based on co-citation network is a specific application in the field of co-citation. In this kind of analysis, the co-citation strength is used as the basic unit of measurement to quantify the classification and aggregation of a given literature citation. This technique can be used to aggregate literatures with similar content into individual clusters, the correlation between clusters can be determined quantitatively according to relevant network indicators, and then, a cluster analysis network graph of literatures in a certain discipline can be generated. In this section, the citation network of CLSC is constructed using the CiteSpace software, and the citation clustering, identification of important nodes of the network and dynamic evolution analysis are carried out in order to identify the development process and popular issues of CLSC research.

Fig. 14 shows the co-citation analysis of 1155 papers on related topics in the Wos from 2001 to 2020. The results of citation frequency are presented in Table 1. The data

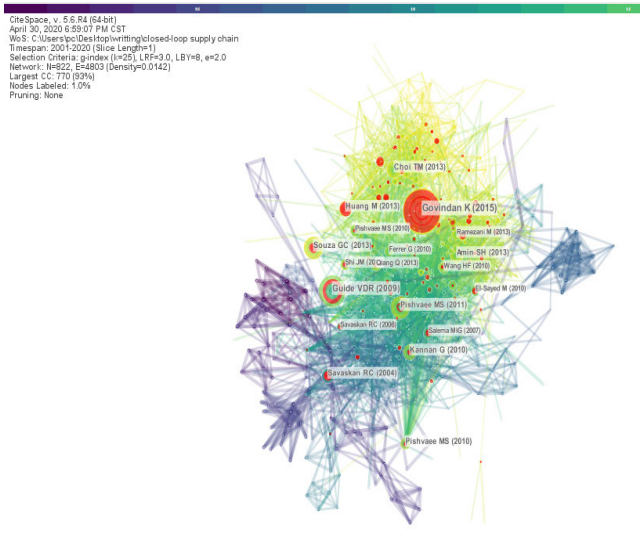

FIGURE 14. Document co-citation cluster diagram.

analysis shows that there are 822 (N = 822) nodes in the network in total,4803 connections (E = 4803) exist between all nodes, and the density of total papers cited in the network is 0.0142, which means that cooperation network has been formed among diverse universities and research institutions but the degree of contact and cooperation is relatively low. In figure 14, the ''citation frequency'' impacts the size of circle. The distance between the circles indicates the closely related literature. Notably, Govindan, Soleimani and Kannan [22] in the third cluster ranks the first in terms of citation frequency, with a citation frequency of 192. The second is the Guide and Van Wassenhove [32] with 143 citations. The third is Pishvaee, *et al.* [33], with 99 citations. The fourth is Souza [21], with 97 citations. The fifth is Choi, *et al*. [34], which has been cited for 77 times. Among the top 10 cited references in Tab. 7, two documents have been cited for more than 100 times, two have been cited for more than 80 times, and six were cited for more than 60 times.

TABLE 7. Literature co-citation list.

No.	Citation counts	Cited References	Year
1	192	Govindan K, ..., EUR J OPER RES,	2015
2	143	Guide VDR, ..., OPER RES,	2009
3	99	Pishvaee MS, ..., APPL MATH MODEL,	2011
4	97	Souza GC, ..., DECISION SCI	2013
5	77	Choi TM, ..., INT J PROD ECON,	2013
6	76	Kannan G, ..., APPL MATH MODEL,	2004
7	76	Savaskan RC, ..., MANAGE SCI	2010
8	74	Huang M, ..., INT J PROD ECON	2013
9	73	Amin SH, ..., APPL MATH MODEL	2013
10	67	Pishvaee MS, ..., FUZZY SET SYST	2010

VI. KNOWLEDGE TOPIC RECONGNITION AND LANDMARK LITERATURE ANALYSIS

A. RESEARCH TOPIC RECOGNITION

In the literature data set, the cited documents constitute the knowledge base of the research field and the research frontier. Thus, on the basis of co-citation relationships of the highly cited document, the subject clustering of citing documents is formed. Meanwhile, according to the subject clustering, the frontier knowledge base of the research field can be identified. On the one hand, it reveals an important turning point of knowledge in the evolution of the research frontier. On the other hand, it also lays a foundation to clarify the relationship between research frontiers. In order to identify the research topic, based on the work of [35], the visualization of similarities (VOS) mapping technology can be used to achieve multidimensional scaling.

