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An Extensive Review on the Closed Loop Supply Chain

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Abstract

With more and more attention has been paid into the domain of closed loop supply chain (CLSC), the number of outputs has increased significantly in the past few years. The purpose of this paper is to provide more information about the characteristics of CLSC-related publications and the evolution of the whole area over the decades. Based on 856 publications retrieved from Web of Science, two effective methods, the bibliometric analysis and main path analysis are adopted in this study. This study helps researchers understand the general information of this domain from a macro level and grasp the history, development status and possible directions for the future research.

Keywords

Closed loop supply chain (CLSC); bibliometrics; cooperation; main path analysis

1. Introduction

Forced by environmental pressure, stricter legislation and increasingly competitive business environment, more and more companies have begun to remanufacture and recycle used products, resulting a new type of supply chain called closed-loop supply chain (CLSC) (Zheng et al., 2019a), which contains the forward supply chain and the reverse supply chain simultaneously (Soleimani et al., 2014). The forward supply chain contains the flow of products and services from material suppliers, to manufacturers and assemblers, and to retailers and end-users (Fahimnia et al., 2013). While the reverse supply chain includes used-product acquisition, inspection and disposition, remanufacturing and remarketing (Guide & Van Wassenhove, 2001), which views back activities as the way to satisfy environmental requirements (Bouzon et al., 2018). In the industry, more and more companies have attached importance to the adaption of CLCS, such as Xerox for recycling copiers and Kodak and Walmart focusing on recovery activities, for the purpose of minimizing cost and environmental impact, as well as improving business status (Mohammed et al., 2017; Alamdar et al., 2018). Combining forward and reverse logistics, CLSC indeed plays an important role in driving sustainability, focusing on

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improving the sustainable performance of supply chain, and generally, a well-designed and effective CLSC is able to strike a balance between the cost reduction and environmental production (Guide & Van Wassenhove, 2009; Kazemi et al., 2019).

Recently, research on CLSC has aroused intense interest from scholars. With the dramatic growth of CLSC research, many of them try to summarize previous works and study the development of CLSC domain systematically. Some are review papers with specific aims, such as the study of quantitative models for inventory and product planning (Akçalı & Çetinkaya, 2011), the summary of CLSC with remanufacturing (San et al., 2012) and analysis of factors affecting CLSC models (Shekarian, 2020). In addition, there are several papers investigating the whole area of CLSC comprehensively. For instance, Guide & Van Wassenhove (2009) analyze the evolution of CLSC domain from business perspective, as well as discuss the future research opportunities in detail. By using bibliometric methods, Kazemi et al. (2019) review papers related reverse logistics and close loop supply chain management (RL&CLSCM), providing valuable information for the future research.

Bibliometrics is a field that studies the bibliographic material quantitatively (Bonilla et al., 2015). Through bibliometric indicators, it is possible for us to analyze many aspects of a domain, such as publications, citations and information sources including authors, institutions and countries, etc. (Blanco-Mesa et al., 2017). It is an effective way to explore the development of a specific domain (Yu et al., 2020). Nowadays, it has been widely used in the overview of a journal (Yu et al., 2017; Silva et al., 2019), the analysis of various fields (Van Nunen et al., 2018; Liao et al., 2018), author cooperative analysis (Van Leeuwen et al., 2016), and so on.

Main path analysis, which is based on a citation network, is first proposed by Hummon & Doreian (1989). In the citation network consisting of a series of publications, each node denotes a publication and the link between two papers represents the citation relationship between them. The authors propose three algorithms to weight the link according to their role in the citation network, including node pair projection count (NPPC), search path node pair (SPNP) and search path link count (SPLC). In addition, the "priority first search" algorithm is proposed to extract the main path. Further, Batagelj (2003) introduces an effective algorithm called search path count (SPC). Liu & Lu (2012) define the "priority first search" as a "local" approach, and propose other approaches such as "global" and "key-route" methods. Main path analysis aims to explore the knowledge diffusion trajectories of a given citation network which are built based on documents such as patents, papers or count decisions (Liu et al., 2019a). There are several advantages when using the main path analysis studying a given domain. First, it simplifies a complicated network into several influential paths, which is able to filter out key publications from a large number of papers in a domain effectively. It is able to handle thousands of papers which is unmanageable for traditional review task (Xiao et al., 2014). Second, it depicts a sequence of historical-development events clearly (Liu & Lu, 2012), which is helpful to get an overview of a domain fully. Recently, it is widely used in exploring development paths in internet of things (Fu et al., 2019), data quality (Xiao et al., 2014), information technology outsourcing (Liang et al., 2016) and blockchain domain (Yu & Sheng, 2020), etc.

The rest of this paper is organized as follows. In Section 2, the data source and data analysis are briefly introduced. Section 3 provides a general analysis of publications from a static angle, followed by the discussion of the dynamic evolution results in Section 4. The last two sections discuss and conclude this paper, respectively.

2. Data Source and Data Analysis

In order to ensure the quality of the data, in this paper, two databases of Science Citation Index Expanded (SCI-EXPANDED) and Social Sciences Citation Index (SSCI) in Web of Science (WoS) core collection are selected. The time is limited to 2019 and the retrieved time was 2020.07.09. Using "closed loop supply chain(s)" as the search subject, a total of 856 publications including articles and reviews are obtained finally.

The bibliometric indicators of annual publications, authors, institutions and countries/territories, such as the number of publications and citations and H-index, are analyzed in Excel. In particular, publications from England, Northern Ireland, Scotland and Wales are merged into UK (Zhang et al., 2010). The whole counting method is used in this paper. If a paper is co-authored by three authors that are from two countries, each country will be counted once (Zhu & Liu, 2020). "Multi-country/territory publication" refers to the paper whose authors are from different countries/territories and "Multi-institution publication" indicates the paper with authors under different institutions. Moreover, the cooperation networks of authors, institutions and countries/territories are carried out in Gephi and VOSviewer (Bastian et al., 2009; Van Eck & Waltman, 2010), respectively. In addition, the Pajek is used to extract and visualize various main paths.

3. General Analysis of CLSC Publications

3.1. Annual Analysis of Publications

According to our search strategy, the data retrieved from the WoS covers 2001 to 2019. Fig. 1 depicts the overall trend of CLSC publications clearly, including the annual distribution of the total number of publications (TP), the total number of citations (TC) and H-index. It is noticeable from the Fig. 1 that the volume of outputs is no more than 30 from 2001 to 2011. However, after 2012, the yearly output has increased significantly with an exception of 2014, accounting for 86.80% of the total, indicating that more and more researchers are paying attention to CLSC domain in recent years. It can be inferred that the upward trend will still be maintain in the coming years. The H-index is also calculated. It refers to the number of papers with citation number more than h (Hirsch, 2005). Obviously, the year of 2013 has the highest h-index of 34, which means that there are 34 papers that receive greater and equal to 34 citations totally. It can be seen that the value of TC fluctuates up and down constantly, reaching its peak of 3360 in 2013. The value of TC in 2001 is least due to the least number of publications. But according to TC/TP, shown in Table 1, it ranks second with the value of 413, far surpassing other years except 2005.

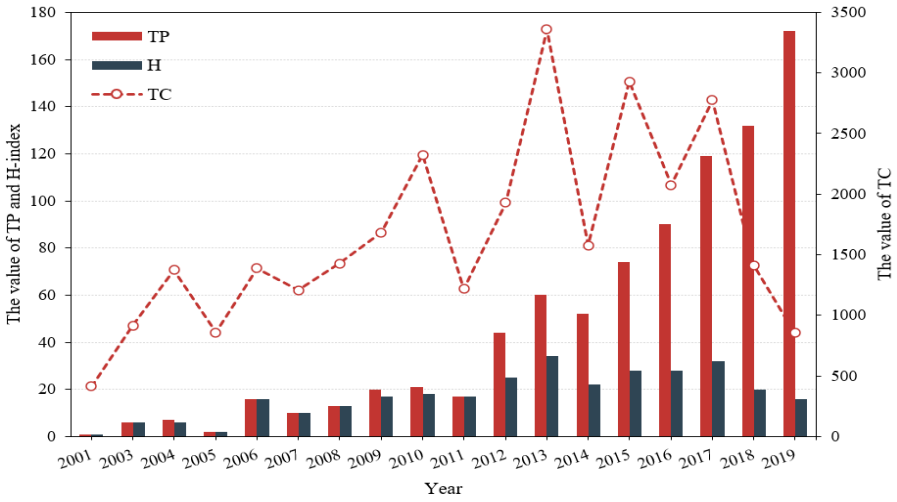

Fig. 1. Annual distribution of CLSC publications

In Table 1, other indicators are calculated to describe the characteristics of cooperation, including single-author publication number (SAPN), single-institution publication number (SIPN), single-country/territory publication number (SCPN) and MAPN, MIPN and MCPN for multi-author, multi-institution and multi-country/territory publication number respectively. Two papers that have no information of affiliated institutions and countries of authors and we do not take them into account. In general, the value of MAPN, MIPN and MCPN increases annually, amounts to 812, 548 and 299 in total.

