Circular supply chain management: A bibliometric analysis-based literature review

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Citation: Zhang, A., Duong, L., Seuring, S., & Hartley, J. L. (2023). Circular supply chain management: a bibliometric analysis-based literature review. *International Journal of Logistics Management*, https://doi.org/10.1108/IJLM-04-2022-0199.

Abstract

Purpose – Supply chain management (SCM) research has contributed to the transition to a circular economy. Still, confusions exist on the related terms, and no review has mapped out the development trends in the domain. This research clarifies the boundaries of the relevant concepts. Then, it conducts a comprehensive review of the circular SCM (CSCM) literature and identifies opportunities for future research.

Design/methodology/approach – Using relevant keywords, 1,130 journal articles published through December 31, 2021 were identified. Unlike the published reviews, which mainly relied on content analysis, this review uses bibliometric analysis tools, including citation analysis, co-citation analysis, and cluster analysis. The review identifies general trends, influential researchers, high-impact publications, citation patterns, and established and emergent research themes.

Findings – The extant CSCM literature includes five prominent clusters: 1) Reverse channel optimization; 2) CSCM review and empirical studies; 3) Closed-loop supply chain (CLSC) and consumers; 4) CLSC and inventory management; 5) CLSC and reverse logistics. Significant research gaps exist in the use of secondary and longitudinal data, a wider range of theories, mixed-methods, multi-method, action research, and behavioral experiment. The least researched topics include zero waste, industrial symbiosis, circular product design, sourcing and supply management, and reuse.

Originality/value – This is the first bibliometric analysis-based literature review on CSCM. It clarifies the interrelated supply chain sustainability terms and thus reduces related confusion. It offers insights into the patterns in the CSCM literature and suggests important research directions.

Keywords: Circular economy; Circular supply chain management; Closed-loop supply chain management; Sustainable supply chain management; Literature review

Article Classification: Review Article

1 Introduction

Confronted by increasing resource scarcity and environmental degradation, many countries and major corporations have embraced the circular economy (CE) as a pathway to sustainable development. In recent years, the CE has gained prominence, rivaling the sustainable development concept itself (Cecchin *et al.*, 2021). In contrast to the dominant take-make-dispose linear economic model, the CE stops waste from being produced in the first place (Ellen MacArthur Foundation, 2019). The CE is a systems solution framework which is based on three design principles: 1) eliminate waste and pollution; 2) circulate products and materials at their highest value; and 3) regenerate nature (Ellen MacArthur Foundation, 2019). It achieves material circularity by two types of cycles: a *restorative* cycle for technical materials and a *regenerative* cycle for biological materials (Farooque, Zhang, Thürer, *et al.*, 2019). Although it was primarily motivated by environmental considerations, CE also contributes to the social and economic dimensions of the triple bottom line (Kirchherr *et al.*, 2017; Mies and Gold, 2021). CE implementation often requires substantial investments to upgrade processes and equipment, so there may be a cost increase in the short term (Genovese *et al.*, 2017; Nasir *et al.*, 2017). However, it can achieve both environmental and long-term economic benefits, such as cost savings resulting from reusing and recycling materials, parts, and packaging (Farooque *et al.*, 2022).

Adopting and implementing CE requires organizations to reimagine and redesign their supply chains from sourcing, operations, and logistics, to returns and disposal. The integration of circular thinking in supply chain management (SCM), circular supply chain management (CSCM), encompasses closed-loop supply chain (CLSC), remanufacturing, recycling, reverse logistics (RL), industrial symbiosis, and other practices focused on achieving a zero-waste vision (Farooque, Zhang, Thürer, *et al.*, 2019; Zhang *et al.*, 2021). Researchers have been making valuable contributions in these individual areas for many years, well before the emergence of the term *circular economy*. For example, Brock (1934) highlighted the need for reverse logistics in a 1934 *Harvard Business Review* article. Research on remanufacturing began in the 1980s, and research to understand CLSC started about twenty years ago (Zhang *et al.*, 2021). A CLSC brings end-of-use products back to the original equipment manufacturer (OEM) to achieve material circularity, while a circular supply chain (CSC) may use third parties other than the OEM for value recovery operations (Batista *et al.*, 2018; Genovese *et al.*, 2017).

The objective of our research is to identify the major trends, themes, influencers, and future research opportunities in the broad CSCM research domain using a bibliometric analysis. Specifically, our review seeks to address the following research questions:

- What are the major trends and themes in the CSCM research?
- Which researchers and publications have been most influential in the CSCM domain?
- What are the important directions for future research in CSCM?

As summarized in Table 1, there have been a number of review articles published recently on topics related to CSCM. Our research builds upon and extends these studies in several ways. First, most reviews are narrowly focused, for example, CSCM drivers and barriers in the agri-food sector (Mehmood *et al.*, 2021), CLSC design methods and applications (MahmoumGonbadi *et al.*, 2021), and supply chain collaboration and sustainability performance in CE (Sudusinghe and Seuring, 2022). Our research contributes by examining the broad CSCM domain. Farooque *et al.* (2019) and Lahane *et al.* (2020) also examined the broad CSCM domain, but their search keywords required explicit use of the term *circular*, thus excluding those relating to CSCM such as *CLSC* and *remanufacturing* if *circular* was not used in the article. CLSC and remanufacturing concepts were well-established before the term CE or CSCM gained popularity, consequently, the reviews of Farooque *et al.* (2019) and Lahane *et al.* (2020) omitted many relevant publications, especially the early works on CLSC and remanufacturing. Our review contributes to the field by including keywords that are both explicitly and implicitly related to CSCM, therefore providing a more accurate and holistic understanding of the CSCM research domain.

Table 1: Review articles relating to CSCM

	Topics/scopes	**Search Databases**	**Coverage**	**Literature Analysis Methods**
Govindan and Hasanagic (2018)	CSCM drivers, barriers, and practices	Scopus and Web of Science (WoS)	60 journal articles published from 2000-2016	• Descriptive analysis • Content analysis
Batista *et al.* (2018)	Restorative processes in SCM for sustainability and CE	EBSCO and ProQuest	49 journal articles published till 2017	• Descriptive analysis • Content analysis
Bressanelli *et al.* (2019)	Challenges in supply chain redesign for the CE	Scopus	63 journals articles and four business cases in the washing machine industry	• Content analysis • Case study
Farooque, Zhang, Thürer, *et al.* (2019)	CSCM	Scopus	261 journal articles published till 2018	• Descriptive analysis • Content analysis
Meherishi *et al.* (2019)	Packaging in SCM for sustainability and CE	EBSCO and ProQuest	59 journal articles published from 2000-2018	• Descriptive analysis • Thematic content analysis
Lahane *et al.* (2020)	CSCM	Scopus	125 journal articles published from 2010 to July 2019	• Descriptive analysis • Categorical analysis
Zhang *et al.* (2021)	CE implementation in practice & academic research in CSCM	Scopus and Ellen MacArthur Foundation's case studies collection	124 articles in a selective list of journals published till 2020 and 68 real-life CE implementation cases	• Descriptive analysis • Content analysis
Bressanelli *et al.* (2021)	Enablers, levers and benefits of CE in the electronics supply chain	Scopus	115 journal articles published till May 2019	• Descriptive analysis • Content analysis
MahmoumGonbadi *et al.* (2021)	CLSC design methods and applications	Scopus	254 journal articles published till 2019	• Descriptive analysis • Content analysis
Mehmood *et al.* (2021)	Drivers and barriers towards CE in the agri-food supply chain	WoS, Emerald Insight, Science Direct, Taylor & Francis, and Willey	58 journal articles published from 2009-2019	• Descriptive analysis • Content analysis

de Lima *et al.* (2021)	R-imperatives, uncertainties, and sustainability performance in CSC	Scopus and WoS	106 journal articles published till 2020	• Descriptive analysis • Content analysis • Contingency analysis
Gebhardt *et al.* (2021)	Industry 4.0 technologies as enablers of collaboration in CSC	Scopus, WoS and EBSCO	76 journal articles published till 2020	• Descriptive analysis • Content analysis
Sudusinghe and Seuring (2022)	Supply chain collaboration and sustainability performance in CE	Scopus and WoS	82 journal articles published from 2016-2020	• Descriptive analysis • Content analysis • Contingency analysis

Second, we ensure the comprehensiveness of the review by covering both Scopus and Web of Science (WoS) databases (Thomé *et al.*, 2016) while excluding grey and tertiary literature to control the quality of publications (Thomé *et al.*, 2016) in the sample. Our sample consists of 1,130 peer reviewed academic journal articles that deal explicitly and/or implicitly with supply chain circularity published through December 31, 2021 and is much larger than samples used in previous review articles. Zhang *et al.* (2021) also examined the broad CSCM domain but targeted a very selective list of 11 journals, resulting in a limited sample of 124 articles. Some major journals, including *Journal of Cleaner Production*, *International Journal of Production Economics*, and *International Journal of Production Research,* were excluded from their review.

