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# Circular economy in manufacturing companies: A review of case study literature

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A B S T R A C T

Manufacturing companies have played an important role in improving standards of living worldwide. However, in a linear setting, they are also linked to unsustainable production and consumption patterns. The concept of circular economy has gained traction in recent years: it aims at eventually severing this link, through keeping resources 'in the loop'. Through a systematic literature review, this paper seeks to revisit the concept of circular economy in the manufacturing industry in order to determine whether the body of research has moved beyond concept development and into verified implementation in industry. Furthermore, we aim to analyse the important link between circular economy in manufacturing and sustainable development. The review shows that the field has indeed moved from purely conceptual work into empirical studies and research into implementation tools. However, in empirical studies, the sustainability impact of CE practices is typically adressed only through the environmental dimension, neglecting the social and economic dimensions. Further, a key finding is that the prevalence of narrow approaches to sustainability in manufacturing leads to a risk that circular economy implementation efforts will fail to provide solutions that are socially, environmentally, and economically beneficial. Holistic approaches are needed to avoid the implementation of solutions that may be framed as circular, but neglect the sustainability component.


## 1. Introduction

### 1.1. Goal and scope

Manufacturing companies, defined as companies that use machinery to produce goods from raw materials and/or components, play an important role in providing improved living standards for people; at the same time, they contribute to environmental problems. The grave environmental costs of unsustainable consumption and production patterns puts the manufacturing industry at the heart of these challenges. Sustainability has been high on the agenda ever since the 1987 Brundtland Commission introduced the concept of sustainable development as an approach to development that can fulfil the needs of the world's population today without destroying the planet's capacity to meet the needs of future generations (Brundtland, 1987). The path laid out by the Brundtland Commission's work is still relevant. The United Nations' *2030 Agenda for Sustainable Development*, with its five key areas for sustainable development (people, planet, prosperity, peace, and partnership), presents a plan of action featuring 17 sustainable development goals (SDGs), with 169 targets and 232 indicators to track progress (UN, 2015). The SDGs address many aspects of sustainable development, and all are relevant for manufacturing companies. Faced with a growing world population and increased expectations for human welfare, we need to meet the goals to avoid exceeding the planetary boundaries (i.e., find the safe operating space for humanity within Earth's system) (Rockström et al., 2009).

The Global Reporting Initiative (GRI), the United Nations Global Compact (UNGC) and the World Business Council for Sustainable

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**Table of abbreviations**

| | |
|---|---|
| 4R — | Reduce, reuse, recycle and recover |
| BM — | Business Model |
| CBM — | Circular Business Model |
| CE — | Circular Economy |
| GRI — | Global Reporting Initiative |
| LCA — | Life Cycle Assessment |
| LCC — | Life Cycle Costing |
| NGO — | Non-Governmental Organization |
| PSS — | Product-Service System |
| SDG — | Sustainable Development Goal |
| SME — | Small and Medium-sized Enterprises |
| UNGC — | United Nations Global Compact |
| WBSCD — | World Business Council for Sustainable Development |

Development (WBSCD) have jointly developed a guide for business actors on how to apply the SDGs: the SDG Compass (GRI et al., 2015). Nevertheless, how business actors (including manufacturing companies) should navigate in this field is still not entirely clear. Manufacturing companies are seeing a change in their operational environment in the direction of sustainability expectations; some manufacturers have embraced these changes. As companies respond to calls for greater sustainability, the concept of Circular Economy (CE) has gained traction. Circular Economy is about decoupling economic growth from environmental degradation (Liu et al., 2009). A transition towards a CE represents a shift away from a take-make-dispose economy and toward a regenerative economy. Schroeder et al. (2019) matched the targets for all the 17 SDGs with CE practices and found strong relationships, confirming that CE practices can be tools to achieve a considerable number of the SDGs. One of the strongest links is found between targets for Sustainable Development Goal 12 (responsible production and consumption) and CE. Target 12.5 is substantial waste reduction, through prevention, reduction, recycling, and reuse - a core aspect of CE. With focus on both the environmental and the economic dimensions of sustainability, CE as a concept is gaining momentum in the business community.

Despite the clear link between the SDGs and CE, and the common goal of more sustainable practices, the impact of CE initiatives needs to be examined (Geissdoerfer et al., 2017). A comprehensive literature review of articles examining CE as it relates to the manufacturing industry, performed by Lieder and Rashid (2016), shows that the coverage of CE is fragmented and that researchers do not yet routinely study CE implementation. Fig. 1 shows the number of hits in the peer-reviewed literature database Scopus on the search phrase 'Circular Economy' for the years 1999—2019. The figure reveals an increase in mentions of CE in published peer-reviewed literature since 2015. Beginning in 2000, the volume of published peer-reviewed literature increased overall, but the growth for CE is greater. Lieder and Rashid (2016) found that CE literature suffered from limited focus on implementation, but the body of literature on CE has grown tremendously since this review was performed. It is therefore time to review the literature with a focus on the implementation of CE in manufacturing companies.

The goal of this paper is to answer, by means of a systematic literature review, the following two research questions: (1) What is the empirical status of CE in manufacturing companies? And (2) What is the relationship between CE and sustainable development in manufacturing companies? Recent years have seen an exponential increase in published academic work related to CE, leading to a large body of published research on the subject. Since the attention in this review is on literature describing CE initiatives in manufacturing companies, the data selection for this review has two parts. First, the entire body of literature (according to the data selection criteria) is analysed descriptively to provide concept clarity, context, and an overview of the status of CE in manufacturing companies. Secondly, an in-depth thematic analysis of empirical research literature (case studies) is performed to provide insight into CE implementation in manufacturing companies.

This paper starts with the historical background of the Circular Economy concept (section 1.1). Next is a description of the method for the literature study, including process, criteria, and analysis (section 2). Third, a descriptive and thematic analysis of the cases is given (section 3), then key findings are discussed, and implications presented (section 4). Lastly, conclusions and suggestions for further research are provided (section 5).

### 1.2. Historical background on circular economy

Efforts to move toward more sustainable manufacturing processes have a long history. The powerful impact of humans on the environment was spotlighted in Rachel Carson's 1962 *Silent Spring* and in a 1972 report, commissioned by the Club of Rome, called *Limits to Growth*. In the EU, the need for sustainability was recognised in environmental policy already in 1972 (Laky, 2019). Efforts to reduce our environmental impact were initiated: for instance, cleaner production initiatives and industrial ecology in the 1990s and life cycle management initiatives in the 2000s.