Therefore, we used VOSviewer to construct the network of co-cited references in the field of CLSC. Four clusters were obtained, and reference co-citation analysis can be conducted to identify potential research. It can be seen from Figure 15 that there are a total of 4 clusters in the topic cluster map of the research area of CLSC from 2001 to 2020. According to Fig, 15, 186 references out of 62,013 were co-cited

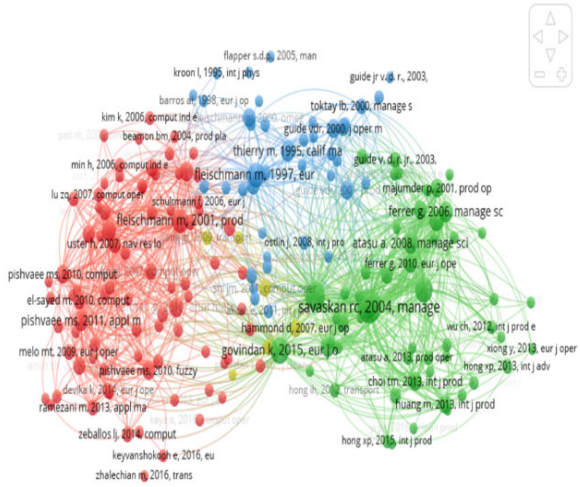

FIGURE 15. Cluster research of topics.

more than twenty times by the publications. As shown in Fig. 15, Savaskan, *et al.* [36] is the biggest node, which indicates that it is the most frequently co-cited reference in the field of CLSC up to now. This study was published in Management Science in 2004 and provided a great contribution to the development of the field of CLSC. Furthermore, Figure 15 shows that the 186 references can be clustered into four groups distinguished by different colours, and each group represents well-connected references in the CLSC research area. The leading ten co-cited references of each cluster were extracted to identify the area of research focus, as shown in Tab. 8.

Specifically, Cluster 1 focuses on CLSC network design. In Cluster 1, the stream of literature can be further extended to explore the product recovery on network design under uncertain return and to investigate the product pricing decision in recycle economy project. Cluster 2 mainly focuses on CLSC models with product remanufacturing. The stream of the literature in Cluster 2 can be further extended to product reuse economics. Cluster 3 provides some strategic suggestions for the product recovery management of remanufacturing. For a multi-product closed-loop system with uncertain demand and return, optimal production planning can be made according to the stream of literature in Cluster 3. Cluster 4 addresses how to realize network equilibrium of closed-loop supply chain. According to the literature in Cluster 4, the works mainly discuss the sustainability of CLSC with uncertain demand and return. It might be a potential research direction. In order to find popular subjects in the field of CLSC, the research topics of co-cited references were clustered using CiteSpace. The dynamic evolutionary path of topics in CLSC is presented in Figure 16, in which, the knowledge source is also indicated. These clusters reflect the popular research topics in CLSC over the past 20 years. The quantity of documents for each topic cluster indicates a large difference in scale, the maximum is 171 articles, and the minimum is 6 articles. After data analysis, the top11 largest research clusters are shown in Tab. 9, each cluster was labelled with a keyword

TABLE 8. Leading co-cited references of each cluster in the field of CLSC.