Third, the published reviews mainly use content analysis and descriptive analysis for analyzing literature. We employ a bibliometric analysis, which encompasses citation analysis and cluster analysis to handle the large sample-size. The bibliometric analysis method systematically classifies research in a field and identifies dominant research clusters and areas that deserve more attention (Centobelli *et al.*, 2021), providing insights to inform future studies. By following a replicable, scientific, and transparent process, a systematic review, unlike a narrative review, ensures that the literature search is thorough and that the results are reliable (Tranfield *et al.*, 2003).

The rest of this paper is organized as follows. Section 2 explains the theoretical background. Section 3 outlines the review methodology. Section 4 presents descriptive statistics. Section 5 conducts a network analysis of publications. Section 6 discusses future research directions. Section 7 concludes the review.

2 CSCM and relevant concepts

2.1 Sustainable development and circular economy

The Brundtland report defined sustainable development as "development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 41). The definition established an overarching goal but did not provide clearly implementable solutions (Cecchin *et al.*, 2021). The CE concept has been evolving. We refer the readers to Kirchherr *et al.* (2017) for a comprehensive review of 114 CE definitions. However, CE, as a strategy for resource management, appears to be gaining prominence as it offers a plausible pathway for sustainable development. Researchers have developed models of CE from a resource management perspective.

The CE can be enabled by four circular business model strategies: *cycling*, *extending*, *intensifying*, and *dematerializing* (Geissdoerfer *et al.*, 2020). *Cycling* is an essential requirement for resource circularity. It is achievable by integrating end-of-life options at the product design stage and using CSCM to establish a circular flow of materials by reuse, remanufacturing, refurbishing, and recycling (Burke *et al.*, 2021; Geissdoerfer *et al.*, 2020). The CE must distinguish *regenerative* loops for biological materials and *restorative* loops for technical materials (Farooque, Zhang, Thürer, *et al.*, 2019); otherwise, value recovery operations such as recycling are inhibited when materials of different nature are mixed (Bocken *et al.*, 2016). Resource loops can be created by closed-loop and open-loop circularity archetypes

(Batista *et al.*, 2018; Genovese *et al.*, 2017; Zhang *et al.*, 2021). After resource loops are created, the other three strategies can further improve resource efficiency in the CE. *Extending* resource loops by designing long-life products and product-life extension slow down the flow of resources (Bocken *et al.*, 2016). *Intensifying* resource loops are associated with more intense use of resources, i.e., higher resource utilization, for example, full truck load logistics (Geissdoerfer *et al.*, 2020; Hazen *et al.*, 2021). *Dematerializing* resource loops substitutes product utility by service (e.g., servitization) and software solutions (Geissdoerfer *et al.*, 2020; Hazen *et al.*, 2021).

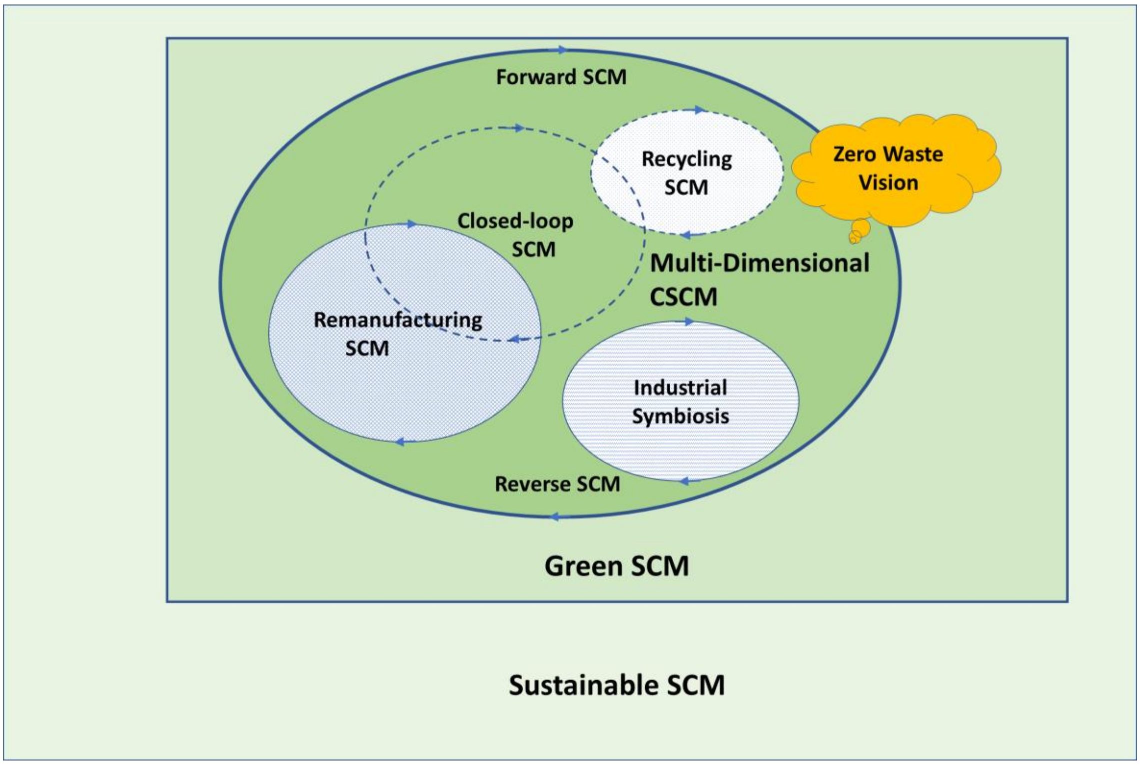
Potting *et al.* (2017) used a 9R framework to prioritize circularity strategies for transitioning to the CE. The most preferred strategy with high circularity is reducing or eliminating consumption with smart product use and manufacture by *refuse*, *rethink*, and *reduce*, for example, product sharing, which requires fewer products. The next option is to extend the lifespan of the product and its parts by *reuse*, *repair*, *refurbish*, *remanufacture*, and *repurpose*. The least preferred strategy with low circularity is to explore the useful application of materials by *recycle* and *recover*, for example, to recover energy from waste by incineration.

2.2 CSCM and related supply chain sustainability concepts

Researchers have explored several concepts related to CSCM, as shown in Figure 1. The broadest concept, sustainable SCM, operationalizes sustainable development at a firm and supply chain level. The seminal work of Seuring and Müller (2008, p. 1700) defined sustainable SCM as:

> *"the management of material, information and capital flows as well as cooperation among companies along the supply chain while taking goals from all three dimensions of sustainable development, i.e., economic, environmental and social, into account which are derived from customer and stakeholder requirements."*

Sustainable SCM is explicitly linked to achieving sustainable development goals (SDGs) and deals with all three dimensions of the triple bottom line. It encompasses the management of major flows in the supply chain for meeting customer and stakeholder requirements, highlighting the importance of cooperation. Green SCM is a subset of sustainable SCM focusing on the environmental dimension (Srivastava, 2007) of the triple bottom line but does not include the social or economic dimensions. For example, child labor issues are a major concern of sustainable SCM but fall outside the scope of green SCM.



Source: Authors and Zhang et al. (2021)

Figure 1: Scopes of supply chain sustainability concepts

We consider CSCM to be a subset of green SCM because the latter includes SCM practices that are not related to resource circularity. Although CSCM contributes to all the three dimensions of triple bottom line, its main tenet is on environmental sustainability which is in line with green SCM (Genovese *et al.*, 2017). Aligned with CE's vision, CSCM aims for zero-waste, which is more ambitious than green SCM and sustainable SCM. For example, replacing lead petrol by unleaded petrol in logistics is a green SCM practice, but it has nothing to do with supply chain circularity. Similar to green SCM (Zhu and Sarkis, 2004), CSCM can enhance a firm's long-term economic performance (Farooque *et al.*, 2022) by creating a marketing advantage and lowering costs using recycled materials. CSCM can enhance social sustainability by creating local jobs in recycling and remanufacturing.