Unlike other sustainability-related tools and concepts, CE originated with business and policy organisations. One of these, the Ellen MacArthur Foundation, provided the well-used definition of CE as 'an industrial economy that is restorative by intention and design' (Ellen MacArthur Foundation, 2013). The timing and the salience of economic prosperity provided the concept with momentum, and numerous initiatives have since been seen in the corporate world. Consequently, academics and scholars have embraced the concept. The CE concept is rooted in the principle, itself derived from industrial ecology, of 'closing loops' (Tibbs, 1993). Industrial ecology describes industrial ecosystems with optimized consumption of energy and materials and minimized waste generation, and where effluents from one system serves as raw materials in another (Frosch and Gallopoulos, 1989). Boulding (1966) described the open economy as a 'cowboy economy', where consumption and production is a good thing and success is measured in the amount of throughput. Boulding's preferred alternative was a 'spaceman economy': a closed system similar to CE, where throughput is something that should be minimized, and maintaining stocks is a primary goal. Despite its recent growing popularity, CE is not a new idea.

In company with many sustainability terms, 'Circular Economy' suffers from the lack of one unifying definition (Kirchherr et al., 2017). Korhonen et al. (2018) argue that CE is an *essentially contested concept*; on their view, it is a cluster concept meaning that it involves scholars from different disciplines as well as other actors and interest groups that are not united behind one common understanding of the concept. Moreover, Sauvé et al. (2016) note that in the field of CE, scientific research has lagged behind practice; they argue that differences in vocabulary between disciplines has hampered dialogue. As for the link between CE and sustainability, efforts to provide clarity have been made (Geissdoerfer et al., 2017). However, more scientific research is needed to understand how CE initiatives contribute to sustainable development along all three dimensions (economic, social, and environmental) (Sauvé et al., 2016). This paper understands the term 'circular economy' as efforts to "replace the 'end-of-life' concept with reducing,

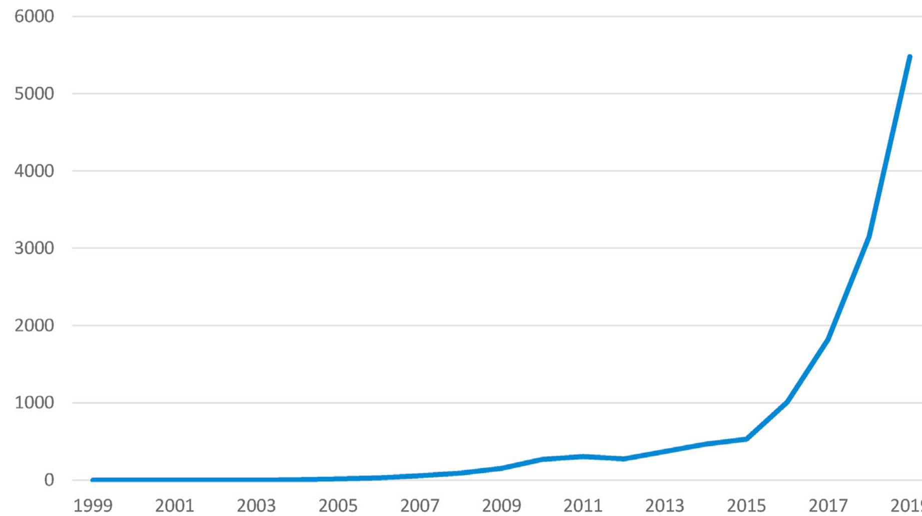


**Fig. 1.** Number of hits in Scopus on the search string 'circular economy', 1999–2019.

alternatively reusing, recycling, and recovering materials in production/distribution and consumption processes" (Kirchherr et al., 2017 pp. 229). The CE efforts should incorporate a systemic perspective (micro, meso and macro), and contribute to environmental, economic, and social sustainability (Kirchherr et al., 2017).

This definition provides a strong link between the replacement of the end-of-life concept and its contribution to sustainable development, not only in the environmental sense, but for all three pillars (environmental, social, and economic) of sustainability. It also states that CE efforts should include a systemic perspective, that is, all CE initiatives should be considered in relationship to their surroundings. CE principles can be employed on different systemic levels: macro (entire production and consumption systems), meso (sector and business type), micro (company), and nano (product) (Blomsma et al., 2019).

Progress towards CE implies efforts to improve the circulation of resources, materials, and energy, through closing, slowing, or narrowing the loops (Bocken et al., 2016). *Closing* the loops means keeping resources in loop through recycling. *Slowing* means extending use time through reuse, repair, and remanufacture. *Narrowing* is using fewer resources per product - this last approach is not circular, per se (Bocken et al., 2016). Kirchherr et al. (2017) present reducing, reusing, recycling, and recovering materials (4Rs) as strategies for replacing the end-of-life concept. These 4 R s are one of several versions of the waste hierarchy, a prioritization of strategies for dematerialisation, from waste prevention to landfill (Van Ewijk and Stegemann, 2016). Reike et al. (2018) distinguish among three separate groups of CE strategies for dematerialisation: downcycling (long loops), product upgrade (medium long loops), and the users' choices (shortest loops). Shorter loops place less stress on natural resources than longer loops. Although the waste hierarchy is the 'backbone' of CE, Van Ewijk and Stegemann (2016) point to certain limitations in terms of the concept's utility in helping us to achieve dematerialisation; these include lack of support (i.e., practices and incentives) for choosing among different CE strategies. Furthermore, for complex products, the different options are intertwined (Reike et al., 2018); indeed, there is a need to combine different strategies on different levels to reach a fruitful CE strategy. Lieder and Rashid (2016) find few strategies to support implementation; such strategies are needed to guide business models (BMs), product and supply chain design, and material selection. Recently, more attention has been given to the role of BMs in stimulating Circular Economy practices in manufacturing companies; thus, the field of circular business models (CBMs) has emerged. The circular business model is understood as a business model that creates, delivers, and captures value in line with CE principles (as defined by Kirchherr et al. (2017)). In a review of CBMs, Rosa et al. (2019) highlight product service systems (PSSs) and reuse, remanufacturing, and recycling as the most common types of CBMs.

## 2. Methods

### 2.1. Method selection: systematic literature review

This paper applied the research method of systematic literature review (Booth et al., 2016). An exhaustive search of the literature was performed, before combining narrative and tabular methods for synthesising literature (Ibid.). The literature on the field of CE is, by now, abundant. It was therefore crucial to limit the scope of the research to only literature relevant to the research questions. A systematic approach was key. The literature review was therefore performed stepwise, starting with research design. This stage included stating the main goal of the study and associated research questions. A search strategy and key criteria for inclusion and exclusion of papers was developed next. Third was the data collection step, at which database selection and the identification of appropriate keywords were central elements. This was followed by sorting and exclusion, the step where the literature base was selected according to the criteria defined in the research design step. After the sorting, literature was categorised for further analysis. All stages of the literature review are further described below.

