Circular Supply Chain Management: A Definition and Structured Literature Review

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Abstract

Circular economy is increasingly recognized as a better alternative to the dominant linear (take, make, and dispose) economic model. Circular Supply Chain Management (CSCM), which integrates the philosophy of the circular economy into supply chain management, offers a new and compelling perspective to the supply chain sustainability domain. Consequently, there is increasing research interest. However, a review of the extant literature shows that a comprehensive integrated view of CSCM is still absent in the extant literature. This prohibits a clear distinction compared to other supply chain sustainability concepts and hinders further progress of the field. In response, this research first classifies various terminologies related to supply chain sustainability and conceptualizes a unifying definition of CSCM. Using this definition as a base, it then conducts a structured literature review of 261 research articles on the current state of CSCM research. Based on the review results, the researchers call for further studies in the following directions that are important but received little or no attention: design for circularity, procurement and CSCM, biodegradable packaging, circular supply chain collaboration and coordination, drivers and barriers of CSCM, circular consumption, product liabilities and producer's responsibility, and technologies and CSCM.

Keywords: supply chain management; circular economy; circular supply chain; circular supply chain management; sustainable supply chain; sustainability

Article Classification: Literature review

1. Introduction

Sustainability has provoked a multitude of discussions and debates in the academic literature, including the Supply Chain Management (SCM) literature (Seuring and Müller, 2008; Morali and Searcy, 2013). However, global patterns of production, consumption, and trade still remain dangerously unsustainable (Preston, 2012). At its current level of consumption, the world will deplete many natural resources in the foreseeable future if there is no change in the way products are sourced, produced, delivered, used, reclaimed and regenerated (Hazen et al., 2017).

One important philosophy that may bring about this change is the circular economy (CE), a philosophy that has been increasingly recognized as a better alternative to the dominant linear (take, make, and dispose) economic model (Ghisellini et al., 2016). The CE philosophy is evolving into an influential driving force behind sustainability, both in the literature and in practice (Hobson, 2016; Stewart and Niero, 2018), and it has begun to be recognized as of great potential to help organizations achieve a breakthrough in sustainability performance.

CE was promoted by the Ellen MacArthur Foundation (EMF) (2014) as an industrial system that is restorative and regenerative by design. CE aims to keep products, components, and materials at their highest utility and value at all times in both biological and technical cycles. This means biological ingredients or nutrients can be safely returned to the biosphere and enhance natural capital. Similarly, geosphere-derived technical nutrients can be designed for recovery (remanufacturing, refurbishing, and recycling); thus, they can be kept within the technosphere by being circulating in and contributing to the economy with minimal wastages (EMF 2012; 2014).

Integrating CE into SCM can provide advantages from a sustainability viewpoint (Genovese et al., 2017; Nasir et al., 2017). Consequently, there is enthusiasm and a growing interest in SCM for CE (Ying and Li-jun, 2012; Aminoff and Kettunen, 2016; Darom and Hishamuddin, 2016; Batista et al., 2018a; Batista et al., 2018b; Bressanelli et al., 2018b; De Angelis et al., 2018; Govindan and Hasanagic, 2018; Howard et al., 2018; Kazancoglu et al., 2018; Liu et al., 2018). However, SCM research is still at a nascent stage when it comes to conceptualizing how to advance supply chain theories and practices to help realize the vision and potential of a CE.

In the SCM literature on sustainability, a number of concepts, such as sustainable supply chains, green supply chains, environmental supply chains, and closed-loop supply chains, have been introduced and used interchangeably (Gurtu et al., 2015) to express the integration of sustainability concepts in SCM (Ahi and Searcy, 2015). While these concepts represent different degrees of integrating sustainable thinking into supply chains, none of them have systematically integrated circular thinking - i.e., the essence of the CE philosophy – into SCM. Some recent reviews on integrating CE into SCM have a rather narrow scope (Batista et al., 2018a; Govindan and Hasanagic, 2018). Meanwhile, the extant literature on CE and SCM sustainability remains fragmented where some key principles of CE are reflected at a strategic level and others around SCM functions such as design, procurement, production, etc.

While the term "circular supply chain" was used in some studies to link CE with SCM (Canning, 2006; Du et al., 2010; Genovese et al., 2017; Nasir et al., 2017; De Angelis et al., 2018; Mishra et al., 2018) it is only very recent that a working definition of circular supply chain management (CSCM) appeared in the literature. CSCM has been defined as:

"*the coordinated forward and reverse supply chains via purposeful business ecosystem integration for value creation from products/ services, by-products and useful waste flows through prolonged life cycles that improve the economic, social and environmental sustainability of organizations*" (Batista et al., 2018a, p. 446).

Apparently, this closely mirrors the definition of sustainable supply chain management:

"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" (Seuring and Müller, 2008, p.1700).

It does not sufficiently reflect the two aspects that make a CSCM unique: 1) its restorative and regenerative cycles designed based on circular thinking; 2) the vision of a zero-waste economy that is inherent in the CE philosophy. Therefore, this definition is likely to lead to confusion with existing sustainability concepts in the context of SCM and consequently may hinder the development of CSCM. In response, the current study aims to achieve the following objectives:

1. To conceptualize a new definition of CSCM;
2. To map the current state of research on all the aspects and facets of CSCM by use of a structured review of literature; and,
3. To identify important directions for future research in CSCM.

The remainder of this paper is organized as follows: section 2 classifies the supply chain sustainability concepts and defines CSCM. Section 3 then describes how the structured literature review on CSCM has been conducted, and section 4 then presents the results of our review. Section 5 discusses important future research directions that emerged from the review. Finally, section 6 concludes this study.

2. Supply Chain Sustainability Terms and CSCM

To the best of our knowledge, this is one of the early attempts to conceptualize and define a comprehensive integrated view of CSCM, to appropriately distinguish it from other sustainability concepts presented in the supply chain literature. To do so, this section first classifies existing supply chain sustainability concepts and discusses its relation to the CE philosophy in Section 2.1. Section 2.2 then presents a working definition for CSCM.

2.1 Classification of Supply Chain Sustainability Terms

Sustainability concepts in the SCM literature have been largely inspired by Elkington's (2004) idea of a triple bottom line (TBL) which suggest that organizational sustainability consists of three components: the natural environment, society, and economic performance at a broader level (Carter and Dale, 2008). Based on these three components different terminologies emerged from the literature, for example, "sustainable supply chain management" (Seuring and Müller, 2008; Craig and Easton, 2011; Anne and Helen, 2015; Leszczynska and Maryniak, 2017), "green supply chains" (Srivastava, 2007; Chakraborty, 2010; Seman et al., 2012; Malviya and Ravi, 2015), "closed loop supply chains" (Souza, 2013; Govindan et al., 2015), and "environmental supply chains" (Darom and Hishamuddin, 2016). Each of these concepts gave different weight to the three components. For example, Ahi and Searcy (2013) performed a comparative analysis of 12 unique definitions of sustainable supply chain management (SSCM) from 56 articles and 22 unique definitions of green supply chain management (GSCM) from 124 articles. They found that most definitions for SSCM explicitly addressed all three dimensions of the TBL. In contrast, none of the published definitions on GSCM explicitly mentioned social issues.

EMF (2017) defined the CE philosophy as *"Looking beyond the current take, make and dispose extractive industrial model, the circular economy is restorative and regenerative by design. Relying on system-wide innovation, it aims to redefine products and services to design waste out, while minimizing negative impacts. Underpinned by a transition to renewable energy sources, the circular model builds economic, natural and social capital"*. The CE philosophy makes a clear distinction between products' biological (regenerative) and technical (restorative) cycles. The biological materials or nutrients become part of the biosphere as natural capital and can be reused as production inputs, whereas the technical materials or nutrients (polymers, alloys and other man-made compounds) are designed for material recovery through repair, refurbishing, remanufacturing, and recycling (Weetman, 2017). Thus, CE may, if actualized, operate in ways where product design, usage, and re-usage based economic activities mimic the natural ecosystem; i.e., natural resources transformed into manufactured products and the manufactured by-products are used as resources for other industries (Zhu et al., 2010).

Integrating CE in SCM would begin to extend the boundary of SSCM and GSCM by reducing the need of virgin materials which could increase the circulation of resources within supply chains systems (Andersen, 2007; Genovese et al., 2017). However, based on our analysis of the literature on CE, there is a knowledge gap in terms of how to integrate CE into SCM (see also Aminoff and Kettunen (2016)). As presented in Table 1, the sustainability discussion in SCM has mainly addressed restoration options (repair, refurbishing, remanufacturing and recycling) while the regeneration concept has not been discussed in the

SCM sustainability context. So, there is a need to enhance the existing sustainability concepts in SCM towards a CSCM.

Table 1: Sustainability in SCM and CE

Sustainability in SCM (Terms)	**Definition Source**	**Sustainability Dimension**			**Integration of CE**	
		Environmental	**Economic**	**Social**	**Restorative***	**Regenerative***
Sustainable Supply Chain Management	Seuring and Müller (2008)	■	■	■	■	
Green Supply Chain Management	Srivastava (2007)	■	■		■	
Environmental Supply Chain Management	Zsidisin and Siferd (2001)	■	■		■	
Closed Loop Supply Chains	Guide and Van Wassenhove (2006)	■	■		■	

* ***Restorative:*** Ability of end of life products/materials to become technical nutrients through repair, refurbishing, remanufacturing, and recycling (Ellen MacArthur Foundation (EMF), 2017)

* ***Regenerative:*** Ability of end of life products/materials to become biological nutrients and become part of the biosphere as natural capital for reuse (Ellen MacArthur Foundation (EMF), 2017)

2.2 Circular Supply Chain Management Definition

The integration of CE into SCM has been termed circular supply chain in the literature (Canning, 2006; Du et al., 2010; Genovese et al., 2017; Nasir et al., 2017). However, there is no comprehensive definition of CSCM. Therefore, we proposed the following definition:

> *Circular supply chain management is the integration of circular thinking into the management of the supply chain and its surrounding industrial and natural ecosystems. It systematically restores technical materials and regenerates biological materials toward a zero-waste vision through system-wide innovation in business models and supply chain functions from product/service design to end-of-life and waste*

management, involving all stakeholders in a product/service lifecycle including parts/product manufacturers, service providers, consumers, and users.