Zhang *et al.* (2021) established CSCM as an inclusive multi-dimensional concept encompassing SCM practices that directly contribute to supply chain circularity, including but not limited to, closed-loop SCM, remanufacturing SCM, recycling SCM, reverse SCM, and industrial symbiosis. CSCM may employ both closed-loop and open-loop circularity archetypes; therefore, it offers more flexibility and opportunities for recovery and reuse than closed-loop SCM (Farooque, Zhang, Thürer, *et al.*, 2019; Zhang *et al.*, 2021). Remanufacturing SCM can overlap with closed-loop SCM when an OEM performs all remanufacturing activities. Recycling SCM is equivalent to closed-loop SCM if all the recycled materials are returned to the original supply chain. However, typically, commonly recycled materials such as paper, metal, and plastics are used in a variety of industries and not sent back to the original supply chain. Reverse SCM sends end-of-use products and materials from downstream to upstream in a supply chain, regardless of open-loop or closed-loop circularity archetypes. Industrial symbiosis reuses wastes, by-products, and intermediates within an ecosystem of firms, often co-located in an eco-industrial park, within and beyond the original supply chain (Bansal and Mcknight, 2009).

In summary, CSCM is a best practice in green SCM and sustainable SCM. CSCM provides a clear pathway to operationalize sustainable development at a supply chain level, aspiring a zero-waste vision. It encompasses multiple dimensions that improve supply chain circularity.

3 Review methodology

We used a bibliometric analysis method for data analysis using data extracted from Scopus and WoS. A bibliometric analysis assesses the connections among various constituents to derive insights from a domain (Khanra *et al.*, 2021). This method has been used widely in business and management disciplines due to its ability to describe, summarize, and analyze articles, as well as for generating new research ideas (Donthu *et al.*, 2021). The bibliometric analysis can analyze relationships amongst different objectives (e.g., countries, keywords) and identify research themes in the field (Centobelli *et al.*, 2021). We adopted the research methodology from recent and comprehensive bibliometric-based literature review studies (e.g., Donthu *et al.*, 2021; Fahimnia *et al.*, 2015).

3.1 Keywords and search procedure

We conducted a literature search in Scopus and WoS using keywords that are explicitly or implicitly related to supply chain circularity, as outlined in Table 2. The search was carried out on "title-abstract-keywords" and considered works published through December 31, 2021.To ensure the quality of the sample, we refined results in Scopus by only including articles in peer-reviewed journals that were published in English and were categorized under the "business, management, and accounting" subject area. The sample collected from Scopus includes 1,791 journal articles.

Similarly, we refined results in WoS by restricting the search to "Articles", "Early access" and "Review articles" in peer-review journals, English sources, and were categorized under Business Economics and Operations Research Management Science subject areas. The sample collected from WoS includes 1,626 journal articles.

The bibliographic information of these articles was exported to RIS format files that were imported into BibExcel. By checking DOI numbers and titles, we identified 915 duplicated articles. That results in 2,502 for manually checking titles and abstracts. Further, 1,051 articles on concepts such as "resilient supply chain", "sustainable supply chain", and "green supply chain" are not included in the sample as they do not specifically focus on supply chain circularity. Articles that are vaguely related to circularity were read in full text. This step excluded 321 articles and resulted in a final sample of 1,130 articles for bibliometric analysis (Figure 2).

Table 2: Literature search keywords and search results

No.	**Keywords including their derivatives**	**Scopus articles**	**WoS articles**
1	Closed-loop supply chain, closed-loop, clos* and loop	698	556
2	Supply chain AND Remanufact*	499	465
3	Circular supply chain*, circular and supply chain, circular* and supply chain	394	314
4	Supply chain AND Recycl*	601	529
5	Circular Economy AND supply chain	335	322
6	Supply chain AND Reus*	272	234
7	Supply chain AND Restor*	97	85
8	Supply chain AND Refurbish*	78	62
9	Supply chain AND Regenerat*	25	21
10	Supply chain AND Zero-waste, zero waste	15	9
11	Supply chain AND Recover	112	104
Total articles retrieved (after removing duplicates)		**1,791**	**1,626**

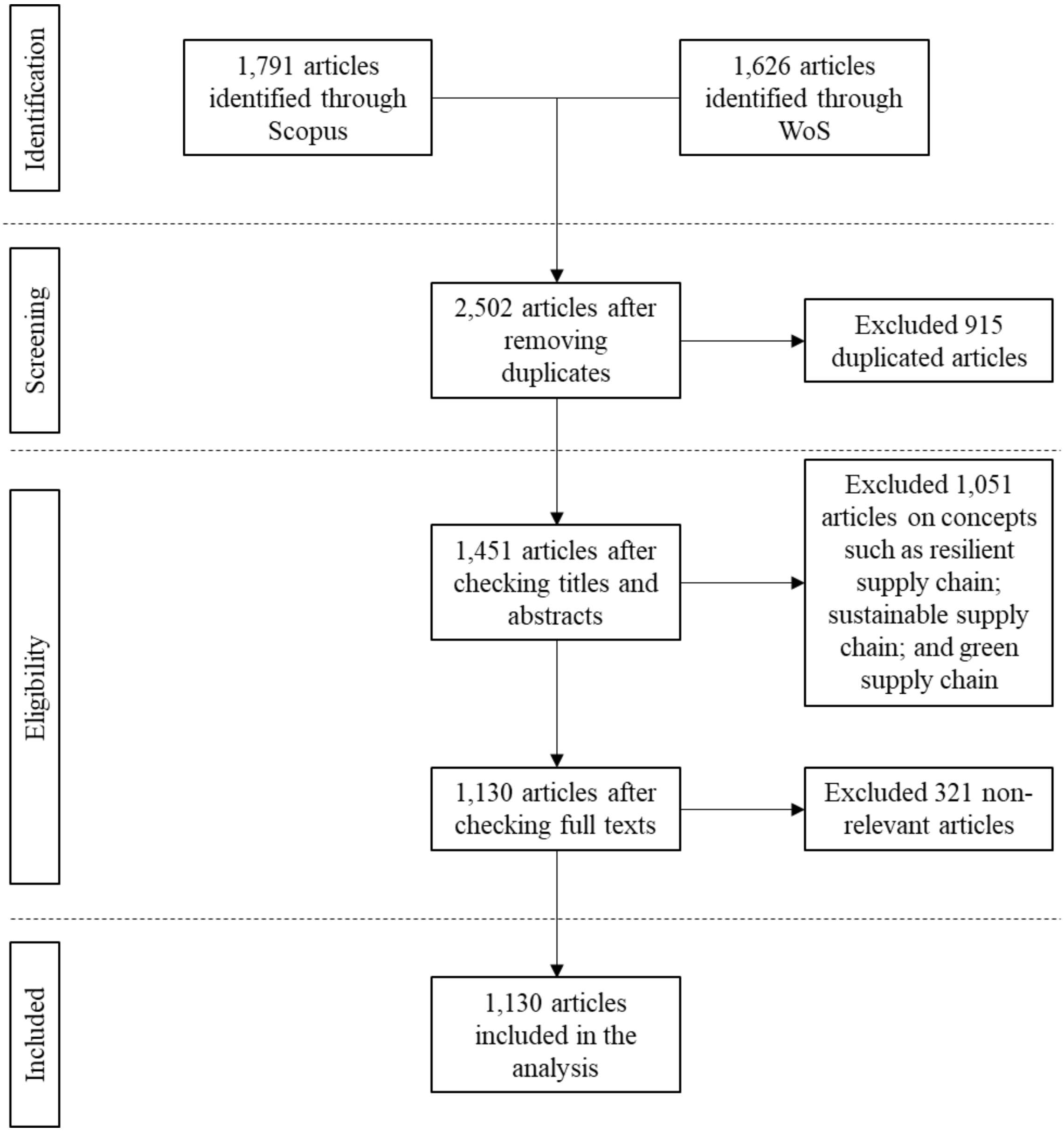


Figure 2: Literature sample selection process

3.2 Data analysis

This study employs two techniques for the data analysis, including bibliometric analysis and network analysis. First, we choose BibExcel for the bibliometric analysis (Tian *et al.*, 2018). It is an open-source program that can provide comprehensive data analysis (e.g., descriptive analysis and network creation), helps to identify clusters of research domains and researchers, and supports network analysis (Donthu *et al.*, 2021; Fahminia *et al.*, 2015). Second, for the network analysis, we chose Gephi due to its advanced abilities and flexibility in visualization and filtering capabilities (Fahimnia *et al.*, 2015). These tools are reliable, so the analysis could be repeated, yielding the same results.