Cluster 1red	Cluster 2 green	Cluster 3 blue	Cluster 4 yellow
Fleischmann, et al. [37]	Savaskan, et al. [36]	Fleischmann, et al. [38]	Hammond and Beullens [39]
Salema, et al. [40]	Guide and Van Wassenhove [6]	Thierry, et al. [41]	Shi, et al. [42]
Pishvaee, Rabbani and Torabi [33]	Govindan, Soleimani and Kannan [22]	Guide, Harrison and Van wassenhove [13]	Qiang, et al. [43]
Jayaraman, et al. [44]	Savaskan and Van Wassenhove [45]	Guide and Van Wassenhove [32]	Yang, et al. [46]
Kannan, et al. [47]	Ferrer and Swaminathan [48]	Fleischmann, Beullens, Bloemhof-Ruwaard and Van Wassenhove [35]	Nagurney, et al. [49]
Pishvaee and Torabi [50]	Atasu, et al. [51]	Toktay, et al. [52]	Dong, et al. [53]
Pishvaee, Rabbani and Torabi [33]	Ferrer and Swaminathan [54]	Ilgin and Gupta [55]	Shi, et al. [56]
Amin and Zhang [57]	Souza [21]	Ostlin, et al. [58]	Gupta and Palsule-Desai [59]
Wang and Chen [60]	Choi, Li and Xu [34]	Vlachos, et al. [61]	Srivastava [62]
Krikke, et al. [63]	Huang, et al. [64]	Rubio, et al. [65]	Sahyouni and Savaskan [66]

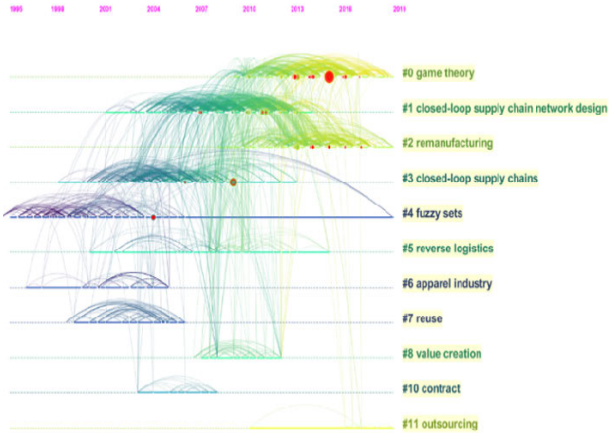

FIGURE 16. Research topic timeline view.

TABLE 9. The largest 11clusters in CLSC research area.

Cluster ID	Size	Silhouette	Label (LLR)	Mean (Year)
0	171	0.74	game theory	2014
1	144	0.676	CLSC network design	2008
2	136	0.758	Remanufacturing	2014
3	126	0.538	CLSCs	2005
4	86	0.917	fuzzy sets	2000
5	29	0.91	reverse logistics	2007
6	28	0.939	apparel industry	2001
7	23	0.98	reuse	2003
8	13	0.963	value creation	2009
10	8	0.94	contract	2005
11	6	0.988	Outsourcing	2013

extracted from the title, and the size represents the number of papers contained in each cluster. Silhouette is an indicator used to evaluate a cluster. Concretely speaking, the cluster is evaluated according to homogeneity indicators of network. The closer the value of silhouette is to 1, the higher the network homogeneity. If the silhouette value >0.5, it implies that the clustering result is reasonable. In this part, the clusters are labeled using the log-likelihood ratio algorithm. In Tab. 9, the column ''Mean'' represents the average of the reference years, which indicates the average year in which these literatures in the same cluster were published.