### 2.2. Data collection, sorting and exclusion

The search was performed using the search term 'manufacturing OR production' together with 'circular economy'. Both manufacturing and production were included because these terms are used interchangeably. To identify relevant literature, a search was performed on titles, abstracts, and keywords. The search was performed in the Scopus database as initial searches in other databases revealed that Scopus covered a satisfying share of the relevant literature and produced less noise. Despite the numerous reports produced by businesses, non-governmental organisations (NGOs), and governments over the last few years, only peer-reviewed literature was included. This decision was made for two reasons: first, we wanted to analyse the state-of-the-art of CE research; second, we wished to avoid the potential problem of discrepancies appearing between the motivations, focus, and results found in commissioned reports and those found in scientific research. Non-scientific sources such as NGOs and business or policy organisations might be prone to present success stories, rather than implementation failures (though, admittedly, this is also a phenomenon in scientific literature [Diaz Lopez et al., 2019]). Only literature in English published between 1999 and 2019 (inclusive) was included.

Sorting and exclusion involves a quality assessment: checking validity, reliability, applicability, and relevance (Booth et al., 2016). To assess quality, an iterative process was chosen (see Fig. 2). First an initial screening of the literature based on article title was performed, dividing the literature into three categories. Articles judged not relevant were coded red, and those that were deemed relevant were coded green. A large share of the literature could not be classified based on title alone; these articles were coded yellow. The second iteration involved reading the abstract for all yellow and green articles, thereby eliminating irrelevant literature.

A systematic literature review requires explicit inclusion and exclusion criteria (Kitchenham, 2004). The criteria used are listed in Table 1. Some articles were also included through snowballing techniques. The reference lists in included articles were scanned for new sources, adding relevant articles to the literature base. The total number of articles assessed was 80; a list can be found in the Appendix.

### 2.3. Descriptive and thematic analysis

The analysis of the literature was divided into two parts: (1) descriptive analysis and (2) thematic analysis (Fig. 3). The goal of the descriptive analysis was to reveal patterns in the data regarding publication year, journals represented, and research method applied.

The focus of this review was implementation of CE in manufacturing companies. Because case studies are well-suited for testing frameworks and investigating how and why (Yin, 2017), they were selected for a deeper thematic analysis. Twenty-nine articles fell into the category of case study, based on the authors' own description of their research methods. Articles that contained several applied research methods were also included in this group. The 29 articles were classified according to themes and constructs aligned with the research questions of the paper: investigating the research literature on CE in the manufacturing sector and examining the relationship between CE and sustainable development in manufacturing companies. This was a two-stage process in which the articles were first analysed in terms of predefined topics (part A of Table 2). Predefined topics were selected based on the definition of CE provided by Kirchherr et al. (2017). The need for part B emerged during the first part of the analysis, at which time it became evident that some topics were more salient than others. To get a full picture of the activities in manufacturing companies relating to CE, the analysis was expanded to part B (Table 2).

## 3. Results and discussion

### 3.1. Patterns in research literature

To illustrate the growth over time in the literature, articles were categorised based on publication year (Fig. 4). With the review by Lieder and Rashid (2016) in mind, it was noted that for this review, all articles but 4 were published after 2016. Moreover, more than 70% were published after 2018. This was in line with the increased popularity of the concept (shown in Fig. 1), as well as with the overall increase in published literature.

Fig. 5 shows that the largest number of articles on CE in manufacturing were in the *Journal of Cleaner Production* (the first article published in 2016), with *Sustainability* as a clear second. *Resources, Conservation, and Recycling* and *CIRP Procedia* also contributed a significant number of articles. Moreover, the figure illustrates the range of journals publishing on CE in manufacturing ('others' in the figure). All journals contributing 1 or 2 articles to the review were assigned to 'others' (for a complete list see the Appendix).

The distribution in journals showed a rather broad dissemination. This was in line with Korhonen et al. (2018), to wit: CE is a broad concept involving scholars from different disciplines as well

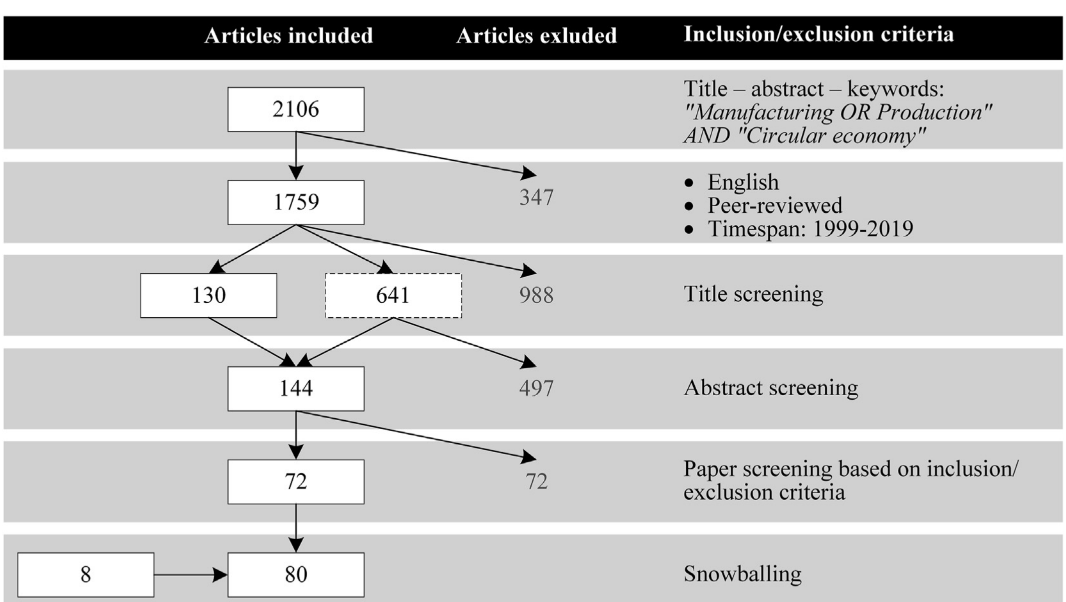


**Fig. 2.** Schematic overview of the sorting and exclusion procedure used to assess the relevance of the literature obtained in the data collection step.