The research method is documented clearly and transparently, offering reliability and replicability. The search strings were run three times with consistent search results, ensuring the validity. Findings from this research were compared to findings from other studies in the field (e.g., Hettiarachchi, Seuring, and Brandenburg, 2022; Hettiarachchi, Brandenburg, and Seuring, 2022), ensuring the external validity of this research.

4 Descriptive statistics

This section describes the publication trends, authors, countries, affiliations, and keyword statistics.

4.1 Publication trend over the years

Figure 3 shows the publication trend over the years. The earliest article related to CSCM was published in 1998, but research was very limited until 2006. Then, another increase occurred in 2013. Over 78% of articles were published in the seven-year period from 2015 through 2021. Furthermore, almost 35% of articles were published in 2020 and 2021, which aligns with the recent public interest on CE and environmental issues[1,2].

[1] https://ec.europa.eu/environment/strategy/circular-economy-action-plan_en

[2] https://www.worldwildlife.org/stories/2020-a-critical-year-for-our-future-and-for-the-climate

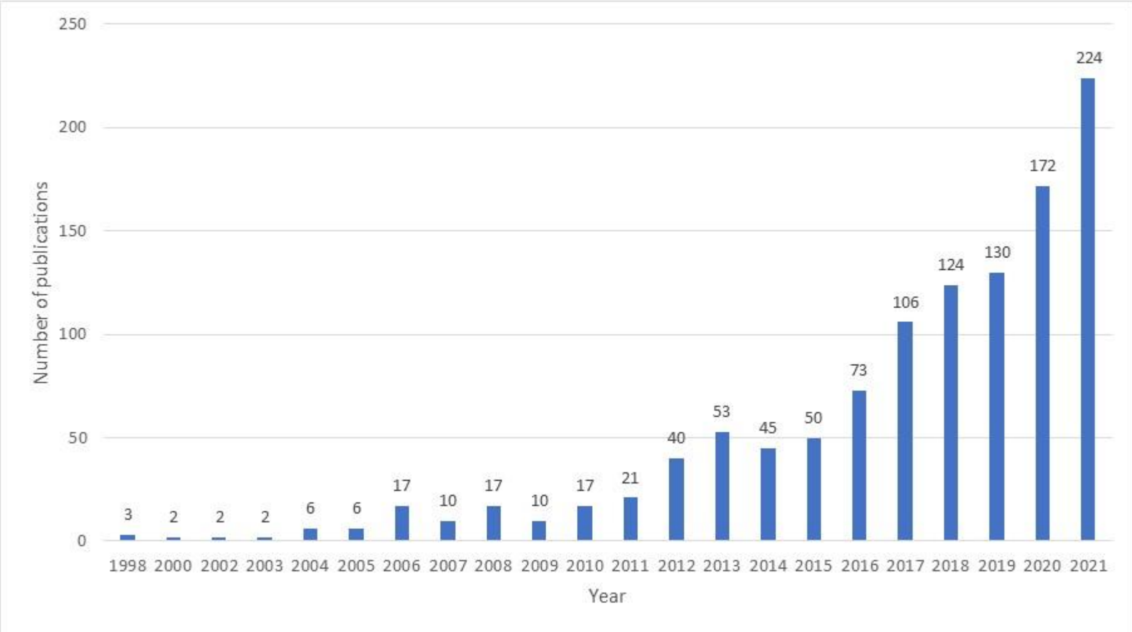


Figure 3: Publication count per year

4.2 Articles by journal

The number of journals publishing CSCM research expanded from three in 1998 to 61 in 2021. Thirty-three journals have published more than six articles on CSCM (Appendix 1). The *Journal of Cleaner Production* has published the most articles (372), almost one-third of the sample on this topic. It is followed by the *International Journal of Production Research* (122 articles) and the *International Journal of Production Economics* (121 articles). *Transportation Research Part E: Logistics and Transportation Review* (37 articles), *Production Planning and Control* (29 articles), and *Production and Operations Management* (22 articles) follow based on the number of articles.

4.3 Influential authors

Table 3 provides the top authors ranked by the number of publications. It shows that van Wassenhove and Govindan have published the most articles on CSCM.

Table 3: Top ten authors ranked by article count

Authors	Affiliation	Location	Articles
Govindan, K.	University of Southern Denmark	Denmark	19

van Wassenhove, L.N.	INSEAD	Europe	19
Kazancoglu, Y.	Yasar University	Turkey	17
Guide, V.D.R.	Pennsylvania State University	USA	14
Mangla, S.K.	University of Plymouth	UK	13
Giri, B.C	Jadavpur University	India	12
Souza, G.C	Indiana University	USA	10
Sarkis, J	Worcester Polytechnic Institute	USA	10
Gupta, S.M	Northeastern University	USA	9
Liu, Z	Anhui Polytechnic University	China	9
Luthra, S	Ch. Ranbir Singh State Institute of Engineering & Technology	India	9

4.4 Articles published by region

We examined where research is being conducted based on the authors' affiliations by geographical region. Countries were grouped into five geographical regions based on the classification of the United Nations (2017). Table 4 shows the number of articles based on the authors' geographical region. Most articles were produced by researchers based in Eastern and Southern Asia, North America, and Northern Europe. Particularly, researchers in the United States (USA), China, and United Kingdom (UK) have the highest number of articles. These countries play key roles in addressing the climate change issue and the transition towards CE. As a result, these countries have many supportive programs for sustainability research. Articles from these regions dominate the list of top studies in the identified five research clusters (discussed in section 5.3) and play vital roles in the development of the CSCM research domain. On the other side, there were a limited number of articles by authors whose affiliations are in Eastern Europe; Central, South-Eastern and Western Asia; Central and South America; Oceania; and Africa. These regions include mainly developing and underdeveloped countries, which have lower priority for environmental protection. These countries normally have less strict regulations, standards, and policies which create low motivation for the transition towards CE.

To understand the common research topics in each region, we analyze the top studies in each region (based on the PageRank score as discussed in section 5.3). While articles from developing and underdeveloped countries appear in all five research clusters (section 5.3), only six of them are top studies (2 articles in Cluster 1, 3 articles in Cluster 2, and 1 article in Cluster 4). Among them, five articles were published recently since 2018. This aligns with the fact that developing and underdeveloped countries have just started to pay attention to the transition towards CE (Halog and Anieke, 2021).

Table 4: Contribution of affiliations based on their regions

Region	No. of articles	Percentage contribution
Asia	**752**	**43.3%**
Eastern Asia	369	21.3%
Southern Asia	257	14.8%
Western Asia	67	3.9%
South-Eastern Asia	58	3.3%
Central Asia	1	0.1%
Europe	**551**	**31.8%**
Northern Europe	236	13.6%
Western Europe	196	11.3%
Southern Europe	108	6.2%
Eastern Europe	11	0.6%
Americas	**362**	**20.9%**
Northern America	319	18.4%
South America	39	2.2%
Central America	4	0.2%
Oceania	**50**	**2.9%**
Australia and New Zealand	49	2.8%
Melanesia	1	0.1%
Africa	**20**	**1.2%**
Northern Africa	8	0.5%
Southern Africa	7	0.4%
Western Africa	4	0.2%
Eastern Africa	1	0.1%

5 Network analysis of publications

This section presents citation analysis, co-citation analysis, and cluster analysis results.

5.1 Citation analysis

Citation analysis assesses the influence of an article by counting its citations. We consider "Local citation" which is the frequency of an article being cited within the sample of 1,130 articles. In total 823 out of 1,130 (73%) articles were cited in the sample. We also consider "Scopus citations" and "WoS citations", which are the numbers of citations found in Scopus and WoS databases, respectively. Table 5 presents the top ten articles with local citations and their Scopus and WoS citations. The gap between "Local citations", "Scopus citations", and "WoS citations" suggests that CSCM has also received substantial attention from articles outside of the sample. Besides that, except for the last two articles, the order in both columns is consistent, validating our results.