CSCM significantly enhances SSCM and GSCM by a regenerative dimension. It advances sustainability thinking by systematically applying CE's circular thinking in all supply chain stages and functions. As with the CE philosophy, CSCM is applicable to manufactured products as well as to service products. In CSCM, organizations collaborate with others within and outside of the sector to maximize the utility of goods/materials. It offers a promising vision to guide supply chain managers to achieve a breakthrough performance in resource efficiency, and consequently, profitability. Simultaneously, it minimizes the negative environmental, social, and economic impacts.

The purpose of CSCM is to lead towards circular supply chains as illustrated in Figure 1. Figure 1 contrasts a circular supply chain (Figure 1c) with a traditional (linear) supply chain (Figure 1a) and a closed loop supply chain (Figure 1b). A linear supply chain extracts resources from the geosphere and the biosphere and disposes off EoL products, packaging materials, and wastes from multiple supply chain stages. The unwanted items are often deposited in landfills. A closed loop supply chain improves environmental performance by bringing back goods and packaging materials to the producer to recover value (Guide and Van Wassenhove, 2006). For example, closed loop remanufacturing of photocopiers can conserve 20–70% of materials, labor, and energy and reduce waste by 35–50% as compared to conventional manufacturing (Toffel, 2004). However, the extent of value recovery in a closed loop supply chain is often limited because the efforts are restricted within the original supply chain (producer's supply chain) and do not include secondary supply chains and/or involve new auxiliary channel members (Moula et al., 2017). A closed loop supply chain still generates substantial amounts of waste as it is rarely feasible to reuse/recycle all unwanted items within the same supply chain. A circular supply chain goes further by recovering value from waste by collaborating with other organizations within the industrial sector (open loop, same sector), or with different industrial sectors (open loop, cross-sector) (Weetman, 2017).

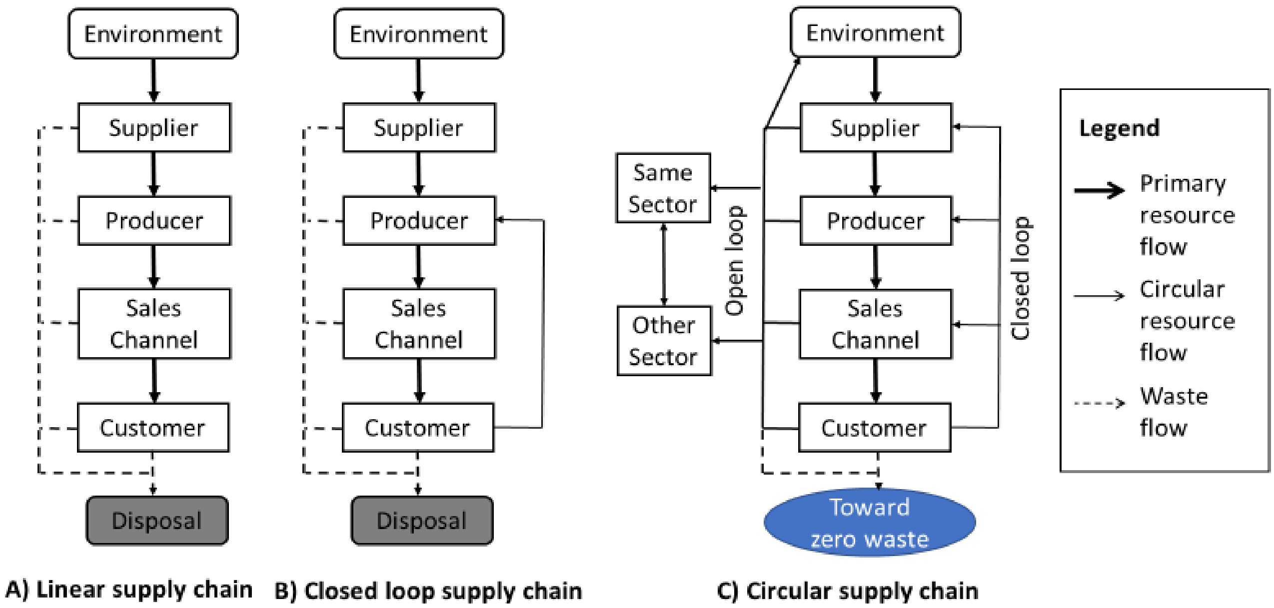

Figure 1. Linear, closed loop and circular supply chains

Ideally, a circular supply chain will generate zero waste because it is designed to systematically restore and regenerate resources in the industrial and natural ecosystem in which it is embedded. Circular supply chains have two types of resource flows: primary resource flows and circular resource flows, as illustrated in Figure 1c. The primary resource flows are identified with the forward flow of goods in the linear and closed-loop supply chains. The circular resource flows represent the "re-" type flows of goods/materials/energy that are recycled, retained, reused, repaired, remanufactured, refurbished, recovered, etc.

In practice, CSCM endeavor to produce zero waste through system-wide innovations to recover value from what was traditionally called “waste”. For example, recycled PET bottles may be used for construction; light concrete is added to the bottles, creating isolated walls for houses (Scheel and Vazquez, 2011; Scheel and Vasquez, 2013). Similarly, a manufacturer may recycle textile materials to produce insulation products for the construction industry (Nasir et al., 2017) while a food supply chain’s waste cooking oil may be refined and utilized to produce biodiesel (Genovese et al., 2017). Food wastes can be minimized at their sources and the remaining food wastes can be composted or anaerobically digested to produce methane as a renewable energy source and fermentate, which can be used as a fertilizer in agriculture/horticulture.

Based on the CSCM conceptualization presented above, we have developed one of the earlier literature reviews in this emerging field. We hope that this significantly furthers the development of CSCM and provides a new dimension for sustainability researchers in SCM, offering significant managerial, policy, human health, and eco-system health implications.

3. Methodology

A structured review of the literature was conducted to summarize the current state of academic research on CSCM. A procedure similar to Seuring and Müller (2008); Harland et al. (2006) and Mayring (2003) was used for retrieving and selecting the articles. The following subsections outline the approach adopted for sourcing, screening, analyzing the articles and sample characteristics.

3.1 Sourcing the Articles

There are, arguably, three major abstract and citation databases: Google Scholar, Scopus, and the Web of Science. We excluded Google Scholar because of its low data quality, which raises questions about its suitability for research (Meho and Yang, 2007; Mongeon and Paul-Hus, 2016). Meanwhile, Scopus has a broader coverage than the Web of Science, but the latter provides access to older sources. Since we are investigating a recent phenomenon, the access to older sources offered by the Web of Science database is not an advantage. We, therefore, focused on Scopus. In general, the number of journals in the Web of Science not covered by Scopus is about 5%, and the number of Scopus articles not covered by the Web of Science is about 50% (Mongeon and Paul-Hus, 2016). Meanwhile, we did not use a full-text database (such as EBSCO, Elsevier, ProQuest, Sage, Springer, Taylor & Francis, or Wilson) in a bid to avoid excluding any particular publisher from the search. All articles published until 2018 were considered.

To maintain the quality of content and to keep the selected articles to a manageable number, the search was restricted to "Articles", "Articles in press" and "Review articles" published in peer-reviewed journals. Although representing a limitation, only English sources were included in our review given the language limitations of the author team. Scopus was queried using the keywords summarized in Table 2. This step retrieved 2987 publications. After removing duplicates, 1748 articles remained.

3.2 Screening the Articles

At the screening stage, articles were included/excluded based on the abstract, which was retrieved from the database. All abstracts of the original sample of 1748 articles were read. Any article that covered aspects of CE in a SCM context were retained. Most of the analysis was executed by two researchers/authors. The abstracts were read by both researchers independently and the results were compared. Any inconsistencies of interpretation were resolved through discussion until consensus was reached. All articles for which no clear decision could be reached were put in a backlog. The backlog was then cleared by both researchers through in-depth discussion, with a bias towards including the article if there was any doubt. This rather subjective procedure based on the judgement was required since the literature on CSCM is very broad and covers many different areas. Hence, no specific inclusion/exclusion criteria could be applied beyond whether or not a paper appeared to be incorporating a focus on CE in a SCM context at the micro level (firm or supply chain level).

The screening reduced the relevant articles to 270. The high number of unrelated articles is justified seen our broad search terms which included many articles that did not explicitly integrate the CE philosophy into SCM (i.e., with an exclusive focus on CE or supply chain sustainability). Focusing on articles that explicitly focus on the integration of CE into SCM differentiates our literature review work from reviews in SSCM (Seuring and Müller, 2008; Ansari and Kant, 2017; Dubey et al., 2017a), GSCM (Srivastava, 2007; Fahimnia et al., 2015; Malviya and Ravi, 2015), closed loop supply chain (Souza, 2013; Govindan et al., 2015; Govindan and Soleimani, 2017) and CE (Su et al., 2013; Ghisellini et al., 2016; Lieder and Rashid, 2016). Using several channels for retrieving the full articles, i.e., database subscription/access available to the authors, a total of 261 articles were obtained and evaluated as the final sample. Figure 2 summarizes the structured literature review process.