**Table 1**
Inclusion/exclusion criteria used for paper screening.

| Inclusion criteria | Exclusion criteria |
|---|---|
| Production/manufacturing of parts, goods, products (discrete manufacturing) | Process/mining industry, bio/agri/food industry, energy (process manufacturing) |
| Consist of one or several key CE elements (efforts aimed at reducing, reusing, recycling, and/or recovering of materials) | Waste management |

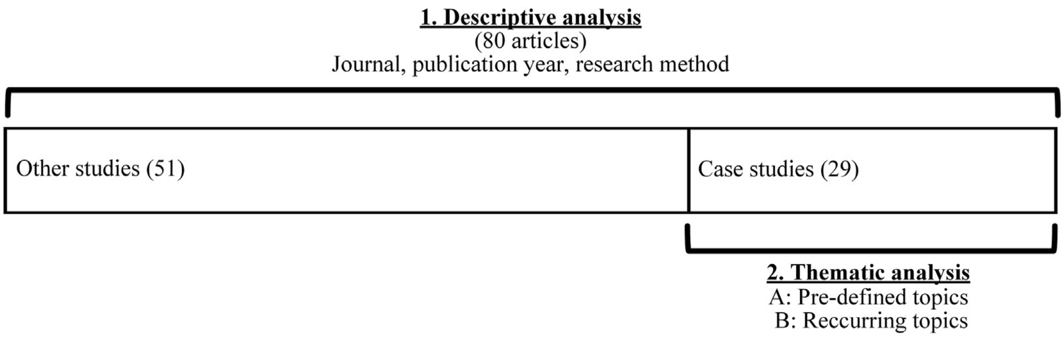


**Fig. 3.** Overview of the descriptive and thematic analyses.

**Table 2**
Description of the thematic analysis of the case study literature.

| Relates to RQ | Topic | Keywords | Content |
|---|---|---|---|
| Thematic analysis part A (pre-defined topics) | | | |
| RQ1 | Closing the loop | Resource consumption, end-of-life, closed-loop, R's, waste hierarchy | What are the efforts towards circulating materials, energy, waste in the case study?<br>Which parts of the waste hierarchy are in focus? |
| RQ1 | Use/user | Use, user, consumer, customer, consumption | How is the use stage of products and user/consumer behaviour addressed? |
| RQ1+2 | Measurement | Measure, measurement, indicator(s) | Is progress towards CE addressed?<br>Qualitative/quantitative<br>Are indicators used/suggested? |
| RQ1+2 | Sustainability | Environmental, social, economic, sustainability, sustainable, sustainable development | What is the connection (clearly expressed/implicit/not expressed) to sustainable development?<br>Is social, environmental, and economic sustainability addressed? |
| Thematic analysis part B (recurring topics) | | | |
| RQ1 | CBM | Circular business models (CBMs), sustainable business models, business models, strategy | Are new business model(s) proposed?<br>What type(s) of CBM are proposed? |
| RQ1 | Collaboration | Value chain, stakeholders, communication, collaboration | Are stakeholders addressed?<br>How are value chain/suppliers discussed?<br>Is communication addressed? |
| RQ1 | Barriers | Barriers, drivers, success criteria | What are barriers for CE?<br>How can barriers be categorised?<br>How can barriers be overcome?<br>What are drivers? |

as other actors and interest groups. The range of research methods was similarly broad. Fig. 6 shows articles classified by research method; analysis uncovered five main categories: case studies, literature reviews, surveys (questionnaire-based and interviews), assessment of quantitative data (variations of secondary data assessment), and concept design. Additionally, some articles employed a mix of research methods. The case study was the dominant research method, indicating that the empirical literature base has grown since the review by Lieder and Rashid (2016) was published. The literature review was the second-most frequently used research method. This is perhaps both a response to and a consequence of the lack of a unified understanding of the CE concept. Both surveys and quantitative data assessment appeared to be commonly applied research methods for CE. These categories included articles presenting research based on data collection (ranging from large industry surveys to interviews with representatives from a few manufacturing companies). A significant share of the literature consisted of articles based on proposed concept/framework design.

Literature reviews covered a range of topics, including CE and consumption (Camacho-Otero et al., 2018), CBMs (de Sousa Jabbour et al., 2019; Upadhyay et al., 2019; Urbinati et al., 2017; Whalen, 2019), product service systems (PSS) (Camilleri, 2019; Kühl et al., 2018), supply chain management (De Angelis et al., 2018; Genovese et al., 2017), indicators (Kristensen and Mosgaard, 2019), small and medium-sized enterprises (SMEs) (Thorley et al., 2019) and drivers and barriers (Govindan and Hasanagic, 2018). Circular Economy transition and history (Winans et al., 2017; Ghisellini et al., 2016; Reike et al., 2018), the link between industrial ecology and CE (Bruel et al., 2019), and CE implementation (Kalmykova