Fig. 2 is presented to clearly show the detailed information of cooperation at author, institution and country/territory levels. Three doughnut charts are shown in the upper of the Fig. 2. Over ninety percentage of publications have two or more authors being the cooperation model of three authors the most remarkable one, making up 35.86% of the total. Inter-institution-collaborative publications accounts for 64.13%. However, in terms of country/territory, the number of publications within a country/territory is more dominant, which indicates that collaboration between different countries/territories is not obvious.

The dynamic change of cooperation rate is clearly depicted in the lower part of Fig. 2. The rate of author cooperation (MACR) maintains a high level with an average of 96.12%. The rate of institution and country/territory cooperation (MICR and MCCR) have declined twice obviously, in 2004 and 2007 respectively. But after 2007, the cooperation rate recovers rapidly.

Table 1. Characteristics of publications from 2001 to 2019

Year	TP	TC	TC/TP	LC	LC/TP	H	SAPN	MAPN	SIPN	MIPN	SCPN	MCPN
2001	1	413	413.00	129	129.00	1	0	1	0	1	0	1
2003	6	914	152.33	206	34.33	6	0	6	2	4	4	2
2004	7	1374	196.29	366	52.29	6	0	7	4	3	6	1
2005	2	858	429.00	42	21.00	2	0	2	0	2	1	1
2006	16	1387	86.69	345	21.56	16	1	15	5	10	9	6
2007	10	1205	120.50	248	24.80	10	2	8	6	3	9	0
2008	13	1428	109.85	269	20.69	13	0	13	4	9	10	3
2009	20	1682	84.10	409	20.45	17	1	19	4	16	16	4
2010	21	2323	110.62	466	22.19	18	0	21	9	12	15	6
2011	17	1218	71.65	371	21.82	17	1	16	7	10	10	7
2012	44	1928	43.82	491	11.16	25	2	42	21	23	29	15
2013	60	3360	56.00	961	16.02	34	4	56	25	35	39	21

2014	52	1576	30.31	401	7.71	22	3	49	22	30	38	14
2015	74	2927	39.55	780	10.54	28	5	69	28	46	52	22
2016	90	2074	23.04	545	6.06	28	7	83	35	55	57	33
2017	119	2774	23.31	633	5.32	32	3	116	34	85	70	49
2018	132	1414	10.71	243	1.84	20	10	122	38	94	77	55
2019	172	856	4.98	103	0.60	16	4	168	61	111	112	60

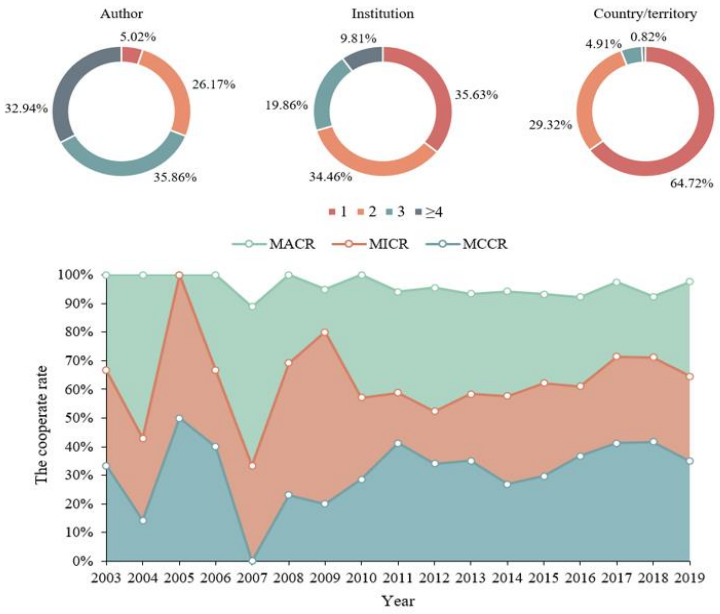

Fig. 2. Characteristics and trends of cooperation

3.2 Author and Its Co-Authorship Network Analysis

Table 2 and Fig. 3 present the top 11 prolific authors in the domain of CLSC with at least 10 publications. In Fig. 3, the size of the circle denotes the number of publications of the author and its color indicates the continent to which the author belongs. These continents are Asia (purple), Europe (blue) and North America (yellow). It is observable that Van Wassenhove, LN from France performs the best in terms of the number of publications (21), TC (3989), TC/TP (189.95) and H-index (15), exerting a far-reaching influence on CLSC research. Govindan from Denmark ranks second with a total of 17 publications and has been cited 1434 times, followed by Guide, VDR from USA with 16 publications. The H-index values of these three authors are higher than 14, ranking top in the list. Although Soleimani, H has the least number of publications, he has a high value of TC/TP (118.60), ranking third among these prolific authors.

It can be seen from the Table 2 that the countries where these authors belong are scattered, and a majority of them are from developed countries. The detailed information such as SAPN and MAPN are also listed in Table 2. Many authors tend to establish cooperative relationships with others and almost all of their papers are co-authored publications. Around 60% of the total are inter-institution-collaborative publications. It should be noted that the collaboration rate of country/territory, 57.25%, is higher than that of in this domain, 35.05%.

Table 2. The most productive authors

Rank	Author	Country	TP	TC	TC/TP	H	SAPN	MAPN	SIPN	MIPN	SCPN	MCPN
1	Van Wassenhove, LN	France	21	3989	189.95	15	1	20	1	20	2	19
2	Govindan, K	Denmark	17	1434	84.35	15	0	17	0	17	0	17
3	Guide, VDR	USA	16	2165	135.31	14	0	16	1	15	7	9
4	Tavakkoli-Moghaddam, R	Iran	12	307	25.58	7	0	12	2	10	6	6
5	Krikke, H	Netherlands	11	731	66.45	10	1	10	3	8	8	3
6	Barbosa-Povoa, AP	Portugal	11	543	49.36	8	0	11	1	10	6	5
7	Amin, SH	Canada	10	572	57.20	8	0	10	7	3	8	2
8	De Giovanni, P	France	10	349	34.90	9	4	6	4	6	4	6
9	Giri, BC	India	10	281	28.10	7	0	10	7	3	9	1
10	Paksoy, T	Turkey	10	407	40.70	7	0	10	4	6	6	4
11	Soleimani, H	Iran	10	1186	118.60	10	0	10	3	7	3	7

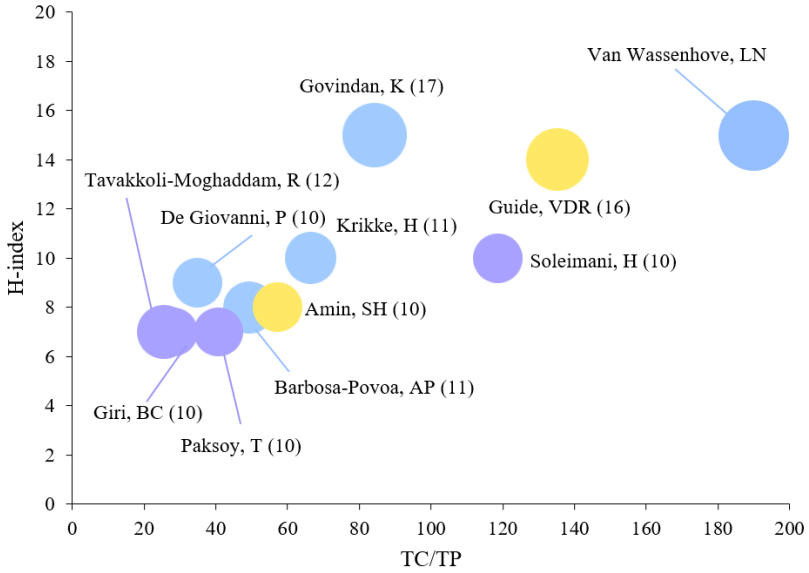

Fig. 3. The top 11 prolific authors with TP, TC/TP and H-index

To investigate the cooperative relationship between authors fully, the collaborative network is drawn with the help of Gephi (Bastian et al., 2009). In Fig. 4, each node denotes an author and the size represents the degree of the node, that is, the total number of links of an author. The co-authorship relations are shown by links and more frequently the two authors collaborate, the thicker the link. For a clearer presentation, only authors who published at least 3 papers are selected and finally 178 nodes are obtained. This paper identifies 7 connected components with more than 5 members, and they are labeled with different colors according to different sizes.