Table 2: Keywords used for search and number of papers retrieved

1st step		
No.	**Keywords used for search**	**Papers retrieved**
1	Circular economy AND supply chain	152
2	Circular economy AND value chain	59
3	Circular economy AND operations management	5
4	Circular economy AND sustainable supply chain	16
5	Circular economy AND green supply chain	14
6	Circular economy AND closed loop supply chain	22
7	Circular economy AND environmental supply chain	1
8	Circular economy AND reverse logistics	25
9	Circular economy AND logistics	47
10	Circular economy AND design	297
11	Circular economy AND procurement	15
12	Circular economy AND manufacturing	175
13	Circular economy AND production	611
14	Circular economy AND end of life	116
15	Circular economy AND remanufacturing	68
16	Circular economy AND refurbish	20
17	Circular economy AND repair	25
18	Circular economy AND reuse	222
19	Circular economy AND recycle	64
20	Circular economy AND reduce	204
21	Circular economy AND restore	5
22	Circular economy AND regenerate	7
24	Circular economy AND consumption	292
25	Circular economy AND product service systems	33
26	Circular economy AND PSS	16
27	Circular economy AND business model	137
28	Circular economy AND waste management	339
Total number of papers retrieved		**2987**
2nd step		
1	Circular economy	**1748**

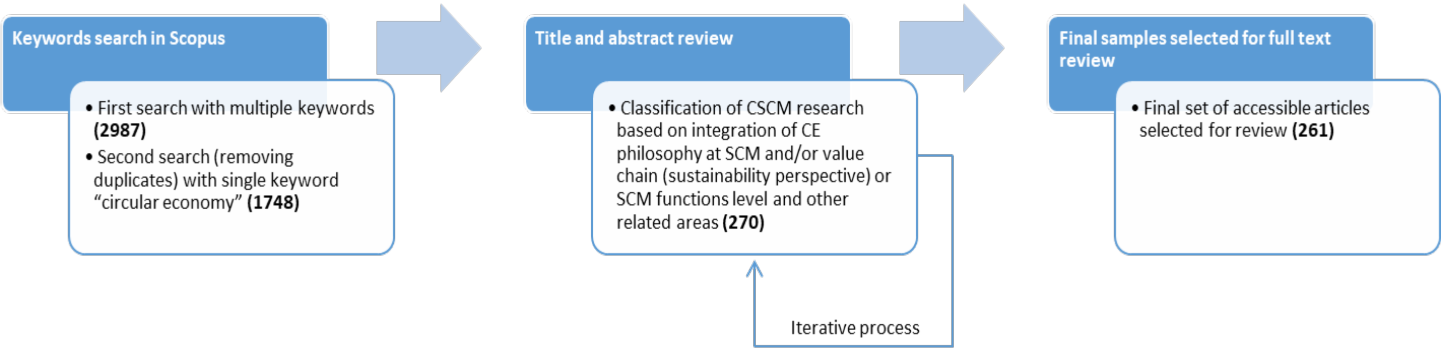

Figure 2: Structured literature review process

3.3 Analyzing the Articles

This stage involved extracting and documenting information from the 261 articles. To minimize subjectivity, the authors: (i) cross-checked results; and, (ii) conducted regular meetings among themselves to resolve any emerging inconsistencies in interpreting the results. Our major research vehicle was content analysis (see, Krippendorff (2004)). To ensure that we did not miss relevant information, we held regular meetings to discuss issues and to clarify ambiguities. As a template for data collection, a simple matrix was used where, for each paper (row), we asked (column) the following questions:

- What part(s) of CE were integrated into SCM or value chain (from a sustainability viewpoint)?
- What part(s) of CE were integrated into SCM functions?
- Which circular business models were discussed in the publication?
- What role did technology play in integrating CE in SCM?
- Which industrial sector did it focus upon?
- Which country was the context of the research?
- What was the research/analysis methodology?

- What were the key findings, lessons, recommendations for the short and long-term future?

Before presenting the results, Section 3.4 summarizes the basic sample characteristics.

3.4 Sample Characteristics

The distributions of publications by the year of publication are presented in Figure 3. The discussion of CE elements in supply chain sustainability literature started in the late 2000s and continued at a modest rate until 2015. There has been an increase of papers on this topic since the beginning in 2016, which indicates a growing research interest in this field, further supporting the need for our comprehensive review (see Figure 3).

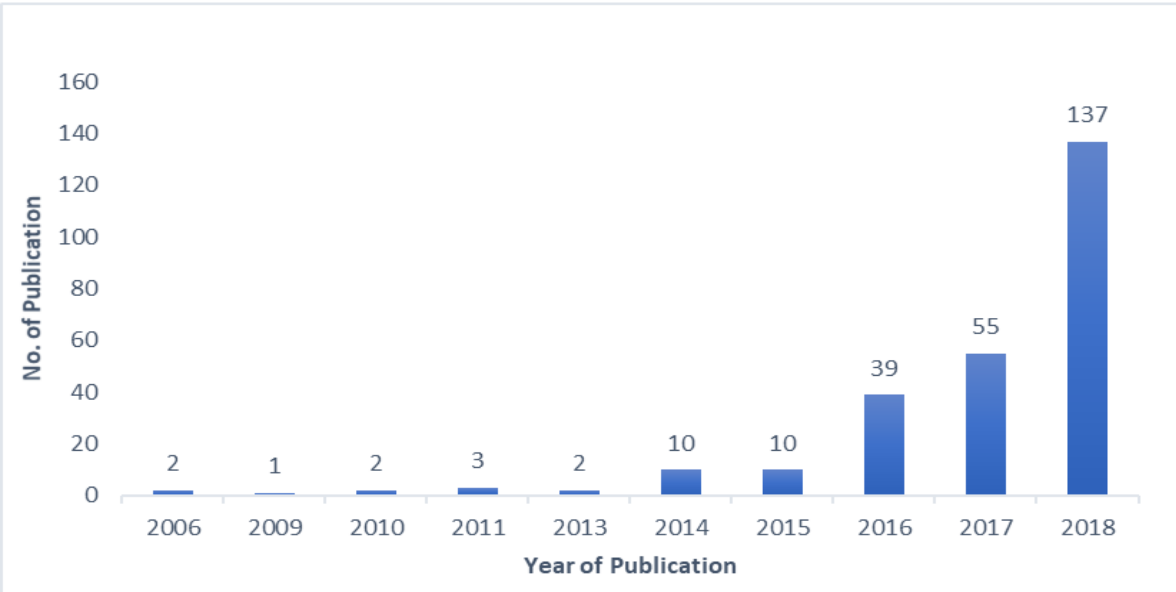

Figure 3. Distribution of articles per year

Table 3 presents the distribution of journals across which the articles were published. The sample contains articles from a broad set of journals. It was found that 51 journals have published just one paper on the topic. Moreover, as anticipated, the leading journals in the field head the list with the highest contribution of relevant articles in the Journal of Cleaner Production (64) in the emerging field of CSCM research.

Meanwhile, Figure 4 presents the distribution of the research context by countries. The results indicate a leading role of China in accelerating CSCM research. Moreover, substantial research in the CSCM has also been conducted in the United Kingdom (UK), The Netherlands, United States of America (USA), and Sweden including other European countries. The European Union's (EU) growing interest in CSCM is evident in Figure 4. However, these statistics exclude the publications where the research context was unclear or unspecified.

Table 3: Distribution of reviewed articles by journal

Journal Name	No. of papers	%
Journal of Cleaner Production	63	24.14
Sustainability (Switzerland)	32	12.26
Resources, Conservation and Recycling	26	9.96
Journal of Industrial Ecology	12	4.60
International Journal of Production Research	10	3.83
Production Planning and Control	10	3.83
Waste Management	7	2.68
Business Strategy and the Environment	7	2.68
California Management Review	5	1.92
Resources	5	1.92
Management Decision	5	1.92
Environmental Innovation and Societal Transitions	4	1.53
Thunderbird International Business Review	4	1.53
Journal of Remanufacturing	3	1.15
Procedia Manufacturing	3	1.15
Journal of Manufacturing Technology Management	3	1.15
International Journal of Production Economics	2	0.77
Waste Management and Research	2	0.77
Journal of Environmental Management	2	0.77
CIRP Journal of Manufacturing Science and Technology	2	0.77
Technological Forecasting and Social Change	2	0.77
Science of the Total Environment	2	0.77
Others	50	19.16
Total	**261**	**100%**

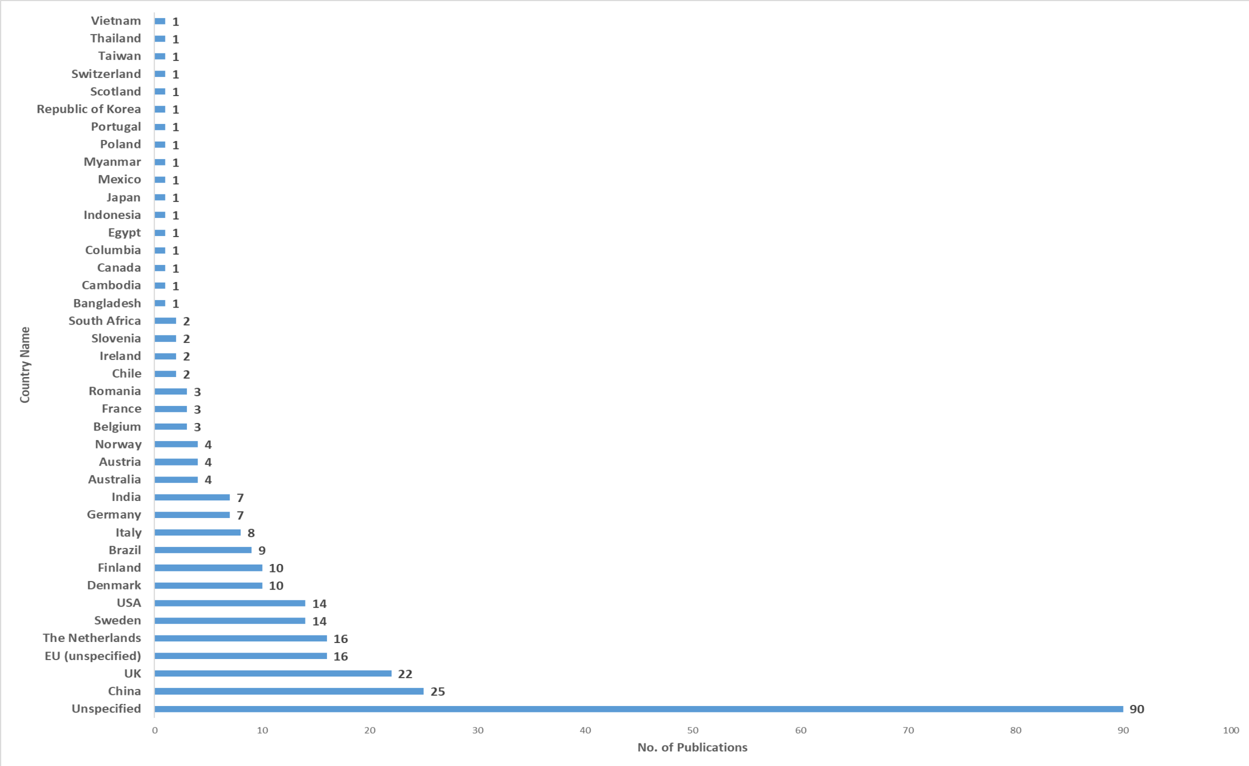

Figure 4. Distribution of reviewed articles by country

Figure 5 presents the distribution of articles by industrial sector. The International Standard Industrial Classification (ISIC), a United Nations system for classifying economic data, was used for classification purposes following Gao et al. (2017). The results indicate that the manufacturing sector (including publications where multiple manufacturing industries were indicated) has been the primary research field along with waste management and remediation activities for the relevant papers for this literature review. Wholesale and retail also play an active role in CSCM. Note that these statistics excluded many publications that did not specify any industrial sector.