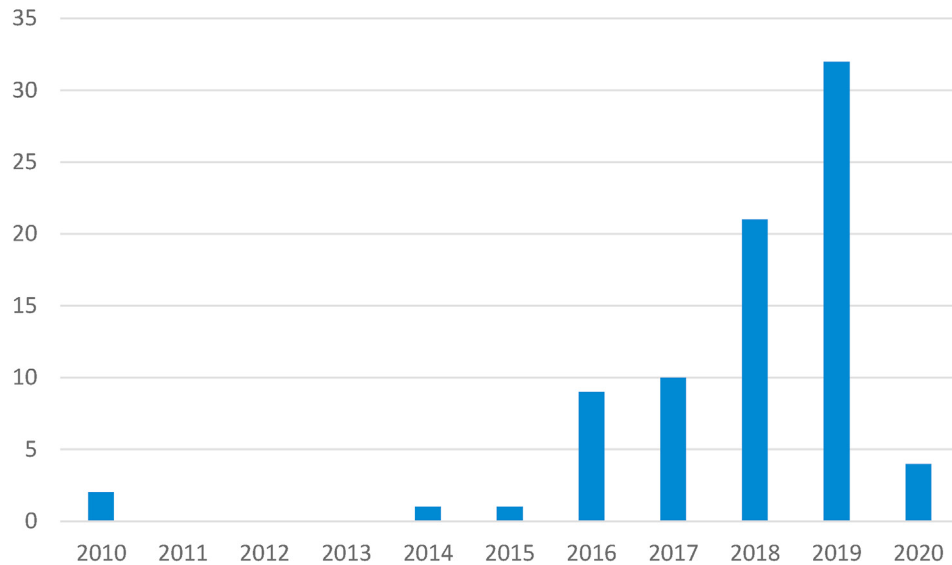


**Fig. 4.** Distribution of the reviewed literature, 2010–2019.

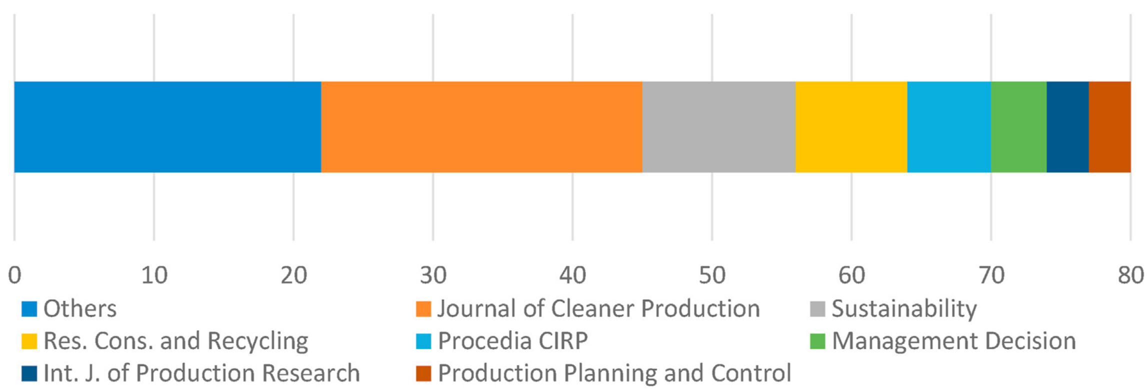


**Fig. 5.** Distribution of the reviewed literature among scientific journals. Journals/proceedings with 1 or 2 contributions is assigned to 'others'.

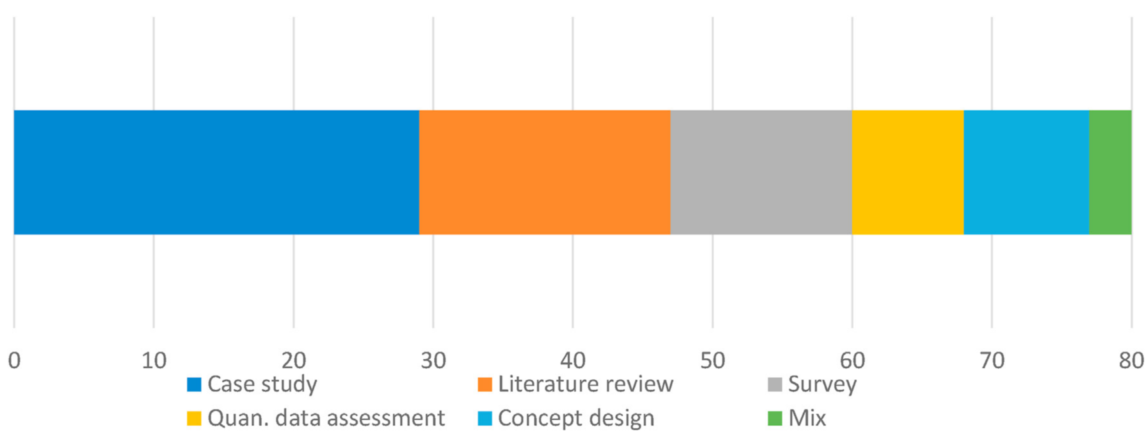


**Fig. 6.** Categorisation of the reviewed literature based on research Methodology.

et al., 2018; Lieder and Rashid, 2016) were also adressed.

Survey literature ranged from addressing CE practices in SMEs (Bassi and Dias, 2019; Mura et al., 2020), drivers and barriers (Agyemang et al., 2019; Garcés-Ayerbe et al., 2019; Gusmerotti et al., 2019; Kumar et al., 2019), attitudes toward and awareness of CE (Lakatos et al., 2018; Liu and Bai, 2014; Masi et al., 2018), innovation capabilities and CE (Jakhar et al., 2019), CE readiness (Singh et al., 2018), BMs for sustainable consumption in CE (Tunn et al., 2019) and supply chain management (Zhu et al., 2010). For the articles performing quantitative assessments of data, the themes were drivers and barriers (Dominish et al., 2018; Moktadir et al., 2018; Rizos et al., 2016), servitisation (Doni et al., 2019), CE approaches and practices (Singh et al., 2019; Yang et al., 2019; Ünal and Shao, 2019), and cyclic manufacturing (Tsiliyannis, 2016).

The literature on concept design yielded the themes of indexing (Azevedo et al., 2017; Ferreira et al., 2019), performance evaluation (Chen et al., 2010), and the user perspective (Selvefors et al., 2019). Some articles applied concept design for CE-enabling strategies such as product stewardship (Jensen and Remmen, 2017), CE transformation frameworks (Laumann and Tambo, 2018; Lieder et al., 2017; Muranko et al., 2018) and innovation tools (Verstraeten-Jochemsen et al., 2018). Some articles employed a mix of methods (or none). Morone and Navia (2016) discussed new consumption and production models. Prieto-Sandoval et al. (2019) presented key strategies and capabilites for implementing CE in SMEs, and Cerdas et al. (2015) discussed circulation factories.

### 3.2. Insights from the case studies

The 29 articles based on case studies were selected for a thematic analysis. Twenty of these were based on multiple case studies, in which data was collected from two or more companies; the remaining nine were single case studies. Thirteen articles proposed a framework or approach for implementing CE. All articles in this category were published after 2016. The thematic part of the analysis was performed as described in Table 2, based on two iterations (parts A and B). Table 3 shows how the different CE keywords were distributed in the case study literature. A score was given for each keyword: 1 (no/weak connection), 2 (mentioned, but not a core aspect), or 3 (core aspect, strong connection).

#### 3.2.1. Closing, slowing, or narrowing the loop?

The thematic analysis showed that 18 of the 29 articles described strategies for narrowing, closing, or slowing loops. Table 4 shows what loop strategies the different articles addressed based on the combination of the frameworks by Bocken et al. (2016) and Reike et al. (2018).