From Tab. 9, cluster #4 ''fuzzy set'' is the earliest cluster in the field of CLSC. This indicates that scholars first studied CLSC because of its uncertainty, which was confirmed by [23]. The model quantifies the uncertainty using four different methods: 1- Stochastic, 2- Fuzzy, 3- Fuzzy-Stochastic and 4-Disrupted. Stochastic approach is the most popular method at present. In addition, we know that Cluster0 and Cluster2 are newly formed Clusters, which means that ''game theory'' [67]–[73], ''remanufacturing'' [74]–[81], and ''outsourcing'' [82], [83] are the hot spots in recent CLSC research. 0 Clustering—Most scholars use game theory to study the problems in the CLSC, Among the top 10 most cited references, there are 4 articles in this cluster. Based on game theory, Min Huang et al [64] characterized the performance of supply chain based on evaluation of pricing decisions and recycling strategies, and they considered the cases for both decentralized and the centralized channels. Many scholars have emerged in recent years to apply game theory to study CLSCs, such as [84]–[87], and so on.

2Clustering—The theme of the cluster is remanufacturing, which plays an important role in constructing of a resource recycling network system. The most cited document is Shi, *et al.* [56]. This study is the first study that considers multi-objective mathematical model in CLSC network configuration under uncertainty. Zeballos, *et al.* [88] proposed a design and planning method for the common multi-product CLSC, which has the structure of a 10-layer network (5 forward + 5 reverse flows). Govindan and Soleimani [9] clarified the main trends of reverse logistics and CLSC topics from 2001 to 2014 for the *Journal of Cleaner Production*, and assessed potential new research directions for the journal. It's worth noting that the number of publications on the general concept of reverse logistics and remanufacturing exceeds

TABLE 10. Landmark nodes, Pivot nodes.

Author	Title	Journal	Cition	Cluster NO.
Landmark node				
Govindan K, Soleimani H, Kannan D (2015)	Reverse logistics and CLSC: a comprehensive review to explore the future.	Eur J Oper Res 240(3):603–626	192	0
V. Daniel R. Guide, Jr.Luk N. Van Wassenhove (2009)	OR FORUM—The Evolution of CLSC Research	Operations Research57(1):10-18	143	3
Pivot node				
Jayaraman V, Patterson RA, Rolland E (2003).	The design of reverse distribution networks: Models and solution procedures	Eur J Oper Res 150(1):128-149	12	1
Krikke, H., Bloemhof-Ruwaard, J., & Van Wassenhove, L. N. (2003).	Concurrent product and CLSC design with an application to refrigerators.	IJPR, 41(16), 3689–3719.	17	3

all publications on CLSC subject areas such as [89]–[96] Amin *et al.* [97] designed a CLSC network for tire remanufacturing using a new decision-tree-based approach, in which, the effects of uncertainty in CLSC network configuration were considered. Besides the above documents, there have been many documents in recent years to study the problem of remanufacturing in CLSC [80], [98]–[100].

B. LANDMARK NODES AND PIVOT NODES

Landmark nodes and pivot nodes are the critical research objects in citation network analysis. Identifying landmark points and pivot points can recognize the development path and obtain important research results of the discipline. Landmark node is a point with a large radius in the citation network, and the citation frequency is high. It has played a foundational role in the development of the discipline and has milestone significance; a node with purple ring is called a pivot node, and it has a higher value of betweenness centrality. The pivot node is a connection point to connect two clusters at the same time, which often results in change of research focus in a certain field. It is an important node in the development and evolution of the discipline. Landmark nodes and pivot nodes can be automatically identified by calculation in CiteSpace, pivot nodes are highlighted in purple circles in the visualization results of the citation network. The node indicated by the purple circle in Figure 14 is the pivot node of the citation network. The basic information of landmark nodes, pivot node and high-cited documents in each cluster is summarized in Table 10.

References [6] and [22] are two remarkable landmark nodes in co-cited article network. Notably, these landmark nodes are computationally identified instead of manually scanning by users so as to ensure that all landmark nodes are correctly found. Govindan, Soleimani and Kannan [22] is a major landmark in the citation network. It discusses the relationship and role of CLSC, corporate strategy and innovation in a more comprehensive and in-depth manner. It has milestone significance in the development and evolution of CLSC research. As for the other two pivot nodes of CLSC, Jayaraman *et al.* [101] contributed to the literature on reverse distribution in two ways: first, they developed a strong formulation and a weak formulation to investigate the logistical problems of reverse distribution, and second, they applied the heuristic concentration procedure to develop a new methodology to solve this very complex problem. Krikke, Bloemhof-Ruwaard and Van Wassenhove [63] developed a double-integrated modeling framework using mixed-integer linear programming, and this framework is applicable to the design of supply chain with multiple product design options and multiple product recovery options which have varying feasibility.