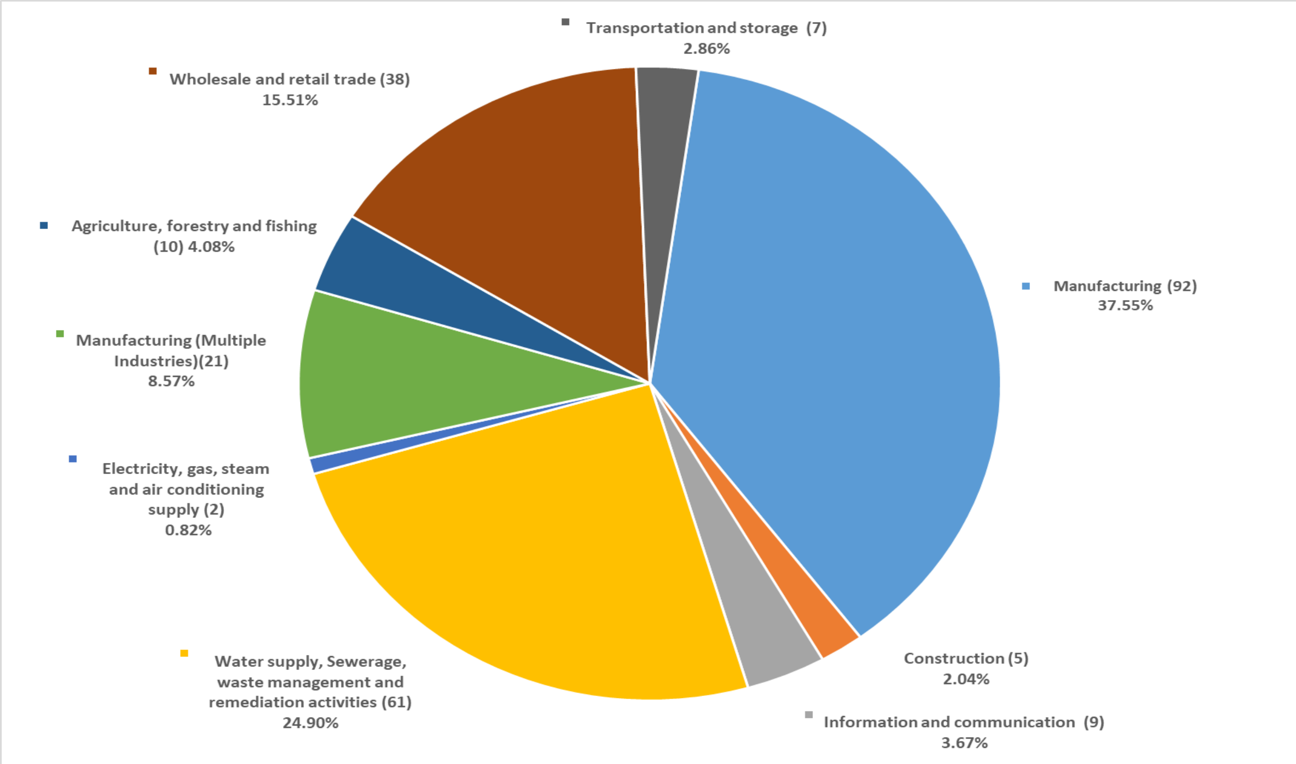

Figure 5. Distribution of reviewed articles by industry

Table 4 summarizes the frequency of research methods after analyzing the articles in detail. Empirical research (148) shows that research in the field of CSCM has mostly been driven by direct observation (case studies, surveys, etc.). Case study (110 papers) has been the most common methodology employed in the studies. Given that CSCM research is still in the early stage of development, it is of no surprise to see a large number of case studies conducted to identify the critical issues and to develop a clearer understanding of the topics. Conceptual/Theoretical model (43 papers) and Literature review (38) are the second and third most frequently used methods in different studies, respectively. These papers serve as the foundation to synthesize the existing knowledge and to develop important guidelines for future research in CSCM. Articles where quantitative approaches (Modeling) have been used for decision-making contribute to 19 papers. Other methods include experimental studies (7), and in a few cases, the researchers used a combination of different methods.

Table 4: Distribution of reviewed articles based on research method

Research Method	No. of papers	%
Empirical	148	56.70%
- *Case study (110)*		
- *Survey (26)*		
- *Interview (10)*		
- *Mixed method (2)*		
- *Others (2)*		
Conceptual/Theoretical	43	16.48%
Literature review	38	14.56%
Modelling	19	7.28%
- *Simulation (6)*		
- *Optimization (9)*		
- *Others (4)*		
Experimental	7	2.68%
Literature review + Case study	4	1.53%
Literature review + Interview + Case study	2	0.77%
Total	**261**	**100%**

4. Review Results:

Overall, the CSCM research is classified in two broad categories. The first category classifies the integration of CE philosophy at a broad SCM and/or value chain (sustainability perspective) level. This classification category includes 60 papers representing approximately 30% of the total papers reviewed. The second major category classifies the extant literature concerning the integration of CE philosophy at SCM functional level. A total of 121 papers across various functional areas included in this category represents nearly 46% of the reviewed article. Moreover, the business model and the role of technology represent the other two subcategories of CSCM classification. These subcategories include 67 and 13 papers, representing 26% and 5% of the reviewed papers respectively. Figure 6 presents the classification of CSCM research.

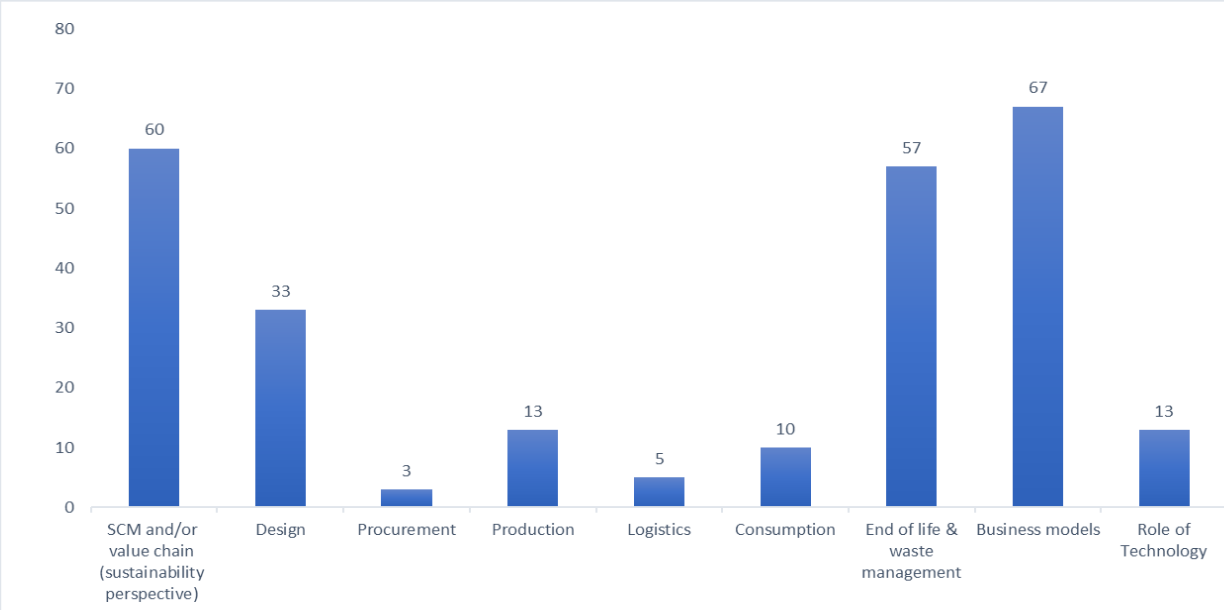

Figure 6. Classification of CSCM research

CSCM classification as presented in Figure 6 has been used to structure the remainder of this section. Note that the most relevant category was chosen when a publication was relevant to more than one category.

4.1 Supply chain-wide integration of CE

4.1.1 Supply chain management/value chain (Sustainability perspective)

A recent review paper (Masi et al., 2017) clustered the circular supply chain research into three supply chain configurations: Eco-industrial parks (EIPs), environmental, sustainable, green systems, and closed-loop supply chains. While EIPs refer to a meso level CE implementation, (which is beyond the scope of this paper) the other two clusters represent the SCM sustainability domain, which is currently active in CSCM research. Recent examples include De Angelis et al. (2018) who explored the implications for SCM in circular supply chains comparing it with the traditional and sustainable supply chain. Batista et al. (2018a) contributed to the understanding of supply chain circularity (i.e., restorative and regenerative processes of

CE). Winkler and Kaluza (2006) highlighted the importance of establishing Sustainable Supply Chain Networks to implement an integrated waste management system to achieve sustainable economic growth. Adopting an SSCM approach was considered to be helpful for organizations to create a blended business and environmental value, thus providing the impetus for organizations to adopt CE (Park et al., 2010). While others consider the integration of CE and CLSC as ‘circular supply chains’ (Lapko et al., 2018; Mishra et al., 2018). Circular and CLSCs focus more on value recovery operations through reverse logistics (Bernon et al., 2018; Larsen et al., 2018). GSCM and CE are also considered as concepts overlapping and supporting each other (Liu et al., 2018). In order to integrate the CE concept into GSCM, Kazancoglu et al. (2018) proposed a new holistic conceptual GSCM performance assessment framework integrating environmental, economic, logistics, operational, organizational and marketing performance.

4.1.2 Drivers and barriers

A number of studies have identified drivers (Bressanelli et al., 2018a; Govindan and Hasanagic, 2018; Huybrechts et al., 2018; Mangla et al., 2018; Ranta et al., 2018) and barriers (Govindan and Hasanagic, 2018; Mangla et al., 2018; Masi et al., 2018; Milios et al., 2018; Ranta et al., 2018) to CSCM development and implementation. However, it is important to note that drivers and barriers significantly vary by geographic and industrial contexts. This needs to be further explored for a widespread implementation of CSCM across the globe.