Braun et al. (2018) and Shahbazi et al. (2016) focused on narrowing loops through material efficiency improvement. In a single case study Braun et al. (2018) focused on improved material efficiency within the facility and in the supply chain to increase circularity. Shahbazi et al. (2016) investigated the potential for improved material efficiency in Swedish manufacturers and the barriers that hinder optimisation of material efficiency. The focus was on the lower parts of the waste hierarchy, recycling, and in-house efficiency measures. The study highlighted a lack of material efficiency strategy implementation, and potential for further improvement of the material efficiency in the targeted manufacturing companies. One strategy for closing the loop and fostering inter-organisational CE development that emerged from case studies is the use of eco-industrial parks or industrial symbiosis (Prosman et al., 2017; Ruggieri et al., 2016). Prosman et al. (2017) explored a case with a cement manufacturer engaging in long-distance industrial symbiosis. Prosman et al. (2017) proposed internal coordination to cope with regulatory and legal challenges as well as communication and transparency issues.

Strategies for slowing the loops were investigated by Pialot et al. (2017) in a study of two manufacturers. For both companies, upgradeability and optimized maintenance was deemed a promising transition route from a material goods-oriented to a more service-oriented business model. Using two case studies, Brissaud and Zwolinski (2017) highlighted the scientific challenges (on the production, strategy, and product levels) associated with upgrading and repurposing components for more sustainable production and consumption. Pieroni et al. (2019) explored the implementation of product-service systems (PSS) in two Norwegian manufacturing companies. From these two cases, three conditions were identified as needing to be met in order for PSSs to contribute to CE (superior customer value, economic growth, and resource decoupling potential). Pieroni et al. (2019) showed that CE solutions are often specific in terms of customer segments. Kaddoura et al. (2019) explored the environmental and economic consequences of implementing a PSS for five product cases.

Most articles covered several CE strategies. The circular strategies scanner, a support tool for CE innovation developed by Blomsma et al. (2019), included strategies for the entire waste hierarchy - from rethink, to recirculate parts and products, to recirculate materials. Jørgensen and Remmen (2018) presented a three-step approach for implementing a CE strategy for businesses, including an environmental organisational mapping with a life cycle perspective, an analysis of the potentials and barriers relating to CE, and lastly an assessment of the environmental impacts of the changes. Jørgensen and Remmen (2018) also covered strategies for maintaining products, reusing, refurbishing, remanufacturing, and recycling. Jawahir and Bradley (2016) introduced a 6R-based framework (reduce, recover, reuse, recycle, redesign, remanufacture) identifying the technological factors key to developing a CE. Jawahir and Bradley (2016) did not provide experiences from a case study, but the framework covered short, medium, and long loops. Parida et al. (2019) presented a two-stage framework for supporting transformation to CE, arguing that manufacturing companies, as a part of an ecosystem, should take a leading role in promoting CE in that ecosystem. The first stage of the framework was an ecosystem readiness assessment, while the second stage offered mechanisms for orchestrating the ecosystem. Analysing the implementation of different resource efficiency measures in 143 cases, Diaz Lopez et al. (2019) connected the different resource efficiency measures with implementation barriers and required BM changes. Moreover, the roles of stakeholders and certifications in enabling CE were investigated by Poponi et al. (2019). Tecchio et al. (2017) provided a framework for product policies connecting CE efforts (reduce the embodied impacts of products, prolong lifetime, reduce waste, increase material efficiency) to product life cycle stages, supporting an expansion of product policies to include more aspects of CE.

#### 3.2.2. Circular business models for manufacturing companies

Of the 29 articles included, 19 refer to CBMs; 3 additional articles had a weaker connection to CBMs. CBMs can serve to enable CE progress for manufacturing companies (Frishammar and Parida, 2019; Guldmann and Huulgaard, 2020; Lieder and Rashid, 2016; Sousa-Zomer et al., 2018) by targeting and organising the efforts made to reach CE goals. Through implementing a CBM, a fair distribution of the benefits and disadvantages of CE efforts can be secured (Braun et al., 2018). Kristensen and Remmen (2019) provided a framework for mapping sustainable value propositions for CBMs. The framework was designed to aid companies in assessing potentials and pitfalls within BMs, and to understand and map value in a broader context than that of the traditional economy. Moreno et al. (2019) explored the role of digitalisation - to support CBMs, to track assets for reuse and take-back plans, to understand wear and tear, to select appropriate recycling technology, and to communicate with users.

The product service system (PSS) was one of the CBMs discussed frequently in the articles included in this study. PSSs can act as enablers for the development of more circular supply chains (Yang et al., 2018). Kaddoura et al. (2019) found that a PSS for prolonged lifetime through repair and refurbishment can be a financially attractive route to CE for manufacturing companies. PSS was found by Vermunt et al. (2019) to be the type of CBM that encounters the