Table 3 lists detailed information about each component. The node with the highest degree is defined as the representative author while the co-author(s) with the most strength is defined based on the times they cooperate. The largest component consists of a total of 35 members being Govindan, K the most outstanding one. The author has established extensive connections with multiple authors, and among them, Soleimani, H is the author who has collaborated with him most. The paper they co-authored entitled "Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future" received 640 citations in the WoS, ranking third in our downloaded data set (Govindan et al., 2015). Van Wassenhove, LN and Souza, GC are the central authors in the second largest component,

but the link strength between them is weak. Tang J has 9 collaborators and most of them are affiliated with Chinese institutions, who has a strong connection with Liu Z. The remaining 4 components are relatively small and the links among them are loose. Two authors, Krikke, H and Tavakkoli-Moghaddam, R, not only perform well in research outputs, but also play an important role in cooperation with others.

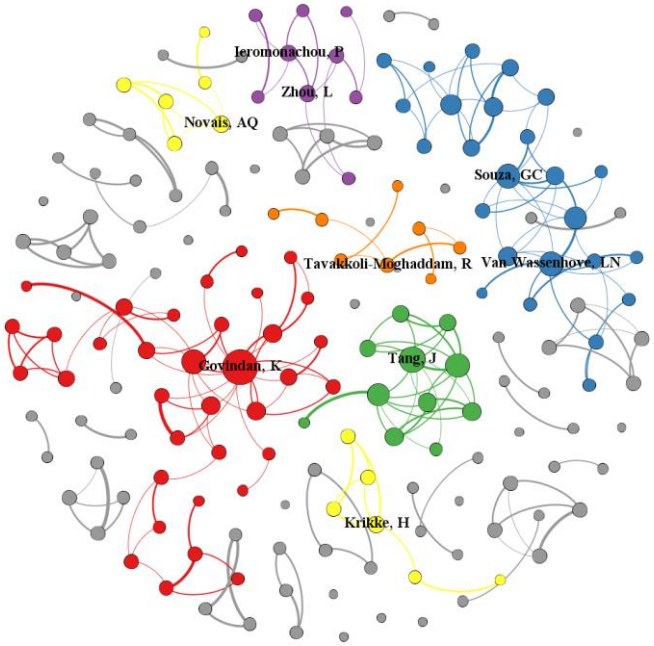

Fig. 4. The collaborative network of authors

Table 3. The information of seven components

# Component	Color	Size	Representative author(s)	Co-authors with most strength
1	Red	35	Govindan, K	Soleimani, H
2	Blue	25	Souza, GC / Van Wassenhove, LN	Abbey, JD; Kleber, R / Guide, VDR
3	Green	11	Tang, J	Liu, Z
4	Purple	9	Ieromonachou, P / Zhou, L	Zhou, L; Tseng, ML / Zhou, L; Tseng, ML
5	Orange	8	Tavakkoli-Moghaddam, R	Vahdani, B
6	Yellow	6	Krikke, H	Schenkel, M; Caniels, MCJ
7	Yellow	6	Novais, AQ	Barbosa-Povoa, AP

3.3. Institution and Its Co-Authorship Network Analysis

In this part, the most productive institutions are investigated which are listed in Table 4. Univ Tehran is the most prolific institution with 32 publications. Penn State Univ from USA and Islamic Azad Univ from Iran both have published 25 papers, ranking second in terms of TP, followed by Huazhong Univ Sci & Technol with 24 papers and Univ Southern Denmark with 22 papers. INSEAD ranks sixth according to the number of outputs. However, in terms of the total citations (3959) and average citations (188.52) the institution receives, it has the highest position far exceeding the

remaining institutions. Among these 10 institutions, three of them are from China, and Univ Tehran, Penn State Univ and INSEAD are three institutions that have the highest H-index of 17, meaning that each one has 17 publications receiving 17 citations or more.

Some indicators, including average citations of single-institution publications (TC_{SIPN}/SIPN), average citations of multi-institution publications (TC_{MIPN}/MIPN) and MICR, are calculated to evaluate the cooperation characteristics of these prolific institutions. Univ Southern Denmark has the highest MICR with 100%, followed by INSEAD with 95.24%. In general, the average citations of inter-institution-collaborative publications is higher than that of publications completed by a single institution. To some extent, cooperation between different institutions has a positive effect on the citation of papers.

Table 4. The most productive institutions

Rank	Institution	Country	TP	TC	TC/TP	H	SIPN	TC_{SIPN} /SIPN	MIPN	TC_{MIPN} /MIPN	MICR
1	Univ Tehran	Iran	32	1544	48.25	17	9	73.00	23	38.57	71.88%
2	Penn State Univ	USA	25	2406	96.24	17	3	24.00	22	106.09	88.00%
3	Islamic Azad Univ	Iran	25	1290	51.60	12	8	12.50	17	70.00	68.00%
4	Huazhong Univ Sci & Technol	China	24	396	16.50	12	6	26.33	18	13.22	75.00%
5	Univ Southern Denmark	Denmark	22	1070	48.64	17	0	0	22	48.64	100.00%
6	INSEAD	France	21	3959	188.52	14	1	0	20	197.95	95.24%
7	Hong Kong Polytech Univ	China	19	831	43.74	11	4	20.25	15	50.00	78.95%
8	Univ Windsor	Canada	16	858	53.63	13	4	108.00	12	35.50	75.00%
9	Chongqing Univ	China	15	412	27.47	12	1	1.00	14	29.36	93.33%
10	Texas A&M Univ	USA	15	759	50.60	10	1	43.00	14	51.14	93.33%

In the following, three influential institutions with the highest value of TC/TP, which are INSEAD, Penn State Univ and Univ Windsor, are selected to further investigate the connections between the target institution and other institutions. The mapping is created by VOSviewer. In Fig. 5, each institution is represented by a node and its size is determined by the total link strength of it. The thickness of links between different institutions denotes the frequency of cooperation. It is not difficult to see that Penn State Univ has the closest connection with INSEAD among 25 institutions that it cooperates with, having completed a total of 7 publications. The time span is from 2003 to 2019, and it can be predicted that cooperation between them will continue in the future. Penn State Univ is also the institution with the most cooperation with INSEAD, followed by Georgia Inst Technol, and the remaining institutions have only cooperated with it once or twice. Anhui Polytech Univ and Nanjing Univ Aeronaut & Astronaut from China are two institutions that collaborate the most with Univ Windsor. An interesting finding is that for these three influential institutions, the closest partners are institutions from another country.