4.1.3 Indicators and measurement tools

Howard et al. (2018) argued that the abundance of CE indicators (typically fragmented and disjointed), make it difficult for firms to monitor, report and communicate progress towards the implementation of CE. Therefore, they proposed a new framework for the development of CE indicators which link to the core goals, principles and concepts of a CE. With regards to

CSCM, Jain et al. (2018) developed a strategic framework for measuring CSCM using the supply chain operations reference (SCOR) model, but they primarily focused on the environmental dimension and not the social and economic dimensions.

Linder et al. (2017) proposed a novel circularity metric based on the ratio of recirculated economic value to total product value, using value chain costs as an estimator. This metric can enable producers and customers to quantify product-level circularity and contribute towards the transition to more sustainable CE. Di Maio et al. (2017) introduced 'value-based resource efficiency' (VRE) indicator to measure resource efficiency and circularity using the market value of resources as opposed to traditional approaches. This highlighted the range of available circularity metrics from being focused on product-level circularity informing about products being 'bad' or 'good' in terms of resource efficiency to being focused on value-based assessment of resource efficiency and CE related performance of supply chain actors.

4.1.4 Industry applications and performance

The implementation of CSCM at a micro level has increased in various industries (Nasir et al., 2017; Batista et al., 2018b; Hahladakis and Iacovidou, 2018; Jain et al., 2018; Laso et al., 2018; Leising et al., 2018; Stewart and Niero, 2018; Vlajic et al., 2018). For example, O'Connor et al. (2016) presented strategies for "Material Supply Chain Sustainability" using principles of Green Engineering and the vision of CE focused upon the electronics sector. Franco (2017) identified the challenges faced by incumbent firms in the textile industry along their value chains (from product design to take-back and reprocessing) in developing circular products. Mohamed Abdul Ghani et al. (2017) stressed on the need for systematic understanding and implementation of CE principles for GHG reduction across the construction supply chain industries in the US. Golev and Corder (2017) performed a detailed analysis of metal flows and values associated with e-waste in the Australian metal value chain. With an estimated metal recovery value from e-waste of about US$ 370 million in 2014, the metal losses associated with e-waste are worth US$ 60–70 million a year, mainly due to 25% of e-waste being landfilled. Winans et al. (2017) focused on the application and assessment of CE in the industries representing critical research gaps (i.e., agricultural industries and chemical/biochemical industry products and value chains). The plastics and food supply chain wastes were concluded to provide interesting and viable organic "waste-to-resource" opportunities (Clark, 2017). Overall, the papers selected for the study revealed that integrating CE into SCM helped to improve environmental performance (Niero and Olsen, 2016; Genovese et al., 2017; Nasir et al., 2017) along with economic performance (Zhu et al., 2010, 2011).

4.2 Integrating CE into individual supply chain functions

The transition towards CE requires considerable transformations in business models, supply chain configurations and practices related to product/service design, production, consumption, waste management, reuse, and recycling (Hobson, 2016; Mendoza et al., 2017). There were implications for logistics flows at all supply chain stages (Bicket et al., 2014). Consequently, some firms have adopted various micro-level CE practices (of organizations' operations and supply chains) (Ghisellini et al., 2016). These included eco-design or green design (Winkler, 2011), green procurement (Zhu et al., 2010), cleaner production and EoL management based on Reduction, Reuse and Recycle (3R principles) (Geng et al., 2012; Su et al., 2013; Lieder and Rashid, 2016).

Quite interestingly, Masi et al. (2017) discovered that since the emergence of CE in SCM, no new practices have been featured under the label of circular supply chain. Similarly, by analyzing the current CE implementation cases, Kalmykova et al. (2017) concluded that 'Recovery, Consumption and Use' parts of the value chain have received the most attention. Whereas, 'Manufacturing, Distribution and sales' are rarely involved in CE implementation.

4.2.1 CE & Product/Service Design

Product/service design for CE has crucial roles in fostering materials and energy recirculation in CEs (Laurenti et al., 2015; Clark et al., 2016). Building upon CE and sustainability concepts, the product/service design functions need to be fundamentally changed as the product/service design greatly influences the whole product/service's value chain (De los Rios and Charnley, 2017; Jensen and Remmen, 2017). Sustainable packaging design and product labeling have also been regarded as important aspects of the circular design strategy (Bovea et al., 2018a; Bovea et al., 2018b; Steenis et al., 2018). Designers must respond to very different social, economic and environmental needs and must adopt holistic approaches to problem solving. They must change their design thinking and interpretation of associated practices that lead to the CE transition by creating products and services that match all inherent criteria of circular business model (Andrews, 2015; Sihvonen and Partanen, 2018). Moreover, the role of chemistry to provide the basis of innovative products (e.g., designed to be reused, recycled, or the feedstock renewed through natural processes) is crucial to creating a world without waste (Clark et al., 2016).

The current literature on design functions offers various design strategies and circular business models based on the notion of product life extension and closed loop systems (Bakker et al., 2014; Moreno et al., 2016; den Hollander et al., 2017; Sumter et al., 2018). Bocken et al. (2016) introduced the taxonomy of slowing, closing, and narrowing resource loops by building upon previous research. Moreno et al. (2016) developed a conceptual model and mapped the identified circular design strategies against circular business model archetypes. The den Hollander et al. (2017) team further extended Bocken's work by making a distinction between circular product design and eco-design. According to den Hollander et al. (2017), the waste hierarchy described in the European Waste Framework Directive (EC, 2009) is one of the guiding principles of eco-design, which details a priority order for managing waste, i.e. moving from prevention of waste, to reuse, recycling, recovery, and disposal. However, circular product design relates to Stahel (2010) work based on the Inertia Principle and to the concept of product integrity. Bovea and Pérez-Belis (2018) identified design guidelines required for a better circular product. Their study findings suggest that there is an urgent need to incorporate lifetime extension and product/component reuse guidelines in circular product design strategies.

Recently, the adoption of design for dismantling (DFD) has increased in many industrial sectors, partly motivated by recent technological advancements that offer cost savings besides extended product responsibility regulations. The DFD offers values to products not only at the EoL stage but also during the usage, life-time and maintenance stages (Sabaghi et al., 2016). Tian and Chen (2014) illustrated the use of the DFD method by reducing the number of incompatible polymers in vehicle dashboards. The DFD resulted in easy separation and recycling of polymers with mechanical methods, eliminated chemical separation methods. Vanegas et al. (2018) proposed a robust method, titled the 'ease of Disassembly Metric' (eDiM) to calculate the disassembly time modelled using the Maynard operation sequence technique (MOST). Important design implications (e.g., design for disassembly) for better CE were also presented in the computer industry (Talens Peiró et al., 2017) and in the crucial area of managing the supply of critical materials (Peck et al., 2015).

4.2.2 CE & Procurement

Introducing CE into the procurement function will re-define price, quality, time and value for money principles in procurement (Meehan and Bryde, 2011). The CE requires raw materials to be technically restorative or biologically regenerative so that there are no negative impacts upon the environment (Genovese et al., 2017). Green procurement has been a very active research topic (Blome et al., 2014). However, probably due to the newness of the CE philosophy, we only found three studies that integrated CE in procurement management.

Based on the CE principles, Witjes and Lozano (2016) proposed a public procurement framework which included technical and non-technical product/service specifications. The framework provides guidelines for reducing raw material utilization and improving resource efficiency through recovery and lower waste generation. A similar CE oriented study by Popa and Popa (2016) addressed the issue of green industrial acquisitions and focused on improving resource efficiency. It considered not only the environmental advantages and disadvantages of diverse options for industrial product acquisitions but also possibilities for complete reuse of the materials of the used products.

Integrating CE principles in SCM has been viewed as potentially viable for managing supply disruptions of critical and strategic materials. Sprecher et al. (2017) introduced resilience metrics for quantifying the resilience of critical material supply chains to disruptions based on CE principles. On the other hand, Gaustad et al. (2018) indicated that many firms are not able to allocate the required time and resources to track these dynamic, complex issues. They suggested that circularity strategies such as recycling, lean principles, dematerialization and diversification have a significant potential for reducing the vulnerabilities in material supply.

4.2.3 CE & Production

Reduction of resource consumption in the production processes has become essential for manufacturing industries to maintain competitiveness and survive in today's sustainability era (Ridaura et al., 2018). As a result, manufacturing industries have started adopting sustainable manufacturing practices and CE in their supply chains to mitigate environmental risks (Moktadir et al., 2018). In this context, green manufacturing has been widely recognized as a strategic model for sustainable development. It incorporates principles such as environmental protection, resource and energy conservation, waste reduction along with the production economy (Zhou et al., 2012). Rehman et al. (2016) argued that adopting green production practices not only offer long-term cost savings but also improve brand image, regulatory compliance, and investors' interest (Dubey et al., 2015). Yet, there are some concerns over increased operating cost for firms implementing green manufacturing (Mao and Wang, 2018).

Increasing material efficiency in terms of reduced generation of industrial waste, extraction and consumption of resources, energy demands and carbon emissions, have led to the development of many strategies in the manufacturing industry (Shahbazi et al., 2016). In order to achieve improved material efficiency in a CE context, green manufacturing (Zhou et al., 2012; Dubey et al., 2015; Rehman et al., 2016) and cleaner production (Brown and Stone, 2007; Cui and Song, 2009) are two highly relevant terms that are often used interchangeably in the literature as ways to help to achieve the needed improvements. We consider cleaner production to encompass green manufacturing as it covers not only manufacturing but also service activities. Cleaner production is defined as a production method which is not only concerned with people's needs, but also with environmental protection, energy conservation, and waste and emission reduction (Cui and Song, 2009). Cleaner production also seeks to prevent the use of non-renewable and harmful inputs (Ghisellini et al., 2016). In more general terms, cleaner production aims to increase overall economic efficiency while simultaneously reducing damage and risks for humans and the environment (Brown and Stone, 2007). Apparently, cleaner production is essential for achieving the CE vision (Li et al., 2010). However, cleaner production practices are yet to be fully implemented in many industries. For example, Ghisellini et al. (2018) found a predominant role of legislative and economic barriers in Chinese construction industry inhibiting companies to implement cleaner production practices.