Additionally, Table 5 presents the average citations per year, which is total citation divided by the number of years from when the article was published. Some articles (e.g., Savaskan *et al.* (2004); Genovese *et al.* (2017); Govindan and Hasanagic (2018)) have high numbers of local citations and average citations. Not surprisingly, they are comprehensive review articles or provide outstanding examples for the adoption of CE in the SCM field.

Table 5: Top ten publications by local citations

Article	Main focuses	Local citations	Scopus citations	WoS citations	Avg. citations
Savaskan *et al.* (2004)	To investigate how reverse channel choice affects the forward channel decisions	243	1,618	1,307	87
Genovese *et al.* (2017)	To compare the performances of traditional and circular production systems	126	560	505	102
Savaskan and Wassenhove (2006)	To understand when a manufacturer would choose to collect used products directly from consumers	124	691	543	42
Souza (2013)	To present a review and tutorial of the literature on CLSC	93	402	371	42

Govindan and Hasanagic (2018)	To analyze the drivers, barriers and practices that influence the implementation of CE in the context of SCM	93	391	336	87
Choi *et al.* (2013)	To examine the performance of different CLSC under different channel leadership	78	315	284	33
Atasu *et al.* (2008)	To critically review analytic research on the business economics of product reuse	67	256	222	18
De Angelis *et al.* (2018)	To propose five propositions concerning implications for circular supply chains	66	189	162	42
Huang *et al.* (2013)	To investigate optimal strategies of a CLSC with dual recycling channel	61	253	221	27
Govindan and Soleimani (2017)	To provide a systematic view of the publications in the field of RL and CLSC in the *Journal of Cleaner Production*	58	343	294	62

5.2 Co-citation and Cluster analysis

Multiple methods assess similarities and identify themes within a research domain. Some of them include co-citation analysis, citation analysis, and bibliographic coupling. Particularly, co-citation analysis detects commonalities among articles in a research domain and has become the most preferred method for network analysis (Pournader *et al.*, 2020). It could provide a better coverage of the literature and provides accurate outcomes (Pournader *et al.*, 2020). Given the advantage of co-citation analysis, we adopted this method to identify research themes in the field of CSCM.

A co-citation occurs when two articles are referenced by the same article (Walter and Ribière, 2013). The main idea of this method is that as two articles are co-cited more frequently, there is more likely that they discuss similar topics and can be ended up in the same cluster.

Thus, a cluster includes a set of articles that have strong two-by-two connections with each other (Pournader *et al.*, 2020). To conduct the co-citation analysis, we used Gephi software for network analysis. The co-citation mapping with Gephi revealed that 654 out of 1,130 (58%) articles had been co-cited by other articles within the sample. To develop meaningful clusters, we set a minimum threshold of three which means that only articles that are co-cited at least three times can be considered for mapping. Gephi initially positioned the nodes (articles) in the citation map randomly. We, then, used the Force Atlas algorithm, which is the most popular algorithm in Gephi due to its readability and simplicity, for mapping. This algorithm moves the most connected nodes into the center of the network while the less connected nodes are moved to the border (Fahimnia *et al.*, 2015).

The network can be divided into clusters based on the density of edges (connection lines) among articles (Tian *et al.*, 2018). Gephi offers the modularity tool based on the Louvain algorithm to determine the optimal number of partitions that maximize the modularity index (Blondel *et al.*, 2008). The modularity index ranges between -1 and +1, which measures the connections between the nodes. Applying this algorithm to the filtered network results in five clusters as shown in Figure 4. The modularity index is 0.374, indicating a strong relationship between nodes (articles) within and between clusters (Newman and Girvan, 2004). Cluster 1 is the largest cluster including 140 articles and cluster 4 is the smallest one with 25 articles.

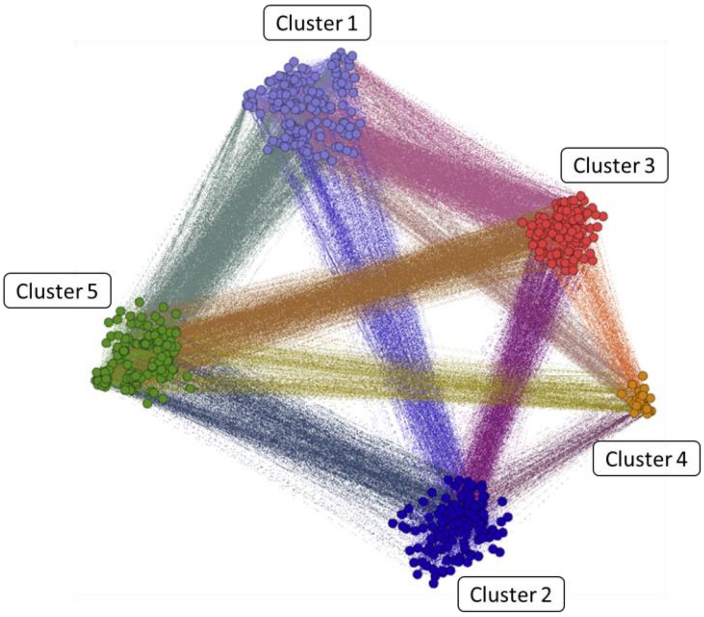


Figure 4: The five clusters in the sample

To understand the evolution of these research clusters over the years, we conducted a dynamic co-citation analysis. Figure 5 depicts the number of articles published in each cluster by year. The earliest articles were in clusters 2 and 3. Note that the publication counts in 2020 and 2021 show a downward trend because the most recently published articles have fewer citations, thus, some of them were not included in co-citation-based cluster mapping.

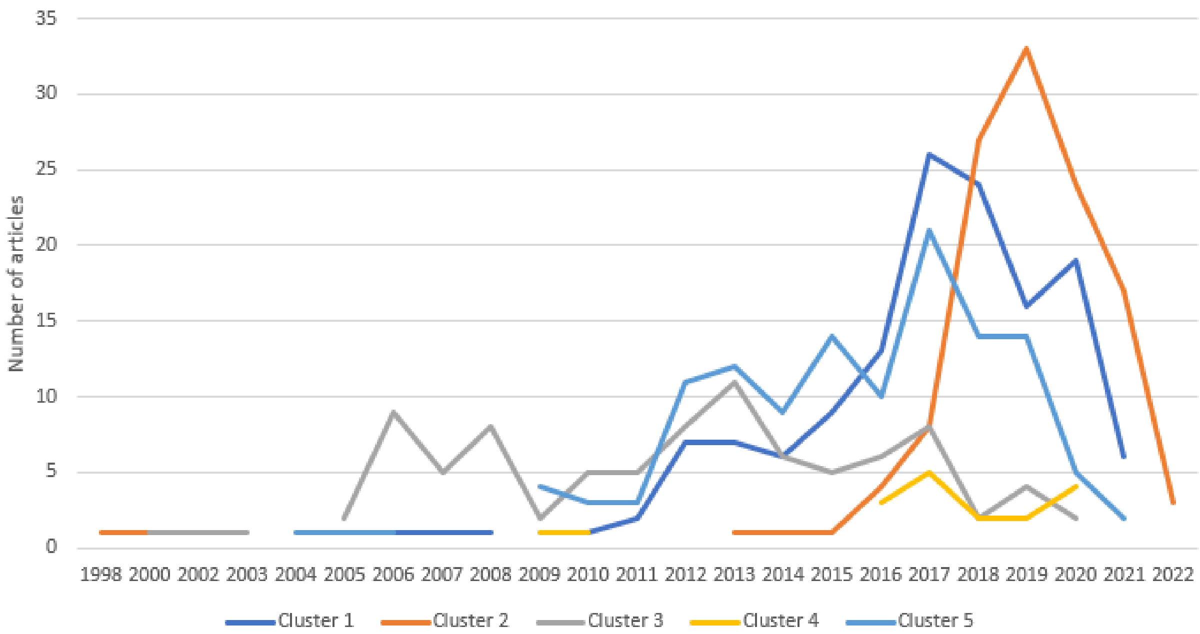


Figure 5: The number of articles in each cluster (based on the co-citation statistics)

Due to the large number of articles in each cluster, we selected the top ten articles in each cluster for content analysis based on their PageRank values (Fahimnia *et al.*, 2015). The PageRank analysis measures the importance of an article. It prioritizes articles having a high citation number globally and articles that are cited by these highly cited articles (Fahimnia *et al.*, 2015). In each cluster, we sort articles based on their PageRank scores. The top ten studies for each cluster are presented in Table 6. The content analysis of top studies in each cluster is discussed in the next section.