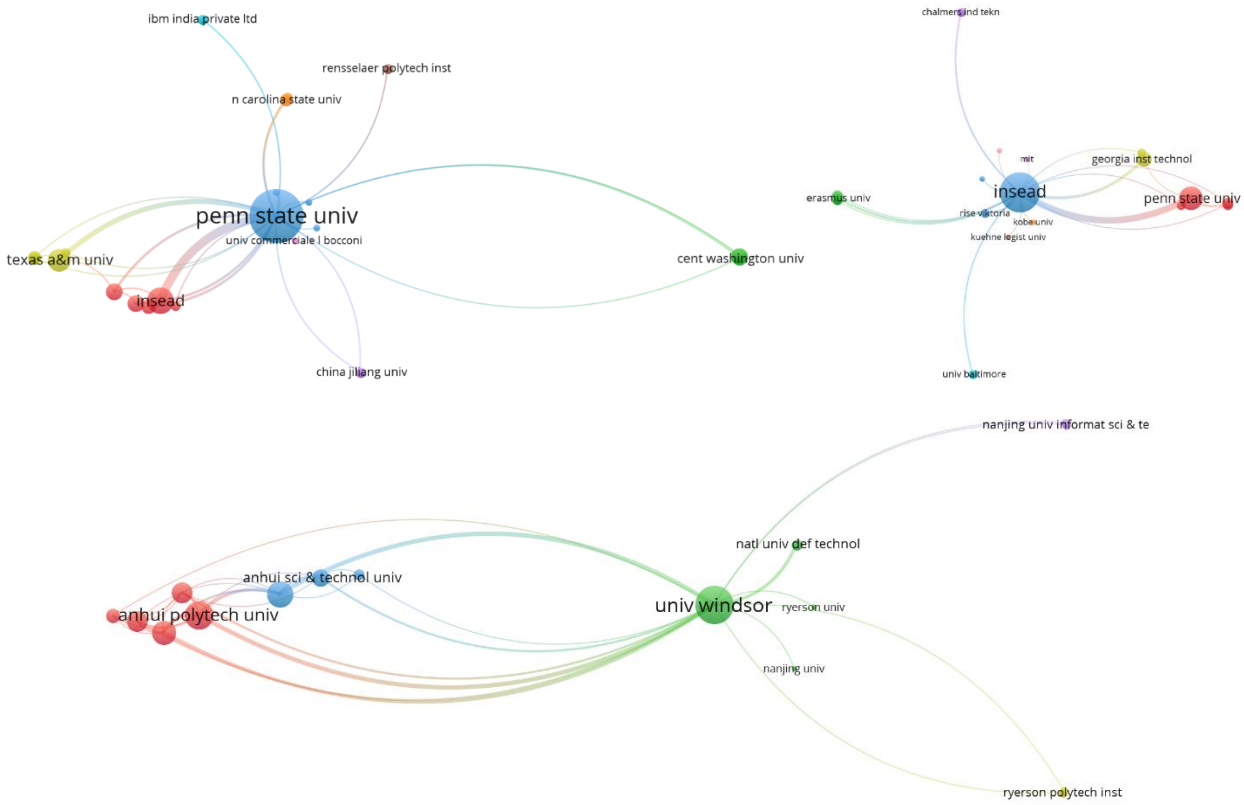

Fig. 5. The cooperative networks of 3 institutions

3.4. Country/Territory and Its Co-Authorship Network Analysis

Authors that pay attention to the study of CLSC distribute all over the world. To identify the most prolific countries/territories, the top 15 are extracted based on the number of outputs, which is presented in Table 5. China is the most productive country with 269 publications, taking up more than one-third of the total in this field. Ranked second to fifth are USA, Iran, India and UK. Among these countries/territories, more than a half are developed countries. USA is the most frequently cited country, and its number of citations is more than twice that of China which ranks second receiving a total of 5015 citations. However, according to TC/TP, China performs the worst, meaning that the number of citations of per publication is relatively low. In contrary, France and Denmark get high TC/TP values of 84.24 and 78.11, respectively.

The average citations of single-country/territory publications (TC_{SCPN}/SCPN), average citations of multi-country/territory publications (TC_{MCPN}/MCPN), and MCCR are also represented in Table 5. Most of publications of these countries/territories are international-collaborative publications. Countries with high cooperation rates are Denmark (100%) and France (88.14%). For a majority of countries/territories, the value of TC_{MCPN}/MCPN is higher than that of TC_{SCPN}/SCPN, indicating that the cooperation across countries/territories has a positive effect on the citation of papers.

Table 5. The most productive countries/territories

Rank	Country/territory	TP	TC	TP/TC	H	SCPN	TC_{SCPN}/SCPN	MCPN	TC_{MCPN}/MCPN	MCCR
1	China	269	5015	18.64	38	170	14.58	99	25.62	36.80%
2	USA	178	10236	57.51	50	80	45.59	98	67.23	55.06%
3	Iran	109	4026	36.94	31	71	24.49	38	60.18	34.86%
4	India	68	2006	29.5	26	33	25.82	35	32.97	51.47%
5	UK	61	1681	27.56	25	13	39.00	48	24.46	78.69%
6	France	59	4970	84.24	24	7	16.29	52	93.38	88.14%
7	Canada	56	2164	38.64	26	19	46.53	37	34.59	66.07%
8	Germany	44	1943	44.16	22	20	59.90	23	25.74	52.27%
9	Taiwan	33	844	25.58	15	22	33.27	11	10.18	33.33%
10	Turkey	33	1500	45.45	21	23	28.39	10	84.70	30.30%
11	Denmark	27	2109	78.11	20	0	0	27	78.11	100.00%
12	Netherlands	26	1922	73.92	19	12	51.42	14	93.21	53.85%
13	South Korea	26	515	19.81	13	16	12.38	10	31.70	38.46%
14	Australia	19	416	21.89	12	6	17.00	13	24.15	68.42%
15	Italy	18	495	27.5	13	6	28.83	12	26.83	66.67%

In order to observe the output of these 15 countries/territories in different periods, the period of 19 years is divided into four periods: 2001-2005, 2006-2010, 2011-2015 and 2016-2019. Fig. 6 presents the output percentages of these 15 countries/territories in the four periods. Compared with other countries/territories, Netherlands has the most uniform production in these four periods. 9 out of the 15 productive countries/territories have no publications during 2001-2005 and Australia only begins to focus on CLSC research in the period 3. Moreover, counties such as Italy, UK, India, Iran and China have gradually increased the number of publications in the period 4, which denotes that these countries have attached importance to the topic of CLSC recently. However, there is a decline in the productivity of Netherlands and Turkey in 2016-2019.

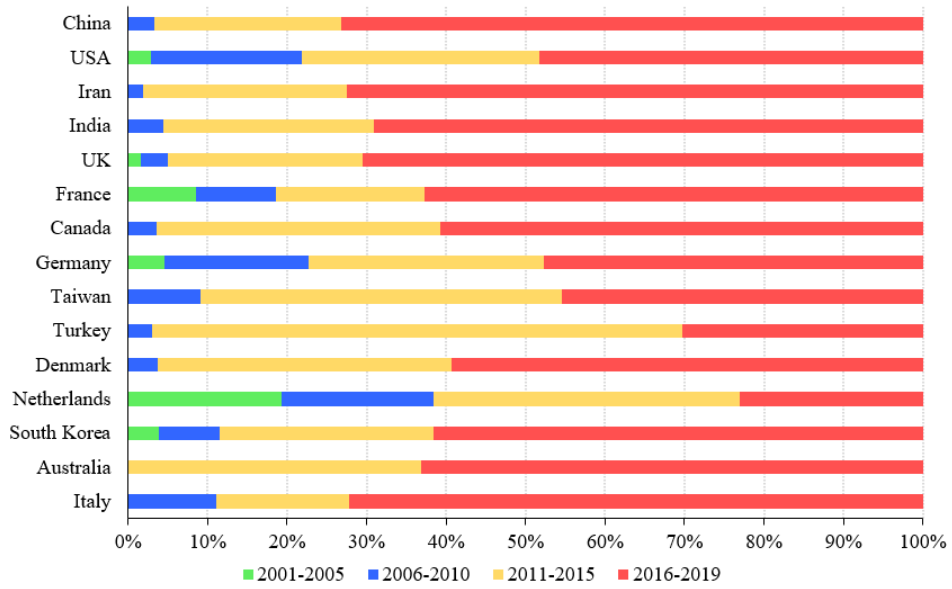

Fig. 6. The output percentages of these 15 countries/territories in four periods

The co-authorship network of these 15 countries/territories is illustrated in Fig. 7. Each note is labeled with the name of the country/territory and its size represents the total link strength of a country/territory. It is noticeable that USA has the most cooperation with other countries, followed by China, which indicates that these two countries have established extensive cooperation with high-

yielding countries/territories in the past few years. The thickness of the link represents the number of co-authored publications. It can be seen from the Fig. 7 that the links between USA and China is the thickest, meaning that there is a close collaborative relationship between them in CLSC research. In addition, USA has frequent cooperation with India and France. In addition to USA, China has built close cooperative relations with UK and France.

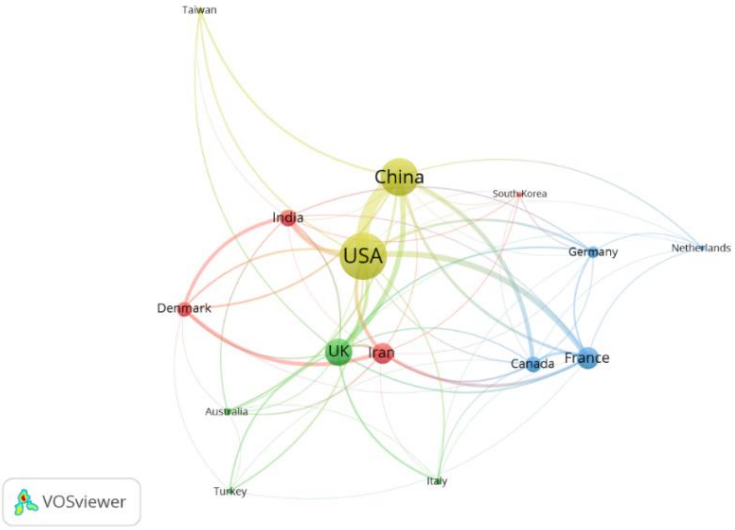

Fig. 7. Collaborative network of the top 15 productive countries/territories

4. The Evolution of CLSC Research

4.1. The Evolution of Hot Spots in CLSC Domain

Based on the frequency of keywords, it is able for us to identify the development trend and research hot spots in a specific domain (Yu & He, 2020). In this paper, the high-frequency keywords in the whole period are determined, which is presented in Fig. 8. Furthermore, the most common keywords in the three subperiods are also identified to analyze the focus of different stages. The top 15 keywords for each subperiod and the entire period are listed in Table 6.