**Table 3**
Overview of the thematic analysis of case study literature.

| Title of article | Author | Closing the loop | Measurement | CBM | Collaboration | Barriers | Use/user | Sustainability | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Economic | Social | Environ-mental |
| Developing a circular strategies framework for manufacturing companies to support circular economy-oriented innovation | Blomsma et al. | 3 | 1 | 2 | 3 | 1 | 1 | 1 | 1 | 1 |
| Case study analysing potentials to improve material efficiency in manufacturing supply chains, considering circular economy aspects | Braun et al. | 3 | 3 | 3 | 3 | 1 | 1 | 3 | 1 | 3 |
| The scientific challenges for a sustainable consumption and production scenario: The circular reuse of materials for the upgrading and repurposing of components | Brissaud and Zwolinski | 3 | 1 | 1 | 1 | 3 | 3 | 1 | 3 | 3 |
| Paradoxical tensions and corporate sustainability: A focus on circular economy business cases | Daddi et al. | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| Business model innovation for resource-efficiency, circularity and cleaner production: What 143 cases tell us | Diaz Lopez et al. | 3 | 3 | 3 | 3 | 3 | 3 | 3 | 1 | 3 |
| Circular business model transformation: A roadmap for incumbent firms | Frishammar et al. | 1 | 1 | 3 | 3 | 3 | 3 | 3 | 3 | 3 |
| A circularity measurement toolkit for manufacturing SMEs | Garza-Reyes et al. | 1 | 3 | 1 | 1 | 1 | 1 | 2 | 1 | 2 |
| Barriers to circular business model innovation: A multiple-case study | Guldmann and Huulgaard | 1 | 1 | 3 | 3 | 3 | 3 | 1 | 1 | 3 |
| Technological elements of circular economy and the principles of 6R-based closed-loop material flow in sustainable manufacturing | Jawahir and Bradley | 3 | 3 | 1 | 1 | 1 | 1 | 3 | 2 | 3 |
| A methodological approach to development of circular economy options in businesses | Jørgensen and Remmen | 3 | 1 | 3 | 1 | 3 | 3 | 1 | 1 | 2 |
| Is prolonging the lifetime of passive durable products a low-hanging fruit of a circular economy? A multiple case study | Kaddoura et al. | 3 | 3 | 3 | 2 | 2 | 1 | 3 | 1 | 3 |
| A framework for sustainable value propositions in product-service systems | Kristensen and Remmen | 1 | 1 | 3 | 3 | 3 | 2 | 3 | 3 | 3 |
| Collaboration as an enabler for circular economy: A case study of a developing country | Mishra et al. | 1 | 1 | 3 | 3 | 1 | 1 | 1 | 1 | 2 |
| Opportunities for redistributed manufacturing and digital intelligence as enablers of a circular economy | Moreno et al. | 1 | 1 | 3 | 1 | 1 | 1 | 1 | 1 | 3 |
| Orchestrating industrial ecosystem in circular economy: A two-stage transformation model for large manufacturing companies | Parida et al. | 3 | 1 | 3 | 3 | 1 | 2 | 2 | 1 | 3 |
| “Upgradable PSS”: Clarifying a new concept of sustainable consumption/production based on upgradability | Pialot et al. | 3 | 1 | 3 | 3 | 3 | 3 | 3 | 1 | 3 |
| Configuring new business models for circular economy through product-service systems | Pieroni et al. | 3 | 1 | 3 | 3 | 2 | 1 | 3 | 3 | 3 |
| The stakeholders’ perspective within the B corp certification for a circular approach | Poponi et al. | 3 | 3 | 3 | 3 | 1 | 3 | 1 | 2 | 3 |
| Closing global material loops: Initial insights into firm-level challenges | Prosman et al. | 3 | 1 | 1 | 3 | 3 | 1 | 1 | 1 | 1 |
| Circular economy indicators for organisations considering sustainability and business models: Plastic, textile and electronic cases | Rossi et al. | 3 | 3 | 3 | 3 | 1 | 3 | 3 | 3 | 3 |
| A meta-model of inter-organisational cooperation for the transition to a circular economy | Ruggieri et al. | 3 | 1 | 2 | 3 | 2 | 3 | 1 | 1 | 3 |
| Material efficiency in manufacturing: Swedish evidence on potential, barriers and strategies | Shahbazi et al. | 3 | 1 | 1 | 1 | 3 | 1 | 1 | 1 | 3 |
| Improving sustainable supply chains performance through operational excellence: Circular economy approach | Sehnem et al. | 1 | 1 | 2 | 3 | 3 | 1 | 2 | 2 | 3 |
| Exploring the challenges for circular business implementation in manufacturing companies: An empirical investigation of a pay-per-use service provider | Sousa-Zomer et al. | 1 | 1 | 3 | 3 | 3 | 3 | 1 | 2 | 3 |
| In search of standards to support circularity in product policies: A systematic approach | Tecchio et al. | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| Exploring barriers to implementing different circular business models | Vermunt et al. | 3 | 1 | 3 | 3 | 3 | 1 | 1 | 1 | 3 |
| Role of manufacturing towards achieving circular economy: The steel case | Wang et al. | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 3 |
| Transition to circular economy on firm level: Barrier identification and prioritization along the value chain | Werning and Spinler | 1 | 1 | 3 | 3 | 3 | 1 | 1 | 1 | 1 |
| Product-service systems business models for circular supply chains | Yang et al. | 1 | 1 | 3 | 3 | 1 | 2 | 1 | 1 | 3 |

most organisational and financial barriers of the CBMs investigated. Proposed measures to limit risks and overcome barriers included stakeholder partnerships and collaboration both internally and externally (Sousa-Zomer et al., 2018). A relevant concern for many manufacturing companies was fear of losing product ownership (Garza-Reyes et al., 2018). Yang et al. (2018) suggested that use-oriented and result-oriented PSSs are most suitable for circular supply chain development due to product ownership issues. In these types of PSS, the producer retains ownership of the products, and thus maintains control over the products; this creates

**Table 4**
The types of loop strategies considered by each article.

| Authors | Narrowing | Closing (long loops) | Slowing (medium loops) | Slowing (short loops) |
|---|---|---|---|---|
| Braun et al. | ■ | | | |
| Shahbazi et al. | ■ | | | |
| Prosman et al. | | ■ | | |
| Ruggieri et al. | | ■ | | |
| Pialot et al. | | | ■ | |
| Brissaud and Zwolinski | | | ■ | |
| Kaddoura et al. | | | ■ | ■ |
| Pieroni et al. | | | | ■ |
| Blomsma et al. | ■ | ■ | ■ | ■ |
| Rossi et al. | ■ | ■ | ■ | ■ |
| Jørgensen and Remmen | ■ | ■ | ■ | ■ |
| Jawahir and Bradley | ■ | ■ | ■ | ■ |
| Parida et al. | ■ | ■ | ■ | ■ |
| Diaz Lopez et al. | ■ | ■ | ■ | ■ |
| Poponi et al. | ■ | ■ | ■ | ■ |
| Tecchio et al. | ■ | ■ | ■ | ■ |
| Vermunt et al. | ■ | ■ | ■ | ■ |
| Wang et al. | ■ | ■ | ■ | ■ |

incentives to reduce environmental impacts over the total product life cycle. Pialot et al. (2017) proposed hybrid solutions designed to suit the needs of manufacturing companies that wish to avoid losing product ownership, such as the upgradability-based PSS.

Some authors proposed frameworks to guide companies through the transformation process (Frishammar and Parida, 2019), or the 'CE journey' (Jørgensen and Remmen, 2018). An investigation of the process typical of companies transitioning to a CBM showed that the process is more iterative than sequential, and more emergent than planned (Frishammar and Parida, 2019). Indeed, Frishammar and Parida (2019) pointed out that BM transition seems to be driven by imitation rather than innovation. Diaz Lopez et al. (2019) argued that resource efficiency measures involving a life cycle perspective require combinations of BM changes. Others (Frishammar and Parida, 2019) concluded that there is risk inherent in attempting to manage two parallel BMs at once, one circular and one conventional. Parida et al. (2019) strongly encouraged manufacturing companies to assess their readiness level, both internal and external, for transitioning to a CBM. This was supported by Sousa-Zomer et al. (2018), who pointed to the importance of a fit between the changes implemented to become more circular and the factors that affect these changes.