Table 6: The top studies of each cluster: co-citation PageRank measure

Cluster 1 Reverse channel optimization	Cluster 2 CSCM review and empirical studies	Cluster 3 CLSC and consumers
Savaskan *et al.* (2004)	Genovese *et al.* (2017)	Souza (2013)
Choi *et al.* (2013)	Govindan and Hasanagic (2018)	Atasu *et al.* (2008)
Savaskan and Wassenhove (2006)	De Angelis *et al.* (2018)	Guide and Li (2010)
Panda *et al.* (2017)	Bressanelli *et al.* (2019)	Kleindorfer *et al.* (2005)
Hong *et al.* (2015)	Nasir *et al.* (2017)	Östlin *et al.* (2008)
Huang *et al.* (2013)	Mishra *et al.* (2018)	Kumar and Putnam (2008)
He (2015)	Farooque *et al.* (2019)	Subramanian and Subramanyam (2012)

Saha *et al.* (2016)	Homrich *et al.* (2018)	Abbey, Meloy, *et al.* (2015)
Jacobs and Subramanian (2012)	Batista *et al.* (2018)	Subramanian *et al.* (2013)
Atasu *et al.* (2013)	Geissdoerfer *et al.* (2018)	Guide *et al.* (2006)
Cluster 4 CLSC and inventory management	Cluster 5 CLSC and reverse logistics	
Cannella *et al.* (2016)	Govindan and Soleimani (2017)	
Braz *et al.* (2018)	Kazemi *et al.* (2019)	
Zhou *et al.* (2017)	Diallo *et al.* (2017)	
Masoudipour *et al.* (2017)	He (2017)	
Moshtagh and Taleizadeh (2017)	Neto *et al.* (2010)	
Goltsos *et al.* (2019)	Shekarian (2020)	
Dominguez *et al.* (2020)	Zhalechian *et al.* (2016)	
Zanoni *et al.* (2006)	Dutta *et al.* (2016)	
Giri and Sharma (2016)	Taleizadeh *et al.* (2019)	
Turrisi *et al.* (2013)	Govindan *et al.* (2016)	

5.3 Content analysis of top studies in the clusters

5.3.1 Cluster 1 Reverse channel optimization

Cluster 1 is the largest cluster (140 articles). Research in this cluster increased since 2011. It focuses on designing reverse channel structure in CLSC via mathematical models. Many articles in this cluster adopt Stackelberg game models to analyze pricing and costing decisions (Hong *et al.*, 2015). The most highly cited article in this cluster is Savaskan *et al.* (2004), who developed a mathematical model for choosing the appropriate reverse channel structure to collect used products from customers. Later, Savaskan and Wassenhove (2006) examined the economics trade-offs between a direct collection system where the manufacturer collects used products directly from the consumers and an indirect collection system where retailers act as product return points. Extending from these works, Choi *et al*. (2013) considered different channel leaderships in reverse logistics structures. Interestingly, Choi *et al*. (2013) found that having the retailer as the supply chain leader can lead to the most effective reverse channel configuration. Consistently, Hong *et al*. (2015) showed that it is optimal to authorize the retailer to do the collection activity. In fact, the retailer-led CLSC is the most profitable (Gao *et al.*, 2016). These findings suggest that retailers have an essential role in designing and managing collection in a CLSC. Moreover, retailers may have more accurate market demand information while manufacturers hold more supply information. Such information is not always shared equally and timely along the supply chain. Thus, it is worth to investigate information asymmetry and how it affects channel partners' decisions (e.g., advertising, pricing) (Gao *et al.*, 2016).

Game theory dominates in this cluster in finding optimal decisions for reverse channel structures. While articles adopting this method provide insights on the role of each partner and channel management, the mathematical modelling used in these articles requires making assumptions (e.g., the demand characteristics, the number of partners, parameters' values). Consequently, these findings should be interpreted carefully and generalizing them is challenging. This cluster can be extended by having empirical data which, when combined with mathematical modelling, can provide additional insights. Further, consumers must be motivated to return products to the collection point. This suggests a need for interdisciplinary research in marketing, communications, and CSCM.

5.3.2 Cluster 2 CSCM review and empirical studies

Cluster 2 (123 articles) had the first article published in 1998 and focuses on defining CSCM, reviewing the literature on CSCM, and exploring factors influencing CSCM adoption and implementation. For example, Farooque *et al*. (2019) was one of the early attempts to provide a comprehensive definition of CSCM. Research in cluster 2 increased dramatically since 2015. This may have been influenced by the European Commission's launch of a work program (2014 – 2020) for Horizon 2020, which looked for ways to promote CE adoption in the European Union[3].

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[3] http://ec.europa.eu/research/participants/data/ref/h2020/wp/2018-2020/main/h2020-wp1820-intro_en.pdf

Researchers have examined the benefits and drawbacks of CSCM which influence adoption decisions as well as its barriers (Zhang *et al*., 2019). Through case studies, Genovese *et al*. (2017) and Nasir *et al*. (2017) asserted that an integration of CE concepts and sustainable SCM provides clear advantages from an environmental perspective. However, CSCM implementation is complex and requires simultaneous reconfiguration of the building blocks to deliver circular value creation – product design, business model innovation, reverse supply chain design, and system enablers (Mishra *et al.*, 2018). Additionally, more empirical research is needed to investigate how CSCM initiatives generate social values (Mishra *et al.*, 2018).

While offering advantages, CSCM has many challenges during implementation. Because of high investment costs, governments play a vital role in supporting implementation of CE projects (Govindan and Hasanagic, 2018). Thus, lobbying is a possible lever to promote CSCM implementation (Bressanelli *et al.*, 2019). De Angelis *et al*. (2018) identified additional challenges facing the implications of CSCM. They include early supplier innovation, risk mitigation through structural flexibility, the global versus local debate, and the shifting perceptions of value. As more organizations begin to adopt and implement CSCM practices, there will be greater opportunities to gather larger scale empirical data to identify the most effective ways to encourage adoption and successful implementation.

Moreover, research studies in this cluster are often limited to a specific industry (e.g., retail, agri-food) in a specific country (e.g., China, India). Thus, it is difficult to generalize the findings to other contexts. For example, whether findings from the Indian context will be valid for other emerging countries is still a question. Cross-industry and cross-country comparisons are needed to further understand generalizability and advance knowledge.

5.3.3 Cluster 3 CLSC and consumers

Cluster 3 (91 articles) focuses on the investigation of consumer perceptions in CLSC. In CLSC, manufacturers take back products from consumers and create value by remanufacturing. This cluster explores how companies define the price of new and remanufactured products using empirical methods as well as mathematical modelling (Abbey, Blackburn, *et al.*, 2015). Empirical studies include a field study (Guide and Li, 2010), an analysis of data on purchases made on eBay (Subramanian and Subramanyam, 2012), or case studies of different remanufacturing companies (Östlin *et al.*, 2008). The number of articles published in this cluster has declined since 2016 suggesting that the price optimization problem for remanufactured products might have reached saturation.

While CLSC has been discussed for many years, the consumer-oriented literature is still sparse (Abbey, Meloy, *et al.*, 2015). Abbey, Meloy, *et al.* (2015) empirically investigated consumer's perceptions of remanufactured products and how consumers evaluate remanufactured products. Interestingly, the findings reveal that some green-minded consumers may not appreciate the environmentally friendliness of remanufactured products. As the CLSC literature generally assumes that consumers perceive remanufactured products to be environmentally friendly, this finding requires further empirical investigation (Abbey, Meloy, *et al.*, 2015). Consumer behavior can be explored through empirical methods such as surveys and behavioral experiments. Interdisciplinary research between marketing and supply chain could prove to be fruitful.