Fig. 8. The top keywords in the whole period

Due to the search strategy is related to CLSC, the keywords sharing the same meaning are deleted to show the hot spots in this domain more accurately. Form Fig. 8 it can be seen that the CLSC with remanufacturing is more popular. In different decisions to manage end of life (EOF) products, such as recycling and remanufacturing, it is no doubt that the CLSC with remanufacturing has attracted the most attention in the past years. Some hot topics revolve around reverse logistics, supply chain management and sustainability. Related to network design, some keywords like genetic algorithm, uncertainty and robust optimization also appear in the Fig. 8.

Table 6. High-frequency keywords at different stages

2001-2010		2011-2015		2016-2019		2001-2019	
Keywords	Freq	Keywords	Freq	Keywords	Freq	Keywords	Freq
reverse logistics	23	remanufacturing	55	remanufacturing	101	remanufacturing	174
remanufacturing	18	reverse logistics	40	reverse logistics	42	reverse logistics	105
supply chain management	14	supply chain management	21	game theory	41	supply chain management	73
system dynamics	6	sustainability	15	supply chain management	38	game theory	51
network design	6	game theory	10	sustainability	33	sustainability	48
recycling	5	uncertainty	9	pricing	24	uncertainty	33
closed-loop supply chain management	4	network design	8	circular economic	23	pricing	30
case study	3	system dynamics	7	uncertainty	23	system dynamics	24
product recovery	3	closed-supply chain network design	7	robust optimization	17	circular economic	23
capacity planning	3	competition	6	coordinate	14	network design	22
genetic algorithm	3	genetic algorithm	6	multi-objective optimization	13	recycling	21
sustainable operations	3	product recovery	6	system dynamics	11	robust optimization	21
distribution planning	2	recycling	6	closed-supply chain network	11	product recovery	18
set partitioning	2	reverse supply chain	6	recycling	10	genetic algorithm	18
vehicle routing	2	supply chain	6	carbon emission	10	multi-objective optimization	17

The high-frequency keywords in three stages are listed in Table 6. Research around remanufacturing and reverse logistic has aroused the interest of scholars no matter in what stages. CLSC network design is one of the main studies across all the three stages. In the third stage, “carbon emission” surfaces in the list of the top keywords, which means that more and more attention has been paid into the effect of CLSC on environmental problems. Reducing the carbon emission is also an objection in constructing the models. Moreover, in many approaches that solve the mathematical problems in CLSC, genetic algorithm is more frequently used by scholars. Another interesting finding is that in the third stage, the problems of pricing and ordination gradually become a hot topic in the CLSC domain. High-frequency keywords in this stage includes circular economic, robust optimization and multi-objective optimization.

4.2. Main Path Analysis

This part examines three types of main paths, including the local main path, global main path and key-route main path, to get an overview of the CLSC domain fully. These paths complement each other rather than replace each other (Lu & Liu, 2013). Therefore, analyzing different main paths simultaneously will help researchers gain in-depth insights into the knowledge diffusion trajectories

in this domain effectively.

Construct the citation network of 856 publications retrieved from the WoS is the first step to perform main path analysis. After obtaining the citation network, the largest subnet is required to extract and loops should be deleted to make sure the network is a direct acyclic one. Then the network is further transformed into a weighted one by SPC algorithm recommend by Batagelj (2003) and different main paths can be extracted further. Visualizing these paths can obtain a set of nodes and links between them. These paths are shown in Figs. 9, 10 and 11 intuitively. In these figures, a node represents a paper labeled with the name of the first author and the year of publication. Following the arrow is the direction of knowledge flow in the CLSC domain. The results of each path will be discussed below.

4.2.1. Local Main Path

The local main path focuses on the most important links at each juncture, which is shown in Fig. 9. It can be seen from the Fig. 9 that Fleischmann2001 is the first paper on this path. Leading by this significant paper, there are a total of 18 publications on this path. Fleischmann2001 proposes a generic recovery network model which is used further to analyze the impact of the return flows on the network design (Fleischmann et al., 2001). Taking both product design and logistic network design into account, Krikke et al. (2003) design a modelling framework aiming to minimize the supply chain costs and environmental impacts. The next three papers, Uster2007, Pishvaee2010 and Ozceylan2013a, propose a mixed integer linear programming (MILP) model for CLSC network design respectively (Üster et al., 2007; Pishvaee et al., 2010; Özceylan & Paksoy, 2013a). A solution method based on Benders decomposition is developed in Üster et al. (2007) while Pishvaee et al. (2010) design a multi-objective memetic algorithm to find the non-dominated set of solutions.

Uncertainty is one of the characteristics in CLSC network with product recovery (Zarandi et al., 2011). However, a majority of the above-mentioned papers ignore the design for CLSC network under uncertainty. To fill this gap, Pashvaee2011 develops a robust optimization model to solve the uncertainty in returned products, demands for returned products and transportation costs (Pishvaee et al., 2011). A fuzzy modelling approach is applied to cope with the uncertainty in capacities, demands and reverse rates in Özceylan & Paksoy (2013b).

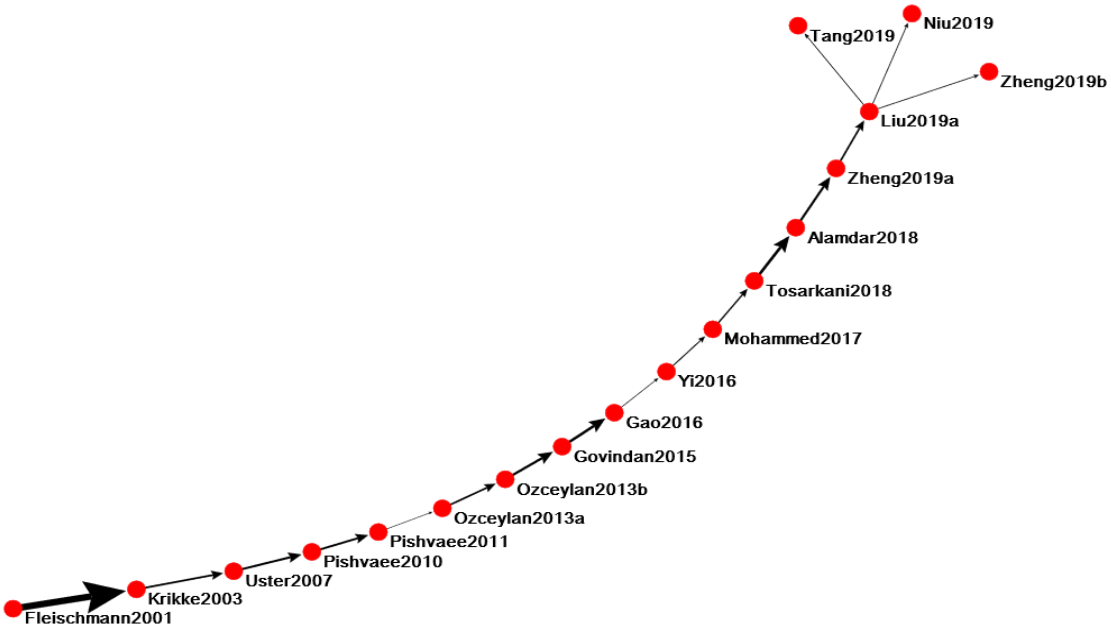

Fig. 9. Local main path

Govindan et al. (2015) is a significant review. The authors summarize previous research efforts on reverse logistic and CLSC systematically and provide researchers with guidelines for the future research works. In the following, there are three papers all revolving around the issue on CLSC network design, including Yi 2016, Mohammed2017, and Tosarkani 2018. Yi2016 dedicates to coping with the retailer oriented CLSC network design in the field of construction machinery (Yi et al., 2016). Mohammed2017 designs a model for CLSC network by taking carbon footprint into consideration. In addition, the authors investigate the impact of several policies, including carbon cap policy, carbon tax policy, carbon cap-and-trade policy and carbon offset policy, on the design and planning of CLSC (Mohammed et al., 2017). Tosarkani2018 applies fully fuzzy programming for the multi-objective battery CLSC network (Tosarkani & Amin, 2018). It should be noted that the last two papers both take uncertain parameters into account and evaluate the environmental impacts.