Cleaner production has been a hot topic in production research. In fact, the Journal of Cleaner Production is devoted to the research topic and has grown in reputation and in the number of articles published each year in this area. Surprisingly, very few studies have explicitly integrated CE's circularity philosophy into cleaner production. Among the few exceptions, Li and Ma (2015) reported that integrating CE into cleaner production achieved significant energy savings and emission-reductions in a papermaking industry park in China. Leslie et al. (2016) developed a new screening method to investigate toxic chemicals and persistent organic pollutants (POP) including brominated diphenyl ether flame retardants (POP-BDEs) in order to promote cleaner production and to reduce human and ecological exposure to toxic, bio-accumulative and persistent chemicals via plastics. Antoniou and Zabaniotou (2015) presented waste-to-resource treatment of EoL tyres (ELT) using pyrolysis (i.e., decomposition brought about by high temperatures) from a cleaner production and CE approach. The pyrolysis method turned ELT into high-value solid material having absorptive properties along with heat conversation in the process.

Overall, cleaner production practices are considered as a key enabler of CE practices at a micro level with implications for other supply chain functions such as circular product design, consumption and EoL and waste management (Sousa-Zomer et al., 2018a).

4.2.4 CE and Logistics

Both consumers and governmental legislation have pushed organizations to redesign their logistics networks to become more environmentally friendly while remaining cost efficient (Frota Neto et al., 2008). 'Green logistics' is recognized as producing and distributing goods in a sustainable way, taking account of environmental and social factors. This includes measuring the environmental impacts of various distribution strategies, reducing energy requirements in logistics-related activities, reducing wastages, and treatment of residual wastages (Sbihi and Eglese, 2010). While the focus has been on traditional logistics which seeks to organize forward distribution, i.e., the transport, warehousing, and inventory management from suppliers to customers, However, reverse logistics is also known to play a key role towards sustainable development (Sun, 2017).

CE is expected to have many implications for logistics management. So far, the efforts to integrate CE into logistics have mostly been observed in reverse logistics. Dhakal et al. (2016) highlighted the significant roles of secondary markets in extracting the value from products and also help to promote the reuse of products in relation to reverse logistics, CE and sustainability. Esposito et al. (2018) developed a conceptual model of a closed loop recovery system by integrating national postal service networks into reverse logistics to help to optimize CE functions. Among the quantitative works related to reverse logistics, Dente and Tavasszy (2018) introduced logistics modeling to explore the possible impacts of circular and functional economy on freight transportation and its emissions. Sun (2017) developed a measurement model to calculate carbon emissions from reverse logistics and explored factors influencing reverse logistics carbon footprints. Bernon et al. (2018) made an attempt to embed CE values in consumer retail reverse logistics operations.

4.2.5 CE & Consumption

The CE philosophy has stimulated a shift towards a more sustainable consumption model in which valuable resources are reused and less waste is created (EMF, 2013). Consumption in the CE context and circular solutions is becoming an area of increased scholarly attention with particular interests in exploring drivers, barriers, the nature, meaning, and dynamics of circular consumption (Camacho-Otero et al., 2018). It is gaining traction in the global mobile phone market as a solution to increasing resource use (Wieser and Tröger, 2016). Canning (2006) studied electronic waste collection schemes in mobile phone supply chains in the UK. He suggested that consumers must cooperate to return unwanted phones and be willing to accept refurbished ones for the collection schemes to be effective. van Weelden et al. (2016) examined the main factors that influence consumers to accept refurbished mobile phones in Germany. They found that refurbished products are often rejected by consumers due to their lack of awareness of what the term actually entails. Wieser and Tröger (2016) studied consumers' motivations regarding mobile phones consumption in Austria using dimensions such as the timing of replacement, repair, and reuse of mobile phones. They found consumers' perceptions of obsolescence as a central consideration of mobile phone replacement, repair, and reuse. The findings of these three studies agreed with each other: the transition toward CE requires changes in consumer behaviors and they may be achieved by an awareness campaign and sustainability education. The product design function must be changed, however, to make it more optimal. For example, a Dutch company has now designed and is producing a totally repairable mobile phone. That will change consumer's attitudes dramatically or at least it should or might.

Jurgilevich et al. (2016) applied the CE philosophy in the sustainable food system in Finland for a transition towards a circular food system. They discussed challenges and potential solutions for circular production and consumption. Wang and Hazen (2016) studied the automobile industry in China. They found that information on cost, quality, and green attributes of remanufactured products affects consumers' perception of risk and value, which consequently influences consumers' purchase intentions of remanufactured products. Castellani et al. (2015) presented a case study of a second-hand goods shop and quantified the environmental benefits of reusing goods in terms of avoided impacts using life cycle assessment. They found a potential for significant avoided impacts by adopting sustainable consumption approaches (e.g., reuse) in many sectors including apparel, furniture, etc.

Overall, there is greater need to design appropriate policy and firm-level measures to enhance the awareness about circular consumption, noting that cultural differences play a significant role in framing consumer attitude towards circularity and nature in general (Gaur et al., 2018; Lakatos et al., 2018).

4.2.6 CE & EoL and Waste Management

EoL and waste management in CSCM is considered critically important for recovering the remaining value within a product to its maximum utility (Cong, Liang et al., 2017). Recirculation of used components and materials has significant economic and environmental performance implications (van Loon and Van Wassenhove, 2017). However, there is a lack of understanding of the true potentials of EoL management for CE in many business sectors

(Parajuly and Wenzel, 2017). In the extant literature, various EoL resource recovery approaches are discussed. These include: repurposing/recontextualizing, refurbishing, remanufacturing and recycling.

Repurposing has been described as the identification of a new use for a product that can no longer be used in its original form (Long et al., 2016). den Hollander et al. (2017) introduced a new term *recontextualizing* (replacing repurposing) for the use of an obsolete product or its components without any remedial actions in a different context than its originally designed use. In a CE context, a recent feasibility study based on a sample of 246 notebook computers found that 9% of the EoL notebooks could be repurposed as thin computers without incurring any cost (Coughlan et al., 2018).

Refurbishing is a process to restore used products to a functional and satisfactory condition, without dismantling the products completely (Rathore et al., 2011). Refurbishing can be applied to regain value from used products and to reduce waste. An efficient refurbishing process enables easy maintenance, recovery, and modification of products after the EoL cycle (van Weelden et al., 2016). However, there is a need to develop refurbishing guidelines and standards because the lack of them has led to variations in production, quality issues, and poor recognition of products (Sharma et al., 2016).

Remanufacturing recovers the residual value of used products by bringing them to a new-like condition (Debo et al., 2005). Typically, remanufacturing is preferred to other EoL processes because the remanufactured product is more environmentally friendly, higher in quality, and has a longer extended life (King et al., 2006; Hartwell and Marco, 2016). However, ambiguity surrounding the true meaning of other related CE activities such as: repair, reconditioning, refurbishment and uncertainty in managing intellectual property (IP) issues in many industries inhibit organizations from adopting a remanufacturing strategy (Hartwell and Marco, 2016). On the other hand, lack of consumer acceptance of remanufactured products throughout the world prevents supply chains from unlocking the full potential of remanufacturing (Hazen et al., 2017; Wang and Kuah, 2018). The diversity of product types, design features, and material compositions also pose serious policy and practical challenges (Zhang et al., 2011; Cong, L. et al., 2017a).

Various authors have suggested different strategies and ways to handle and optimize remanufacturing operations in a CE context. For example, Krystofik et al. (2018) introduced a term adaptive remanufacturing to suggest the use of an EoL product core to create a similar but non-identical product thus, enabling more viable lifecycles when compared to traditional remanufacturing. Zhang and Chen (2015) emphasized the adoption of more energy efficient and cleaner remanufacturing strategies. Jiang et al. (2016) used mathematical models to select an optimal remanufacturing process planning solution for the new arrival of used parts by utilizing the knowledge generated from remanufacturing of existing parts. Others have developed simulations for predicting the performance of remanufacturing systems operating under uncertainties (Low and Ng, 2018) and various production control policies (Gaspari et al., 2017).

Our literature search also identified several examples of CE inspired *recycling* practices in different industries. The steel industry is regarded as an integral part of the CE model. Given the recyclable nature of the material itself, steel scrap is an important resource for steelmaking which can be recovered from products (Wübbeke and Heroth, 2014; Broadbent, 2016; Diener and Tillman, 2016). Despite having huge potential for increased profits, the literature highlights several barriers ranging from economic, policy, information, and technology-related barriers in recycling value chains, which prevent firms recycling and reusing metals (Wübbeke and Heroth, 2014; Golev and Corder, 2016; Densley Tingley et al., 2017). On the other hand, better regulations and effective use of taxation, encouraging R&D in metals, establishment of extended producer responsibilities systems (Mo et al., 2009; Gumley, 2014) and use of robust forecasting models (Gauffin et al., 2016) were discussed as the possible remedies to the lack of metal recycling. In the construction industry, Jiménez-Rivero and García-Navarro (2016); (2017) developed performance indicators and presented best practices for the management of EoL gypsum under the framework of the European collaborative project GtoG (Gypsum to Gypsum) (Marlet, 2014). Tires and agricultural plastic waste recycling are other examples where pyrolysis technique has been successfully applied (Antoniou and Zabaniotou, 2015; Rentizelas et al., 2018). Recycling systems for post-consumer plastic packaging have huge potential to positively contribute towards circularity (Brouwer et al., 2018; Hahladakis et al., 2018).

Moreover, understanding the links between economic activities and waste generation is critically important to help achieve CE goals (Salemdeeb et al., 2016). Integrating CE into EoL & waste management faces some practical challenges. Prevalent EoL materials management is concerned with collecting waste for material recovery (Singh and Ordoñez, 2016). However, to support other EoL processes, for example, reuse, the collection systems need to be improved to prevent physical damages to the EoL products during the collection process. Cobo et al. (2018) describe such a system as a circular integrated waste management system (CIWMS) that enhances the circularity of resources by strengthening the link between waste treatment and resource recovery. This is especially important in the case of waste electric and electronic (WEEE) products because they are often vulnerable to damage and the recovery or reuse of critical metals as a secondary supply source offers both economic and environmental benefits (Parajuly and Wenzel, 2017; Işıldar et al., 2018). With regard to minimizing transport emissions, mobile collection methods are found to be the lowest impact and a low total cost solution when compared with stationary collection methods (Nowakowski and Mrówczyńska, 2018).