VII. CONCLUSION

With data from WoS core database from 2001 to 2020 and scientific citation network analysis software CiteSpace and Vosviewer, this paper presents a systematic and extensive bibliometric analysis of 1155 publications which was published in the area of CLSC. This paper will provide a roadmap for managers who wish to adapt and implement CLSC to achieve overall growth and development. It also provides an in-depth knowledge on CLSC to researchers working in this domain. Conclusion can be drawn as follows:

First of all, in the past 20 years, the number of publications related to the topic of CLSC increased steadily, which grew from 3 related publications in 2001 to a peak number of 179 in 2019. This indicates that research on CLSC had attracted increasingly more attention from the society and scholars. The influential works, their authors, the existing and emerging research clusters/themes are identified.

Second, no relatively stable core author group was found in the CLSC field. The Chinese Academy of Sciences published the most CLSC-related research papers. We also found that the geographic dispersion of the published papers. Although the number of publications in China had increased significantly in recent years, early researches in the United States had laid down a solid foundation for research in this field. Furthermore, the international exchanges and cooperation in CLSC research mainly involve the developed countries.

Third, ''Reverse logistics and CLSC: a comprehensive review to explore the future'' published by ''European Journal of Operational Research'' is the most cited paper among the 1155 documents. Furthermore, ''game theory'', and ''remanufacturing'' were CLSC emerging research trends, and ''dual channel'', ''quality'' and ''circular economy'' had become hot topics.

Fourth, in accordance with time-zone view, landmark point, pivot nodes, the hop topics at different stages in CLSC are discussed. We can also analyze development path of CLSC in recent 20 years according to dynamic clustering map, which makes the research situation of CLSC demonstrated vividly.

Finally, this research has determined that a number of gaps still exist, these research areas are ripe for further investigations. The circular economies has been widely applied in CLSC [102]. The redesign of CLSC network arouses extensive attention [103]–[105]. For the next 10 years, the big data technology and data-driven modeling with the support of advanced AI tools will be employed in researches in this field [106]. In addition, the Internet of things (IoT) also presents a huge potential to impact all areas of supply chain management, and Industrial Revolution 4.0 will reshape the future of the CLSC [107]. With the development of information technology and the availability of data, big data analytics are employed by more companies in their supply chains. In the work of Ma and Hu [108], the Internet service platform with big-data marketing was integrated into the dynamic CLSC system, which served as an independent game subject. Meanwhile, sharing and learning of information is also critical in determining the efficiency and the benefit of supply chain [109].

In addition, creation of holistic value should also be considered in research on CLSC. The results of this paper have great practical implications for business practitioners. To be more specific, case studies should be conducted, in which the data mining technology should be used on CLSC in real businesses. Meanwhile, more attention should be paid to the sustainable development multi-objective programming model in the research of CLSC, which considers the economic and social factors including the environment.

In order to better research CLSC, the most influential papers can serve as a good reference point. This paper, which applied Citspace and VOSviewer software for the bibliometric review of CLSC, provides a good perspective on many aspects of the CLSC., this Although this research strived to conduct a robust and systematic investigation for this literature review, it still has limitations. This study uses limited keywords for searching the literature papers in the database. The quality of searching the literature paper could further be enhanced by using different keywords in the area of CLSC. In the further, content analysis of the study could further be enhanced. Future work is likely to investigate the dynamic evolution of the field and explore the impact of emerging tools from big data and artificial intelligence on the CLSC research.

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