Several papers on the main path focus on the study of coordination, such as Gao2016 and Akamder2018. The former establishes centralized and decentralized game theoretic models under three channel power structures, including manufacturer Stackelberg, vertical Nash and retailer Stackelberg (Gao et al., 2016). The authors also propose a coordination strategy for improving the performance of the decentralized CLSC. In a fuzzy CLSC consisting of a manufacturer, a retailer and a collector, the latter studies all possible alliance strategies, as well as proposes a new coordination scheme (Alamdar et al., 2018). Zheng et al. (2019a) and Zheng et al. (2019b) are the research that both incorporate retailer's fairness concerns into the coordination of a CLSC.

At the end of the main path are several papers that are mainly completed by authors from China. There is a bifurcation after Liu et al. (2019a; 2019c), which studies the product design and its effect on the operations of a CLSC consisting of a supplier and non-integrated manufacturer. Tang2019 investigates the pricing and warranty decisions under two models (Tang et al., 2020). Niu et al. (2019) establish an overall research framework for design for remanufacture (DfRem)-driven CLSC operation issues.

After the comprehensive analysis of these 18 works, it is not difficult to see that more than a half of

papers fall in the scope of the research about CLSC network design. It is the main concern in the field of CLSC, nearly throughout the entire development process. The model is gradually closer to the reality by tanking different types of parameter uncertainties into consideration, such as the product demand and returns. In addition, incorporating the environmental impact into CLSC design also attracts more attentions in recent years. Papers like Mohammed2017 and Tosarkani2018 on the main path are such examples. From the perspective of model approach, it should be mentioned that MILP is more prevalent for the design of network in the field of CLSC.

Another interesting finding is that coordinating the members of a given CLSC structure is also a popular topic in CLSC domain being outstanding in the second half of the path. The related papers propose different effective coordination mechanisms. It is foreseeable that fairness concerns will continue to be incorporated in the coordination of a CLSC in the future.

4.2.2. Global Main Path

Different from the local method, the global method is able to identify the path which has the largest accumulated value and obtain the global main path. The path is presented in Fig. 10 and green nodes represent the same papers on the local and global main paths.

Kleindorfer2005 is a significant paper that has received 767 citations in the WoS, which ranks second in our downloaded data set. In Kleindorfer et al. (2005), the authors provide us with a comprehensive introduction to CLSC-related papers published in *Production and Operations Management* and new opportunities are pointed out. This paper is also recommended by the following paper, Atasu2008, which focuses on the discussion of CLSC analytic research on business economics and is driven by practice (Atasu et al., 2008). Based on system dynamics methodology, Georgiadis2010 investigates the influence of two-product joint lifecycles on capacity planning (Georgiadis & Athanasiou, 2010), and insights for capacity planning policies are also provided.

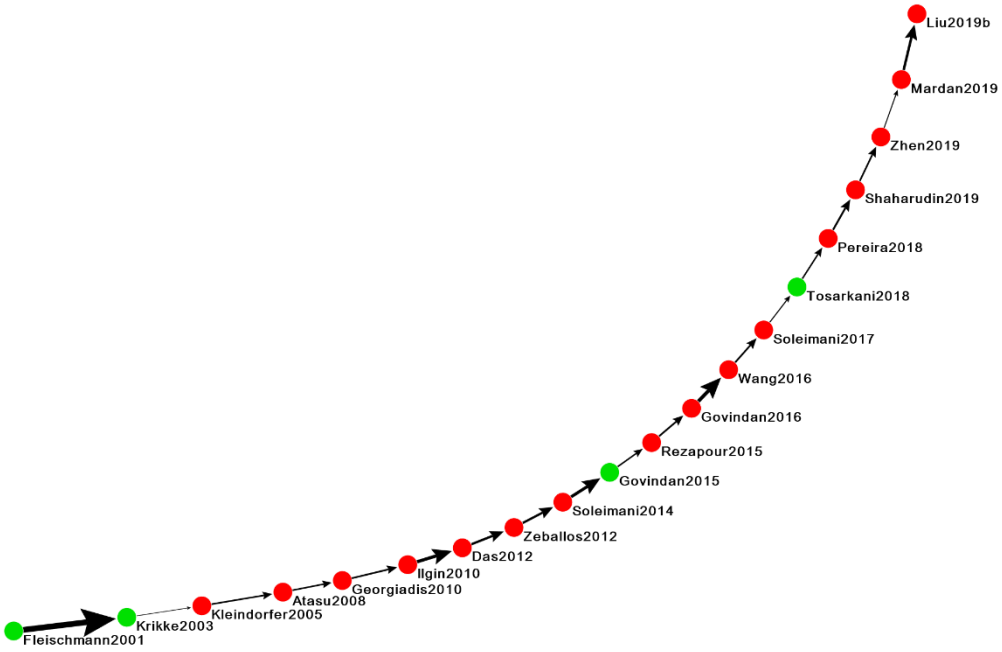

Fig. 10. Global main path

Ilgin2010 confirms that a vast majority of studies on reverse and closed-loop supply chain is related to network design (Ilgin & Gupta, 2010). Checking the following papers on the global main path, it can

be found that, even in the next ten years, the majority of these papers involve the network design problem. For example, Das2012 proposes a mixed integer programming model and a numerical example is used to prove the applicability of the model (Das & Chowdhury, 2012). In Zeballos2012 (Zeballos et al., 2012), the authors propose a two-stage scenario-based approach for addressing the CLSC design and planning problems. However, there are no risk parameters in the work and the model is risk-neutral which is inefficient for volatile conditions. Soleimani et al. (2014) extend the research by constructing three models with different types of risk measures. Rezapour2015 considers the external and internal competition simultaneously in the designing of CLSC network (Rezapour et al., 2015). Govindan et al. (2016) quantify three dimensions, including economical dimension, environmental and social dimensions, and present a multi-objective mathematical model.

In recent years, the environmental and societal impacts of a supply chain have received increasing attention. Soleimani2017 and Zhen2019 are such examples that cope with the design problems of green and sustainable closed-loop supply chain. Soleimani et al. (2017) proposes a model with the objective functions of maximizing the chain profit, minimizing the lost working days due to occupational accidents and maximizing satisfying customer demand. While in Zhen et al. (2019) present a bi-objective optimization model aiming to minimize CO_2 emissions and optimize the total operational cost.

With the aspect of solution approach, different solutions have been proposed and the effectiveness of them have been verified. In Wang2016, the authors propose a new algorithm called "advanced cross-entropy" for solving CLSC design and planning problems (Wang et al., 2016) while Mardan2019 designs an accelerated benders decomposition algorithm (Mardan et al., 2019).

Several papers at the end of the main path make it possible for us to explore more about CLSC domain from different perspectives. In Pereira2018 (Pereira et al., 2018), the authors propose a model for the return forecasting which is applied further to a tire CLSC. Shaharudin2018 (Shaharudin et al., 2018) examines the product returns as a mediating factor on the relationship between green capabilities and CLSC adoption. Liu et al. (2019b) studies four different alliance models, endeavoring to find the best alliance for a manufacturer in a CLSC which consists of a dominant manufacturer, a retailer and a third-party recycler.

Compared with the local main path, the global main path depicts a totally different picture of the knowledge diffusion in CLSC domain since there are only four same papers on these two paths. This path digs out two influential papers at the beginning of the path, Kleindorfer2005 and Ilgin2010, receiving much attention from the inside and outside CLSC domain. The in-depth discussion of related papers about CLSC research in these two papers lay out foundations for the following research.

Even though papers on the global and local main paths are quite different, generally, the global main path shows that the network design in CLSC domain is still the main concern. Usually, a case study is illustrated to validate the proposed model, such as a case study of electrical manufacturing industry or wire-and-cable industry. With the increased environmental awareness from the society, the authors tend to incorporate the impact on the environment in their models, such as CO_2 emission indicator. In addition, the research which considers environmental and social responsibility issues simultaneously has stand out gradually. Thus, the research about green and sustainable CLSC has attracted more and more attention recently.

4.2.3. Key-Route Main Path

At the beginning of the path is the paper entitled "Closed-loop supply chain models with product

remanufacturing". In this paper, the authors focus on addressing the problem of selecting the appropriate reverse channel to collect used products (Savaskan et al., 2004). It makes great contribution to the CLSC domain with a total of 954 citations according to global citation score (GCS), ranking first in our downloaded data set. Following this significant research, in Modak2018, the authors assume that the demand is related to the price and quality level, and compare three types of reverse channel structures, including retailer led collection, third party led collection and manufacture led collection (Modak et al., 2018). Liu et al. (2017) addresses the problem of selecting the best choice for remanufacturer for collecting used product. In this paper, the authors discuss three dual recycling channels systematically. The results show that, no matter how the competition intensity is, original equipment manufacturer (OME) and retailer dual collecting model is always the best choice for OME (Liu et al., 2017).