Appropriate treatment of EoL products (particularly WEEE) has been a popular item on regulators' agendas (Atalay and Ravi, 2012). Many countries have adopted product take-back schemes based on the concept of extended producer responsibility (EPR) where producers are physically or financially responsible for the collection of EoL electronics and their recovery so as to divert hazardous materials away from landfills (Manomaivibool and Hong, 2014; Botelho et al., 2016; Favot et al., 2016; Polzer et al., 2016; Gu et al., 2017). Optimizing EPR schemes help to promote collection and recycling of both hazardous and critical materials by closing material loops and also incentivize eco-design (Richter and Koppejan, 2016).

4.3 CE & Supporting business Models

The inability of prevalent linear economic models to manage the current sustainability issues has led to the development of new business models based on CE philosophy (Gorissen et al., 2016; Goyal et al., 2018). Nußholz (2017) defined circular business model (CBM) as *"how a company creates, captures, and delivers value with the value creation logic designed to improve resource efficiency through contributing to extending useful life of products and parts (e.g., through long-life design, repair and remanufacturing) and closing material loops"* (p.12). Linder and Williander (2017) further described the conceptual logic of creation logic in CBM as *"utilizing the economic value retained in products after use in the production of new offerings"* (p. 2).

Several researchers have contributed to the development of CBMs. Roos (2014) outlined the process of CBM development and proposed specific questions for creating an appropriate business model for a circular value chain. Lüdeke-Freund et al. (2018) performed a morphological analysis of 26 CBMs from literature to be able to identify a broad range of business model design options and proposed six major CBM patterns of closing resource loops. Bocken et al. (2017); Bocken et al. (2018) provide in-depth insights on how established businesses might pursue business model experimentation for sustainability and circularity goals.

Various business model frameworks have also been proposed in the extant literature. Lewandowski (2016) modified the traditional business model canvas and further included take-back systems and adoption factors to develop an extended framework for designing business models for CE. Mendoza et al. (2017) proposed a novel, 'backcasting and eco-design for the circular economy' (BECE) framework aimed at helping companies to develop sustainable business models that translate CE principles into industrial practices. The BECE framework has proven equally successfully in a product as well as service-oriented business applications (Heyes et al., 2018). Urbinati et al. (2017) proposed a taxonomy of CE business models to distinguish how some companies have implemented cost efficiency improvements in their adoption of CE. Their CE business model canvas framework introduced adoption of circularity along two dimensions: customer value proposition & interface (value proposition to customers) and value network (interaction with suppliers and restructuring internal activities). Recently, an environmental value propositions table (EVPT) and a step-by-step evaluation approach of CE business models were developed by Manninen et al. (2018).

van Loon et al. (2017) provide an empirical evidence of the total cost of ownership for consumers and profitability for manufacturers in CBMs. Their study results provide interesting insights for firms wanting to make a transition from selling to leasing products in the presence of an effective second-hand market structure. However, it is important to note that moving from ownership to services (for example leasing) does not automatically contribute to environmental rents unless consumption patterns change accordingly (Junnila et al., 2018). For example, access-based services for cars are more successful when compared to smartphones where such models have largely failed (Hobson et al., 2018; Poppelaars et al., 2018). Lieder et al. (2018) present another example of customer preferences and acceptance of circular business model (pay per use washing machines) in Sweden.

In addition, many studies have identified and discussed the role of various drivers/enablers (Rizos et al., 2016; Mativenga et al., 2017; Veleva and Bodkin, 2017) as important factors for successful implementation of CBMs while others have identified barriers (Rizos et al., 2016; Linder and Williander, 2017; Spring and Araujo, 2017; Oghazi and Mostaghel, 2018; Singh and Giacosa, 2018; Sousa-Zomer et al., 2018b; Whalen et al., 2018) hindering the implementation of CBMs.

Product-Service Systems (PSS) represent a hybrid class of business model for CE (Vasantha et al., 2015). A PSS *"consists of tangible products and intangible services designed and combined so that they are jointly capable of fulfilling specific needs of customers"* (Tukker, 2015, p. 81). The PSSs exemplify a range of business models from being 'product orientated with a few extra services included' to more 'result-oriented' services with no predetermined product involved (Hobson, 2016; Yang et al., 2018). Pialot et al. (2017) further expanded the scope of PSS by proposing "Upgradable Product Service System (Up-PSS)". Up-PSS combines the upgradability concept with optimized maintenance, EoL management and the servitization of the offer. Product upgradability in a PSS context is further Khan et al. (2018) explained in the review paper. However, According to Kjaer et al. (2018) PSS does not automatically lead to achieving CE's vision of resource decoupling, i.e. decoupling economic growth from resource consumption. It only happens when there is a decrease in resource usage irrespective of the growth rate of the economic driver.

Overall, CBMs including PSSs promise significant cost savings and radical reductions in environmental impacts (Linder and Williander, 2017) in addition to improved entrepreneurial opportunities for services connected to products involving both forward and reverse supply chains (Spring and Araujo, 2017).

4.4 CE & Role of Technology/ Role of Technology in fostering CSCM

A comprehensive understanding of how innovative and emerging technologies can support the transition towards CSCM is crucial. Yet, the research in this critical area is at infancy. Industry 4.0 term is used for the fourth industrial revolution that is enabled by smart technologies such as the Internet of Things (IoT), augmented reality, 3D printing (additive manufacturing), big data analytics, cloud computing, simulation, industrial automation and cybersecurity (Nascimento et al., 2018). Although, research concerning the integration of Industry 4.0 technologies into CSCM is in its early stages but there is already some clear evidence showing a promising future in line with achieving CE vision (Lopes de Sousa Jabbour et al., 2018).

In the last few years, WEEE has become a serious environmental issue given the rate of technological change and the throwaway culture in most consumer societies. Cong, L. et al. (2017b) claimed that most of the value recovery from EoL products (e.g., WEEE) is being carried out without rational planning, which results in a loss of recoverable value embedded in EoL materials and components. Esmaeilian et al. (2018) proposed an IoT enabled waste management (WEEE) framework for smart and zero waste sustainable cities while connecting waste management to the whole product life cycle. Their proposed framework is based on four interrelated strategies such as waste prevention, upstream waste separation, on-time waste collection, and proper value recovery of collected waste. In order to optimize the WEEE recycling process, Alvarez-de-los-Mozos and Renteria (2017) proposed the introduction of collaborative robots into the recycling lines to work in collaboration with humans in enhancing the recovery of valuable components and materials.

Giurco et al. (2014) discussed future trends in 3D printing and its possible application in CE. However, the entire discussion relied on conceptual scenarios given the lack of supporting business cases. While 3D printing offers substantial promise for CE but there are significant barriers in its way (Garmulewicz et al., 2018). Limited knowledge on the extent to which 3D printing affects the sustainability and circularity premises leaves more questions than answers (Despeisse et al., 2017). Zhong and Pearce (2018) present an interesting case of 3D printing application in a CE context. They upscaled the plastic waste from computer waste into 3D printing filament and produced valuable consumer products such as camera tripod, SD card holder and camera hood. The study results show significant economic and environmental benefits by tightening the CE loop.

Another stream of research relates to the roles of big data in CSCM. A recent paper documented a significant impact of big data and predictive analytics on the supply chain sustainability performance (Dubey et al., 2017b). However, our review identified only one study related to the application of big data in CE. Jabbour et al. (2017) in their research proposed a framework of CE and large-scale data (big data) in CE. They presented a relational matrix illustrating the complexities of CE, big data and stakeholder management in CE. They developed several propositions to advance the literature in this emerging field.

5. Future Research Directions

The review presented above showed that CSCM is still an emerging research field. Most relevant publications are conceptual works and case studies, which is typical for a research field that is still at its infancy. A few specific research topics in CSCM, including supply chain performance and EoL product management, have received relatively more attention. Nevertheless, much more research work must be done on all supply chain functions in order to reap the full potential of CSCM. There are many technical, process, and incentive issues to overcome for making CE a reality. We, therefore, call for research in the following directions that are important to CSCM but have received very little or no attention. Based on the review results, Table 5 outlines the importance of each research direction, the extent of relevant knowledge gap, potential impact of conducting research in the research direction, and the urgency for further research. Given that CE is a promising new frontier in sustainable thinking, we believe that advancing CSCM in the following areas will substantially enhance SSCM and GSCM to aid organizations to achieve a higher level of sustainability performance.

Table 5: Summary of future research directions in CSCM

Future research directions	Importance	Knowledge gap	Potential impact	Urgency
Design for circularity	Very high	Very large	Critical	Very urgent
Procurement and CSCM	High	Very large	Moderate	Urgent
Biodegradable packaging for CSCM	Very high	Large	Critical	Very urgent
Circular supply chain collaboration and coordination	Very high	Large	Critical	Very urgent
Identifying drivers and barriers of CSCM	Very High	Large	Critical	Very urgent
Circular consumption	High	Large	Moderate	Urgent
Product liabilities and producer's responsibility	Very high	Very large	Critical	Very urgent
Technologies and CSCM	High	Very Large	Critical	Urgent

Design for circularity: It is clear that CSCM requires a complete rethinking of the way products, processes, and supply chains are designed (Bakker et al., 2014; Aminoff and Kettunen, 2016; Flink, 2017). Design for circularity is a cornerstone of CSCM. Ample research opportunities exist in CE driven processes innovations, supply chain design for EoL management, and new product design methods/techniques including DFD (Tian and Chen, 2014), design for remanufacturing (Ijomah et al., 2007), and design for recycling (Gaustad et al., 2010).

Procurement and CSCM: Procurement is a strategic function of many organizations, playing a vital role in a firm's sustainability performance. Surprisingly, much less research has been conducted on integrating circular thinking in procurement than in most other supply chain functions. The CSCM requires product with new or stronger features such as durability, reliability, and reusability to support life cycle extension, easy recovery of resources, and minimal wastages. More research is needed to integrate CE oriented performance indicators into procurement and supplier management (Nissinen et al., 2009) to reduce the environmental impacts of products/services throughout their life cycle (Tarantini et al., 2011).