5.3.4 Cluster 4 CLSC and inventory management

Cluster 4 (25 articles), the smallest cluster, focuses on inventory management in CLSC. In CLSC, the return flow of products affects inventory across the supply chain and can impact phenomena such as bullwhip effect (Cannella *et al.*, 2016). Inventory management helps to address how to manage the returned products (e.g., segmentation policies) based on the rate of return (or quantity of return) and quality of returned products (Jeihoonian *et al.*, 2017). Cannella *et al.* (2016) found that the higher the return rate, the lower the bullwhip effect and inventory instability. However, it is difficult to find an optimal solution to mitigate the bullwhip effect or inventory instability (Zhou *et al.*, 2017). Additionally, this cluster considers the quality of returned products (Masoudipour *et al.*, 2017; Moshtagh and Taleizadeh, 2017). The returned products are sorted by their quality; high quality returns could be sent to a repair center, and lower quality returns could be sent to a remanufacturing center or a recycling center (Masoudipour *et al.,* 2017). Considering quality of returns offers guidelines in maximizing profit of a returns management program. Articles in this cluster adopted mathematical modelling or simulation methods. Thus, empirical studies would further enhance and increase knowledge of returns inventory management practices and problems.

There are also a few review papers in this cluster. Braz *et al*. (2018) conducted a systematic literature review and suggested that CLSC can reduce the bullwhip effect, which improves the environmental performance of supply chains. Braz *et al*. (2018) found that majority of papers on bullwhip effect in CLSC were from an engineering or operations research perspective. There is an opportunity to study this topic from the management perspective such as the bullwhip effects in different CLSC configurations and causes of the bullwhip effect in CLSC (Braz *et al.,* 2018). Goltsos *et al*. (2019) provided an interdisciplinary lens of three pillars (i.e., inventory, forecasting, collection) to investigate the behavior of CLSC and how it can be controlled. Unquestionably, the quality uncertainty of returned products complicates the balancing between supply and demand. Therefore, there is a need to understand the effects of uncertain quality in the returns. For example, the mechanisms to cope with the uncertain quality, how to estimate the quality of returns, and how to control the quality of returns (Goltsos *et al.*, 2019).

5.3.5 Cluster 5 CLSC and RL

Cluster 5 (125 articles) focuses on CLSC and RL. Research in this cluster has increased since 2012. This cluster covers planning issues in CLSC. The top three articles in this cluster review research on RL and CLSC (Diallo *et al.,* 2017; Govindan and Soleimani, 2017; Kazemi *et al.,* 2019). RL plays a vital role in planning, implementing, and controlling the flow of physical products and information from the consumption point to the value recovery point (Govindan and Soleimani, 2017). RL is the nucleus of CLSC (Kazemi *et al.,* 2019). An integration of

CLSC and RL help design circular processes that consider both forward and backward flows of products (Carrasco-Gallego *et al.*, 2012). The remaining articles in this cluster focus on designing sustainable CLSC. For example, Zhalechian *et al*. (2016) designed a novel CLSC with routing and inventory. Taleizadeh *et al.* (2019) proposed a mixed integer optimization model for a CLSC, which considers the social and environmental effects of the supply chain decisions. Zhen *et al*. (2019) formulated a bi-objective optimization for designing a CLSC network considering the trade-off between CO_2 emissions and operating costs. Such supply chain planning related studies were generally done via mathematical modelling. Like Cluster 1, empirical data based on actual practices can further extend knowledge.

6 Future research directions

This research contributes to the literature by providing a holistic review of CSCM journal articles that have been published through 2021 and identifying opportunities for future research. The influential authors and high-impact articles identified in our bibliometric analysis have been instrumental in shaping the development of the field and provide the foundation for future CSCM research. Since 2015 the number of articles published has grown by 374%, and the number of journals publishing CSCM research has increased by 167%. Further, research is expanding globally with authors from more countries making scholarly contributions. It is important to expand CSCM research, to include developing and underdeveloped countries that face unique institutional environments, challenges, and opportunities. Developed countries have initiated a few supportive programs for the transition towards CE in developing and underdeveloped countries (Langsdorf and Duin, 2022; Wellesley *et al.*, 2019). This calls for more international collaborative research projects between researchers in developed countries and those in developing and underdeveloped countries to improve sustainability and promote the transition towards CE. Because most supply chains extend across many countries, cross-country comparisons can provide a deeper understanding of how to implement CSCM more effectively in different countries.

Figure 6 maps out the state of CSCM research for projecting future research direction. We categorize the development stages of research in four dimensions relating to the choice of data, theory, method, and topic, respectively. Zhang *et al.* (2021) found that over 85% of the CSCM papers published in the leading operations and supply chain journals are modeling-based. We also observed that mathematical modeling is a common method in our much larger sample. Many modeling works used hypothetical data or so-called realistic estimates, so there are opportunities for more empirically grounded modeling research. Empirical studies have been growing, mainly using cross-sectional primary data. The use of secondary data is somehow rare and offers additional opportunities for future research. For example, secondary data could be used to investigate the relationship between CE practices and firm performance (Yang *et al.*, 2019). We also advocate longitudinal studies, despite its difficulty in data collection, to uncover the evolution paths in CSCM research phenomena over time.

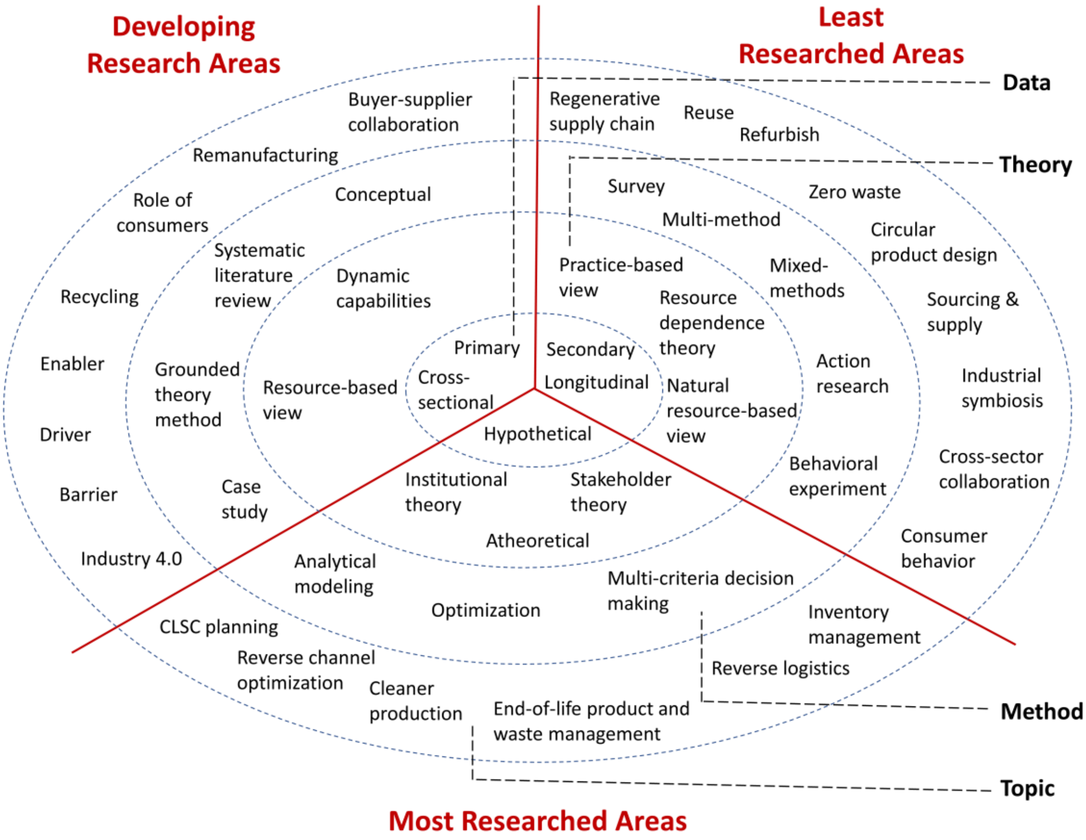

Figure 6: State of CSCM research

On the adoption of theories, we concur with Liu *et al.* (2018) that most research in CSCM focused on quantitative analysis and practices with limited theory adoption. Studies in cluster 1 (Reverse channel optimization), cluster 4 (CLSC and inventory management), and cluster 5 (CLSC and reverse logistics) are mostly atheoretical and quantitative, assuming decision-makers are rational in their search for optimal utilities. In cluster 2 (CSCM reviews and empirical studies), stakeholder theory (Freeman and Reed, 1983) was widely used to investigate barriers that influence the implementation of CE practices (Govindan and Hasanagic, 2018). Resource-based view (Barney, 1991) and dynamic capabilities (Teece *et al.*, 1997) were used to discussed how to implement CLSC successfully (Miemczyk *et al.*, 2016). In cluster 3 (CLSC and consumers), institutional theory (DiMaggio and Powell, 1983) helped explain external forces that motivate CLSC implementation (Kumar and Putnam, 2008). Institutional theory has become one of the most widely adopted theories in CSCM research in recent years.