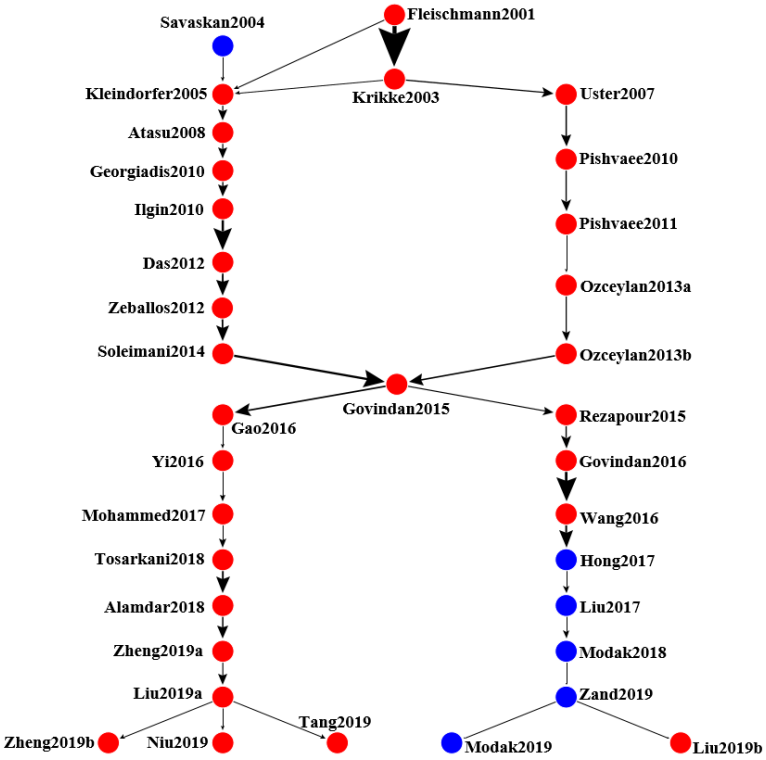

Fig. 11. Key-route main path

A majority of new papers center at the end of the path. Hong2017 (Hong et al., 2017) investigates the effect of different licensing patterns, including fixed fee and royalty, on the product and collection decisions for manufacturer and remanufacturer. Zand et al. (2019) analyze the impact of government intervention on members' decisions and profits under an online to offline CLSC. Under demand uncertainty, Modak2019 discusses the influence of social responsibility, recycling and carbon emission on the decision making (Modak & Kelle, 2019).

From the key-route perspective, several new papers surface on this path. It unearths the most frequently cited paper in our downloaded data set which two paths we discussed above are unable to uncover. This paper provides a new direction for CLSC research, which is, selecting the appropriate reverse channel to collected used products. Similar studies center at the end of the path, such as Liu et al. (2017) and Modak2018, which compare different channels systematically from different perspectives.

Exploring the key-route main path is able for us to get an overview of CLSC domain deeply. This path exhibits a divergence-convergence-divergence structure clearly where the bifurcations appear at Krikke et al. (2003) and Govindan et al. (2016). The latter paper is a review paper that usually cites more prior papers to integrate different points. Due to this nature, it increases the importance of the review paper (Liu et al., 2019a). From the Fig. 11 it can be seen that it is the core of the key-route main path where various paths converge at this point and then different paths diverge from it, which verifies its unique role in the CLSC domain.

5. Discussion

5.1. Research Findings

From both static and dynamic perspectives, the main findings in this paper can be drawn as follows:

(1) The number of publications yearly shows that since 2012, the attention paid into the domain of CLSC has increased significantly. The proportion of papers published from 2012 to 2019 accounts for 86.80% of the total. In addition, from the perspective of the number of annual citations, they fluctuate up and down in the past years, which are unevenly distributed. Papers published in 2013 receive the most attention from various fields while papers published in 2005 have the highest value of TC/TP. The collaborative characteristics of the papers indicate that the cooperation mode of three authors is more common and the number of publications within a country/territory is more dominant.

(2) The most productive and influential author in the CLSC domain is Van Wassenhove, LN from France, who ranks first in terms of output and citation. Guide, VDR, with the closest cooperation relationship with Van Wassenhove, LN, also performs well in the CLSC domain. Papers co-authored by them provide good references for both the new and experienced scholars, exerting a far-reaching influence in this domain. Govindan, K from Denmark has established extensive cooperative relationships with different authors. As the research continues, the largest component centered on him has gradually formed and Soleimani, H from Iran is the author that collaborates the most with him.

(3) Univ Tehran is the most productive institution with 32 publications. However, given TC/TP, it falls out of the top 5. INSEAD from France and Penn State Univ from USA are two institutions that rank the top according to the total citations and average citations of their publications. Moreover, these two institutions have the most collaboration with each other and it is foreseeable that their cooperation relationship will continue in the future.

(4) Through the analysis of the most prolific countries/territories in this domain, this paper finds that several countries, including Italy, UK, India, Iran and China have begun to pay more attention to CLSC research in the past four years. China has a dominant position in this field with 269 publications, but performs the worst according to the average citations among the top 15 productive countries/territories. Publications from USA have received the most attention in the WoS and it has established wide cooperation with many countries/territories being the China the most remarkable one.

(5) The evolution of hotspots indicates that CLSC with remanufacturing, reverse logistic have been the main concerns from 2001 to 2019. Topics around CLSC network design has attracted more attention, and related keywords like genetic algorithm, uncertainty and robust optimization are usually frequently used. In addition, the research about pricing and coordination has stand out recently.

(6) The combination of three types of paths, including the local main path, the global and key-route main path, systematically uncovers the knowledge diffusion trajectories in the domain of CLSC in the

past years. The first paper on these paths, Fleischmann et al. (2001), which extends models to include reverse flows in the MILP formulation, providing a valuable reference for the following research. From a local view, the local main path shows that leading by this influential article in this domain, a majority of papers on this path revolve around the topic of CLSC network design. Usually, the MILP model is constructed for solving the network design problems. By taking into more and more factors account, such as uncertainty of demand, the model is getting closer to the reality. With the development of CLSC, the focus has shifted to the coordinate research and different effective coordination mechanisms have been proposed recently. From a global view, the global main path uncovers several influential papers at the beginning of the path, including Kleindorfer et al. (2005) and Ilgin & Gupta (2010), which systematically discuss the state-of-the-art research of CLSC. Emphasis on the green and sustainable development makes scholars gradually take the environmental impact and social impact into consideration when solving CLSC problems. Hence, research around green and sustainable CLSC has attracted more attention. The key-route main path provides us with a divergence-convergence-divergence structure in CLSC domain. It is no doubt that Govindan et al. (2015) plays an important role in integrating different concepts and inspiring new ideas in the process of knowledge transmission, which is the core work in the domain of CLSC. New papers at the end of the path focus on the study of reverse channels, which select the most appropriate way to collect used products by comparing different channels.

5.2. Comparative Analysis

The past few years have witnessed the rapid growth of the number of publications in the domain of CLSC. In this regard, more and more efforts have been made to summarize the previous publications systematically. Table 7 lists eight influential papers that make great contributions to the CLSC domain from different perspectives. A detailed comparison between their research and our work is shown in the Table 7.

Compared with first five partial review papers that study the CLSC with special aims, this paper extends the research scope to the entire CLSC. It can be seen that the size of data in their research is limited. This is partially because that the task for handling a number of previous publications by traditional review method is difficult. Due to the inherent excellent nature of bibliometrics and main path analysis in analyzing substantial studies, this paper focuses on the development of whole CLSC domain by adopting both methods.

Guide & Van Wassenhove (2009) is the first review paper in the domain of CLSC, which investigates this domain from a business perspective deeply. Followed by it, Govindan et al. (2015) target at the conjoin of reverse logistics and closed loop supply chain (RL&CLSC). The methods used in their research are limited to content analysis. However, it is more subjective when selecting papers that represent the study of the CLSC domain. Kazemi et al. (2019) extend the research by adopting a quantitative method named bibliometric analysis. Through comparison, several differences between the above-mentioned research and our study are explored. First, in selecting influential papers for content analysis, this paper is based on quantitative method which is more objectively and is able to avoid personal bias. Second, with bibliometric analysis, the cooperative characteristics at author, institution and country levels are analyzed in this paper, which is able to provide readers with more cooperation information in this domain. The main difference is that the main path analysis is adopted in our research, for the purposing of explore the citation relationships between influential studies and a sequence of significant historical-development events in the past few years, thus forming knowledge

diffusion paths of this field fully.