Biodegradable packaging for CSCM: Every year, the world produces millions of tons of non-biodegradable plastics for packaging which creates severe environmental problems (Mohanty et al., 2000). For example, in China, packaging waste is the 4th largest source of pollution (Zhang and Zhao, 2012). The new, CSCM requires packaging materials to have characteristics such as availability from renewable sources, recyclability, and composability. They should also be of low cost and should possess physical and chemical properties for easy customization for diverse uses. Recently, significant progress has been made in obtaining biodegradable packaging materials such as polylactide (PLA), an aliphatic polyester (Ahmed and Varshney, 2011), and polysaccharide (SSPS) based on soluble soybean products (Tajik et al., 2013). Packaging solutions based on biodegradable materials deserve much future research and investments for enhancing the rate of transition to CEs.

Circular supply chain collaboration and coordination: In a CE, waste residuals from a process/supply chain become resources for another process/supply chain. This requires long-term collaboration not only among supply chain partners (Flink, 2017) but also among different supply chains. Many research opportunities lie in the areas of incentives and strategic value alignment (Genovese et al., 2017), collaboration and coordination mechanisms including contracts, supply chain integration, and knowledge management with suppliers, customers, and other stakeholders to keep used products/components/materials in circulation (Aminoff and Kettunen, 2016; Grimm et al., 2016; Stewart and Niero, 2018).

Drivers and barriers of CSCM: Drivers and barriers of CSCM are likely to vary in different contexts. So far, only a few studies have investigated challenges in the information technologies (IT) and electronics industries in China (Park et al., 2010), and textile (Flink, 2017) and retail industries in Finland (Aminoff and Kettunen, 2016). Investigations are urgently needed on how cultural and industrial sector-specifics contexts affect the drivers and barriers of CSCM. Furthermore, research is necessary to prioritize the drivers and barriers in a specific context in order to devise the most effective intervention policies to prevent and/or to overcome them.

Circular consumption: Despite a few early studies (Canning, 2006; Xue and Yang, 2010; Jurgilevich et al., 2016; van Weelden et al., 2016; Wang and Hazen, 2016), the consumer perspective on circular products has been largely unexplored. More research is required to explore how circular products can be made more appealing to customers. For example, marketing strategies based on demonstrating product reliability, innovative offerings, warranty, and assurance of quality control mechanisms may be developed to shape positive consumer attitudes towards circular products (Hazen et al., 2017). Given that many consumers are unwilling to return used products (van Weelden et al., 2016), it is important to study strategies and incentives for changing consumer behaviors to support the cause of circularity.

Product liabilities and producer's responsibility: The expansion of CEs will require systematic product take-back by producers to recover resources through EoL management. Therefore, EoL and waste management scenarios must address:

- Liability due to toxic substances used in production or usage of the products causing a new set of human health and environmental health consequences.
- Liability due to malfunctioning of products.

- Liability due to mismanagement of materials during the life cycle or lives cycles of substances used in the synthesis and production of products as well as in the operation of products and in the management of materials at the EOL/recycling phases.

Future research is needed to investigate the feasibility and effectiveness of an extended producer responsibility legislation (King et al., 2006; Zhu et al., 2010) to hold producers accountable for their products, even long after a sale to end customers. An alternative approach is PSS, a 'functional service' model in which the producers retain the ownership of physical products and act as service providers focusing on the service end user wants (Nasir et al., 2017). The PSS systems can be designed to help to facilitate EoL management by manufacturers. It can substantially reduce the need of production activities in a shared economy, resulting in lower environmental impacts (Tukker, 2015).

Technologies and CSCM: Technologies can be an enabler of sustainable development, but their role in CSCM has not been well researched. Recently, the Journal of Cleaner Production published a special issue titled "Improving natural resource management and human health to ensure sustainable societal development based upon insights gained from working within 'Big Data Environments'" A review of waste prevention through 3R under the concept of circular economy in China. However, none of the included papers integrated circular thinking! Ample room is left for exploring big data analytics for CSCM. Also, 3D printing, another promising technology, has become an important driving force for realizing high-efficiency and low-cost customized production. Researchers need to investigate the CE issues arising from the proliferation of product varieties and the consequent short lifecycle of customized products (Helen et al., 2016; Despeisse et al., 2017).

In addition, the internet of things (IoT) and Radio Frequency Identification (RFID) technologies can be used in CSCM to improve traceability and to enhance lifecycle information management (Zhang et al., 2010). Moreover, there is an urgent need to integrate the CE principles into an enterprises' information systems (EIS) (Jensen and Remmen, 2017).

6. Conclusions

The evolving visions and actions in planning and implementing CEs have been increasingly recognized as better alternatives than the prevalent linear (take, make, dispose) economic model. It offers much potential to help organizations achieve breakthroughs in sustainability performance. Consequently, integrating CE into SCM has received growing research interest. However, many confusions on the terms related to supply chain sustainability remain. It was argued in this study that the advancement of the field is hindered by the lack of understanding of what CSCM actually entails and which research directions are of strategic importance. In response, we provided a definition of CSCM out of the broader literature. Using this definition as a base we then conducted a structured review of the literature to gain an in-depth understanding of the current status of CSCM research. The field is promising and warrants many further studies using the CSCM conceptualization presented in this paper which covers restorative and regenerative processes, appropriate business models (closed and open loop) and supply chain functions (reorientation) to achieve a zero-waste vision. Finally, the authors suggested future research directions (summarized in Table 5) based on the importance of the research direction, current knowledge gap in the extant literature, potential impact of future research on the research direction and the level of urgency required for action and implementation. Overall, the research provided timely guidance to help researchers, practitioners, and policy-makers to understand how to operationalize CEs from a supply chain perspective to substantially enhance SSCM and GSCM.

This literature review has some limitations. We have only reviewed publications in English. There might be an important loss of knowledge for not including publications in other languages. Some relevant publications in the forms of conference papers, industry reports, books, and book chapters were cited in this research paper. However, they were not included in the structured literature review as the review methodology deliberately focused on academic journal articles to ensure the quality of the publications reviewed. The field of CSCM is developing rapidly. Therefore, it is necessary to update the literature review in a few years' time to keep up with the progress of the research field. We hope that this literature review will help to accelerate the transition to equitable, sustainable, livable, post-fossil carbon societies. We invite readers to provide feedback for further advancing this promising research field.

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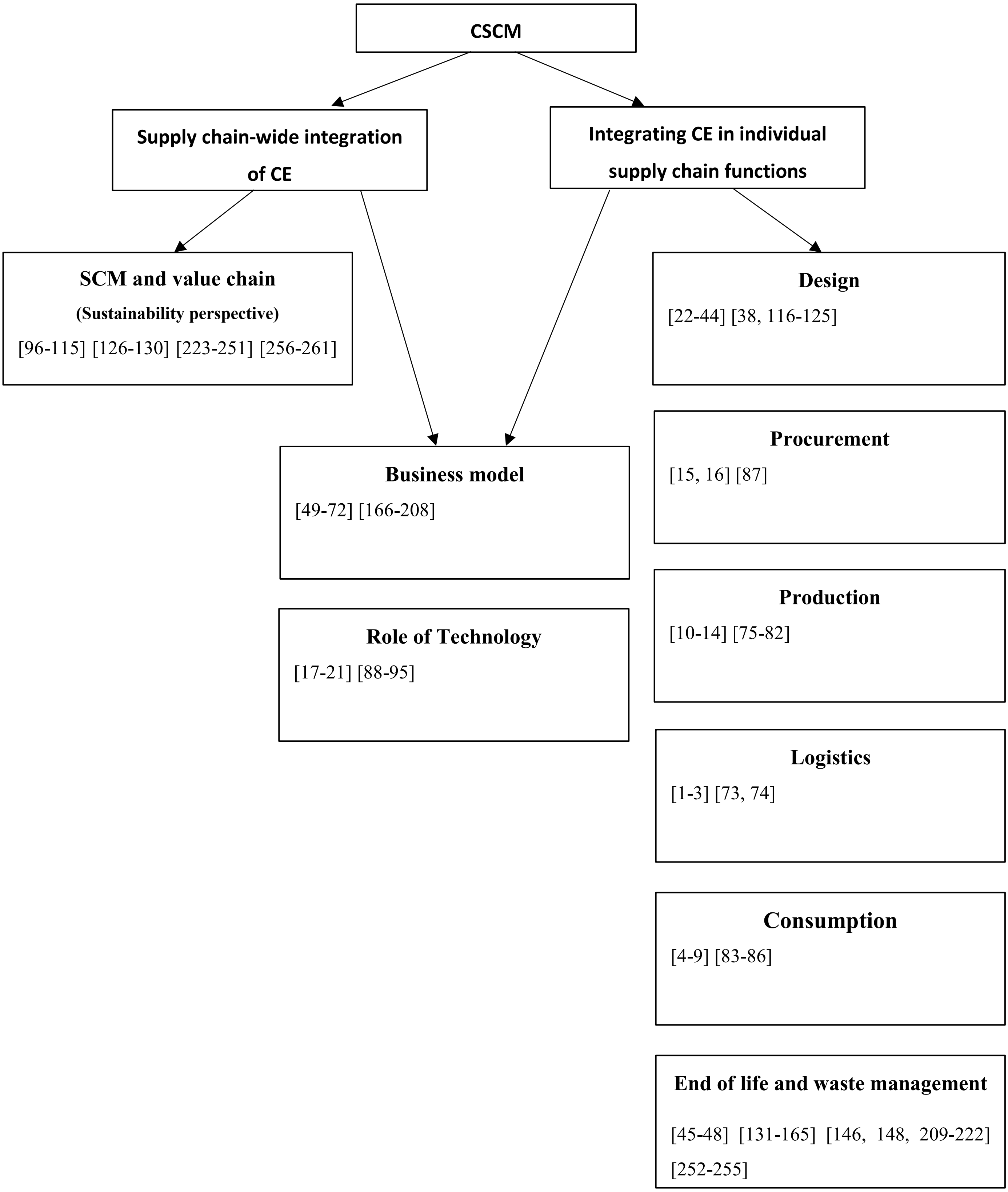
Supplementary file

Classification of literature on CSCM



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