We encourage researchers to explore a wider range of theories other than popular theories such as stakeholder theory, institutional theory, resource-based view, and dynamic capabilities. For example, Farooque, Zhang and Liu (2019) found that resource dependence theory (Pfeffer and Salancik, 1978) is relevant to collaboration in CSCM and contingency theory explains that a lack of economies of scale and uncertainties in benefits were barriers to CSCM in the Chinese food sector. Farooque *et al.* (2022) employed a natural resource-based view (Hart, 1995; Hart and Dowell, 2011), an extension of resource-based view, to theorize a positive relationship between CSCM practices and firm performance. Given that empirical CSCM research is still at a nascent stage, a lot more studies are required in a variety of contexts (e.g., different product/industry sectors, countries, etc.) for exploring and testing the explanatory power of the relevant organizational theories. Specifically, we advocate practice-based view (Bromiley and Rau, 2016) as an alternative to resource-based view. This is because CSCM practices are imitable and transferrable across firms, so practice-based view is likely to be more suitable for explaining the practice-to-performance relationship. Apart from theory testing and application, there is also ample room for theory building and extension in the emergent CSCM domain.

In term of research methods, optimization is often employed for CLSC planning problems involving network design (MahmoumGonbadi *et al.*, 2021). As mentioned in subsection 5.3.1, game theory method is dominant in analytical modeling works in the research cluster 1 (reverse channel optimization). Multi-criteria decision making is popular among the studies on drivers and barriers (Farooque, Zhang and Liu, 2019). In comparison with mathematical modeling, qualitative methods are used less frequently, and they can be found in conceptual papers, case studies, and grounded theory method-based papers. In addition, systematic literature review is commonly used for literature survey, theory building, and informing future research directions. Among the empirical works, survey studies are comparatively few. This is understandable because CE implementation is relatively new in the industry, so it is challenging to meet the large sample size requirement of survey studies. The situation may change, however, after CE practices are more widely adopted. There has been a sporadic but increasing use of a mixed-methods approach or a multi-method approach to improve academic rigor and the validity of study results, but much more works can be done to utilize the complementary strengths of different methods. Industry practitioners and policymakers were largely absent in the authorship so there are opportunities to involve practitioners in action research projects to ensure relevance to practice and to increase the impact beyond the academia. Furthermore, we call for behavioral experiments in CSCM research to gain insights on how to improve consumers' willingness to recycle product packaging, return end-of-use products, and purchase remanufactured/refurbished products.

As revealed in the cluster analysis presented in the preceding section, traditional supply chain topics including CLSC, remanufacturing, cleaner production, and end-of-life product and waste management have dominated CSCM research. CLSC has been an active research area for over two decades but recently appears to have matured especially in the topics relating to inventory management, reverse logistics, and returns channel optimization. Some topics have observed rapid growth of publications in recent years, for example, the topics relating to Industry 4.0 (Lopes de Sousa Jabbour *et al.*, 2018), barrier, driver, enabler, recycling, role of consumers, remanufacturing, and buyer-supplier collaboration. There is still much room for further research in these topics, especially in the contexts of developing countries and less-researched product sectors.

We advocate more attention to be given to the least researched topics, for example, regenerative supply chain of products made of biological materials would benefit from interdisciplinary research in SCM and agriculture. Although remanufacturing has received good attention, articles on reuse and refurbish are rare. Zero waste has received broad-based commitment from leading corporations such as Unilever and Google, but it has not been an active topic in the research community. Circular product design is a foundational step (Burke *et al.*, 2021; Wang *et al.*, 2022) for transitioning to CE, however, it has received rather limited attention. Similarly, sourcing and supply management is strategic to business operations, but relevant studies are seriously lacking in the extant CSCM literature. To further advance circularity, more research is required on the under researched CSCM dimensions especially industrial symbiosis (Zhang *et al.*, 2021), which is enabled by cross-sector collaboration (Luthra *et al.*, 2022). Because of its complexity, industrial symbiosis would benefit from interdisciplinary research that cuts across engineering and business disciplines.

A cluster of research studies investigated the role of consumers in CSCM, especially on consumer perception of remanufactured products. Consumers may have concerns about the quality of remanufactured products, products for reuse, and products that contain recycled materials. Hence, we call for more studies on consumer behavior because a CE transition can never succeed unless consumers are willing to purchase remanufactured products, use recycled materials, and return end-of-use and end-of-life products. There is an urgent need to investigate intervention strategies, at both government policy level and managerial level, for inducing positive consumer behavioral changes.

7 Conclusions and limitations

Research in CSCM is growing in terms of number of articles, outlets, and researchers. However, there are many more opportunities to increase our knowledge in industrial symbiosis, zero waste, regenerative supply chain, circular product design, sourcing and supply management, reuse, refurbish, and consumer behavior. Research methods should expand to include behavioral experiment, mixed-methods, multi-method, and action research. Empirical researchers may consider the use of secondary data and longitudinal data. We also call upon researchers to employ a wider range of theories including practice-based view, resource dependence theory, and natural resource-based view, among others, especially in the developing country contexts.

The bibliometric analyses are limited to articles retrieved from journals in the Scopus and WoS databases and published in English. Future research may expand the search to different databases and include conference proceedings, book chapters, and books. Furthermore, given the rapid growth of literature in the CSCM domain, future reviews may consider topic modelling (Bansal *et al.*, 2020) a relatively new method for qualitative data analysis, for literature analysis. Some recent review papers (Ali and Kannan, 2022; Sharma *et al.*, 2021) have shown that topic modelling can handle a very larger number of articles when manual coding is very challenging or practically infeasible. Last but not the least, there will be a need to update the review after several years because the CSCM research domain is very active and many more articles are likely to be published in the next few years.

Acknowledgements

Dr Abraham Zhang acknowledges partial funding support from the 2020 Endeavour Fund, Ministry of Business, Innovation & Employment of New Zealand (Project title: Āmiomio Aotearoa - A Circular Economy for the Wellbeing of New Zealand).

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Appendix 1

Top journals based on the number of publications

Journals	Count	Per cent
Journal of Cleaner Production	372	32.9%
International Journal of Production Research	122	10.8%
International Journal of Production Economics	121	10.7%
Transportation Research Part E: Logistics and Transportation Review	37	3.3%
Production Planning and Control	29	2.6%
Production and Operations Management	22	1.9%
International Journal of Logistics Systems and Management	18	1.6%
Business Strategy and the Environment	15	1.3%
Supply Chain Management: An International Journal	13	1.2%
Journal of the Operational Research Society	13	1.2%

Journal of Enterprise Information Management	13	1.2%
Omega	12	1.1%
IEEE Transactions on Engineering Management	11	1.0%
International Journal of Supply Chain Management	11	1.0%
Textile Outlook International	11	1.0%
Technological Forecasting and Social Change	10	0.9%
International Journal of Physical Distribution and Logistics Management	9	0.8%
Decision Sciences	8	0.7%
Industrial Management and Data Systems	8	0.7%
Management Science	8	0.7%
Manufacturing and Service Operations Management	8	0.7%
Journal of Industrial Engineering and Management	8	0.7%
Journal of Industrial and Management Optimization	7	0.6%
International Journal of Business Performance and Supply Chain Modelling	7	0.6%
International Journal of Integrated Supply Management	7	0.6%
Journal of Operations Management	7	0.6%
Journal of Advanced Manufacturing Systems	7	0.6%
International Journal of Systems Science: Operations and Logistics	7	0.6%
Benchmarking	6	0.5%
International Journal of Logistics Research and Applications	6	0.5%
Journal of Manufacturing Technology Management	6	0.5%
International Journal of Supply and Operations Management	6	0.5%
Journal of Japan Industrial Management Association	6	0.5%