Table 7. Comparative analysis between studies

	Paper	Area	Scope	Time span	Number	Method	Contributions
1	Akçalı & Çetinkaya (2011)	CLSC	Quantitative literatures on inventory and production planning (I&PP) for CLSC systems	/	/	content analysis	(1) review of the deterministic and stochastic I&PP models (2) highlight promising avenues of research in I&PP
2	San et al. (2012)	CLSC	remanufacturing	2001-2012	61	content analysis	(1) construct the structure of literature review from managements and technical aspects (2) present an outline of research opportunities
3	Souza (2013)	CLSC	Literatures in strategic issues and tactical issues	/	/	content analysis	(1) focus on strategic decisions and tactical decisions (2) find areas for future research such as calling for research on CLSC for recycling.
4	Stindt & Sahamie (2014)	CLSC	Process industry	1984-2012	167	content analysis	(1) classify previous works from natural science perspective and business perspective (2) give an outlook for further research potential
5	Jena & Sarmah (2016)	CLSC	Acquisition management	2000-2012	92	content analysis	(1) discuss literatures related to acquisition management (2) point out future directions and opportunities of research in acquisition management
6	Guide & Van Wassenhove (2009)	CLSC	Whole area	/	/	content analysis and description of research methodology	(1) define the concept of CLSC management (2) use five stages to describe the evolution of CLSC (3) find potential future operations research opportunities
7	Govindan et al. (2015)	RL& CLSC	Whole area	2007– 2013	382	content analysis	(1) present a comprehensive review of whole area of RL/CLSC research (2) identify gaps and discuss future research directions
8	Kazemi et al. (2019)	RL&CLSC	Publications in International Journal of Production Research (IJPR)	2000-2017	94	(1) bibliometric analysis (2) content analysis	(1) explore basic characteristics of IJPR publications, including the year of publications, author's contributions, affiliations and citations (2) classify the IJPR publications into two general categories (3) state research gaps and future research opportunities
9	This Study	CLSC	Whole area	2001-2019	856	(1) bibliometric analysis (2) main path analysis (3) content analysis	(1) present the annual analysis of publications, most productive authors/institutions/countries/territories, and their cooperation characteristics (2) explore the knowledge diffusion trajectories

(3) point out possible future opportunities

With the help of main path analysis, the evolution of the CLSC development is clearly uncovered. The results show that the network design is the main concern along the time. According to Kazemi et al. (2019), the category of network design is one of the most dominant topics, which is confirmed by our results. Observing papers revolving around this concern on the main paths, it shows that different variables are incorporated into the models and they become more complicated, aiming to collect and process used products from market effectively and minimize energy consumption to achieve sustainable operations. Driven by the environmental concerns, the purpose of CLSC design is not limited to decrease total costs or increase profits. The requirement for a friendly environment makes the models incorporate more environmental factors. Minimizing the total carbon emissions is usually one of the objects. An effective and well-designed CLSC can not only meet customers' need at a low cost, but also can improve environment significantly. The latest papers on the main paths show that green and sustainable CLSC has gradually stand out recently. It is foreseeable that more advanced models will be designed by considering the impact into the environment and society.

6. Conclusion

With more and more attention has paid into the CLSC domain in the past years, it is required to study the CLSC domain systematically and comprehensively and thus provide valuable information for the future research. Hence, based on a total of 856 papers retrieved from the WoS, this paper tries to give more in-depth insights into the CLSC research from both static and dynamic perspectives. Specifically, based on bibliometrics, this paper first provides a general analysis of 856 papers published from 2001 to 2019 from a static angle. Not only the annual distribution of publications, the most productive authors, the most productive institutions and countries/territories are identified, but also the annual collaboration characteristics of publications, authors, institutions and countries/territories are explored. Moreover, form a dynamic perspective, this paper studies the evolution of hotspots based on the high-frequency keywords by dividing the whole period into three stages, as well as the knowledge diffusion trajectories in this domain are revealed through the combination of local main path, global main path and key-route main path.

6.1. Contributions and Research Values

The Contributions of this paper are threefold. First, the detailed information in the domain of CLSC is explored. Not only the statistical indicators are used to analyze the characteristics of publications, productive authors, institutions and countries/territories, but also the co-authorship relationships at the author, institution and country levels are investigated. Second, this paper makes the first attempt to extend the main path analysis to the CLSC domain to reveal the evolutionary process of the whole area. Third, combing the bibliometrics and main path analysis, a large number of papers in this domain are studied systematically and comprehensively.

There are several points of applicability of this paper. First, based on the bibliometric analysis, it is helpful for the readers to understand the basic information of the CLSC domain at a macro level. In addition, it provides valuable references for understanding which authors, institutions and countries/territories lead the development of the field and finding the possible collaborators for a deeper of the research. Second, the adoption of the main path analysis is able to filter out some influential points in the history of the CLSC development objectively and effectively and construct main paths representing the main idea flow, which can help readers know the changes of topics as time passes and identify the possible directions for research.

6.2. Implications

(1) The increasing number of publications in the domain of CLSC means that there is still vast potential for future development. In recent years, the number of papers that co-authored by multiple authors, institutions or countries/territories is significantly increasing. With the complexity of scientific development and continuous enrichment of knowledge, it is necessary to solve the research problems through scientific cooperation (Yu & He, 2020). Especially the CLSC has been embedded into many other disciplines, including operations research management science, engineering industrial, engineering manufacturing, environmental science and management, etc. The multidiscipline feature further requires scholars from different disciplines cope with CLSC problems effectively, thus further influences the increase in collaboration between multiple authors, institutions or countries/territories.

(2) Through analyzing the top productive authors and co-authorship network of authors, it is not difficult to see that a majority of them tend to cooperate with others from the same country/territory. Papers by authors who have established international cooperation usually have a higher value of average citation. This phenomenon indicates that the international cooperation has a positive impact on the citations. Pay more attention to the influential author's publications, especially studies that co-authored by several influential researchers, which are able to provide valuable information for future research.

(3) Productive institutions and countries/territories come from all over the world. Through this study, it is able for us to know which institutions and countries are active in the CLSC domain, how their studies received and what the cooperative characteristics of their publications are. In the future, different institutions and countries can strength the cooperative relationship with potential collaborators, thereby boosting the interaction between researchers and promoting the diversity and richness of research.

(4) Our results show that the majority of papers on the main paths prefer to illustrate numerical examples instead of real cases. Actually, different industries have their own characteristics and the effectiveness of models need to be verified based on the real data. The combination of theory and practice will undoubtedly be strengthened to solve the problem of industrials to achieve sustainable development and reduce their impacts on the environment. In the future, the number of practical-oriented studies in the CLSC domain can be increased by building cooperation between scholars and industrial practitioners.

(5) The evolution of the knowledge indicates that network design models that only concern deterministic parameters have faded out. More and more approaches have been applied under uncertainty, such as stochastic and fuzzy. In the future, various extensions of fuzzy set, which is fist proposed by Zadeh (1965), such as intuitionistic fuzzy set and hesitant fuzzy, can be adopted to handle the problems under uncertain environment. It will be closer to the reality and provides more effective suggestions for the researchers and industrial practitioners.

(6) More attention should be paid into the government policies. To some extent, government policies have an impact on the research. In recent years, China's emphasis on environmental protection has promoted the increase in the number of CLSC-related studies. Taking into some related policies into account is likely to extend the CLSC research to new directions.

(7) The end of the main paths indicates that topic revolving around different reverse channels is relatively more popular recently, while the focus is mainly on the offline channel. With the popularity of internet and online retail, researchers can attach importance to studies about collecting used products through online channel. Aiming to collect used products more effectively and minimize the

wastes of products, in the future, research around online to offline CLSC will be a potential trend.

6.3. Limitations

To our knowledge, few papers have investigated the overall development of CLSC research fully based on bibliometrics and main path analysis. In particular, the use of the main path analysis makes trajectories of knowledge diffusion in the past years clearer. It not only identifies some influential papers by taking into the direct citation and indirect citation into account, but also the citation relationship between them is revealed and thus different development paths are formed to provide valuable information about this domain.

Though this paper tries to analyze the CLSC domain systematically, some limitations still exist. First, the result of the bibliometrics and the main path analysis is related to the downloaded data set. In this paper, the authors only select CLSC-related papers in the SCI-E and SSCI databases in the WoS core collection, which makes the data is not sufficient and misses some other CLSC papers. Therefore, the result may not fully uncover the development of the entire CLSC domain. Second, although three main paths uncover the knowledge diffusion trajectories form different angles, some important papers may not be discussed in this paper. In the future, clustering algorithms can be combined with main path analysis to explore different trajectories of knowledge diffusion in various aspects in the domain of CLSC, so as to have in-depth observations in this domain.

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