#### 3.2.3. *Measuring progress towards circular economy*

The thematic analysis of the articles showed that 7 of the 29 articles propose a way to measure progress towards CE implementation. Responding to the need to evaluate CE performance, Rossi et al. (2020) proposed CE indicators for companies and products (microlevel). The indicators were qualitative and covered all three dimensions of sustainability; the authors stressed the importance of this coverage and concluded that the indicators should be analysed as a set, not singled out individually. Further, several frameworks used resource efficiency to track and measure CE progress (Braun et al., 2018; Diaz Lopez et al., 2019; Shahbazi et al., 2016). Others (Garza-Reyes et al., 2018) provided approaches that included other CE practices, such as supplier selection, design for longevity, and end-of-life recovery of products.

Evaluating the effects of CBMs in the plastics industry, Moreno et al. (2019) found positive effects, but maintained that there is a need to further quantify the environmental effects. Frishammar and Parida (2019) argued that measuring the effects of BM changes quantitatively is difficult. Haupt and Zschokke (2017) introduced life cycle assessment (LCA), a method for quantifying environmental effects, to measure progress towards environmental sustainability. Jawahir and Bradley (2016) suggested an assessment that integrates all three pillars of sustainability through a sustainable value creation assessment consisting of LCA, a 6R life cycle cost (LCC) model, and social metrics and indicators, but they did not provide empirical evidence to support the assessment. A combined LCA/LCC was used to assess the economic implications of the viability of prolonged lifetime through repair and refurbishment for five product cases (Kaddoura et al., 2019). The environmental impacts were reduced for all cases, and so was the LCC (measured from the manufacturer's perspective). Although the importance of tracking and measuring effects of CE initiatives was addressed (Jørgensen and Remmen, 2018; Rossi et al., 2020), less attention was given to the use of assessments as a point of departure for circular strategies (Jørgensen and Remmen, 2018) or further development of CBMs.

#### 3.2.4. *Collaborating for progress towards circular economy*

Of the articles included, 20 examined collaboration and 1 article had a weaker connection (considered, but not in depth). Sehnem et al. (2019) highlighted the importance of an organisational culture in which sustainability is a core issue in achieving progress towards CE in manufacturing. Others pointed out that success requires belief in the idea and both internal and external stakeholder collaboration (Sehnem et al., 2019; Sousa-Zomer et al., 2018). Research exploring the implementation of CBM in developing countries (Mishra et al., 2019; Sousa-Zomer et al., 2018) also highlighted the need for collaboration between stakeholders. Moreover, Mishra et al. (2019) suggested that, for multinational companies, CBMs can create a basis for beneficial relationships with local actors. Poponi et al. (2019) found, from their analysis of two case studies, two virtuous paths for CE: 'social recycling' addresses the role of the social participation of primary and secondary stakeholders, while 'highly regenerative recycling' involves stakeholders in building an inter-organisational relationship to facilitate more circular waste recycling. Similarly, Kaddoura et al. (2019) argued that a CE strategy for prolonging product lifetime requires a life cycle perspective involving actors all along the value chain.

Frishammar and Parida (2019) highlighted the risk of tensions between the initiating company and other actors in the value chain when transforming to a CBM. By managing external communication and reducing possible negative links between CE activities and a firm's competitiveness (Daddi et al., 2019), this risk can be reduced. Transparency in communication between and towards stakeholders is important for success with CE (Braun et al., 2018; Daddi et al., 2019). Furthermore, important factors for stimulating well-functioning collaboration between organisations include regulations, incentives, and user behaviour (Ruggieri et al., 2016). Regulations on waste treatment fosters innovation and inter-organisational cooperation, but if the regulations are too complex and fragmented, they can also hinder it (Ruggieri et al., 2016). Providing a set of indicators for CE implementation, Rossi et al. (2020) included collaboration internally and externally, transparency, and systems thinking. Ruggieri et al. (2016) provided a model for inter-organisational cooperation around CE.

### 3.2.5. Barriers to circular economy implementation

Fourteen of the articles discussed barriers to CE implementation explicitly, and 2 mentioned barriers more indirectly. When exploring tensions between CE and the competitiveness of a firm, Daddi et al. (2019) found that managing them, might open doors to new business opportunities. Kumar et al. (2019) explored a wide range of barriers and found that key barriers to CE implementation were related to costs (e.g., investment costs, high scrap material costs), lack of incentives (in the form of taxes or financial support), lack of public awareness, lack of appropriate partners, and lack of available systems/technology. Diaz Lopez et al. (2019) explored implementation barriers for different resource efficiency measures and found several relevant technical barriers because the technologies for CE are not yet fully developed. Investigating the barriers for improved material efficiency, Shahbazi et al. (2016) found a wide range of barriers, including economic, organisational, and technical barriers. The lack of a material efficiency strategy with a broader perspective (one that went beyond the company level) was evident; the authors recommended implementing such a strategy as well as working to improve the value of the waste fractions by sorting. Sousa-Zomer et al. (2018) highlighted barriers such as stakeholder engagement, financial and organisational challenges, and knowledge needs.

Exploring barriers to CBM innovation, Guldmann and Huulgaard (2020) discovered that companies of same size, in the same industry, and with similar customer segment experienced different types of barriers. Further, they suggested that the type of CBM influenced the barriers experienced (Ibid.). Vermunt et al. (2019) investigated and confirmed that barriers differ with different types of CBMs. They further noted the usefulness of distinguishing between internal and external barriers and that key barriers were faced in external activities.

### 3.2.6. The role of users

Of the 29 articles, 11 addressed users, consumers, or customers explicitly, and 3 included perspectives more indirectly. User behaviour is an important factor for CE implementation in companies (Ruggieri et al., 2016; Poponi et al., 2019). Users' behaviour can be influenced by innovation; likewise, users can influence organisations (Ruggieri et al., 2016). Brissaud and Zwolinski (2017) reported that reuse strategies are often driven by market conditions and users' acceptance. Users' rejection of reused products or products made from recycled materials (or a company's fear of it) was revealed by Daddi et al. (2019) to be a barrier to CE progress. Kaddoura et al. (2019) suggested that users might not be willing to pay the same amount for a repaired/refurbished product as for a new item. Sehnem et al. (2019) argued that maintaining the perception that customers do not pay more for sustainability is important for a successful CE transition. On the other hand, Ruggieri et al. (2016) pointed out that CE strategies do not necessarily lead to increased costs for customers. The relationship between user and producer can be dynamic, as exemplified by a case study on sustainable school furniture (Kristensen and Remmen, 2019). In this case, PSS facilitated a shift in use patterns, influencing students' perspectives on consumption in general through the provision of more sustainable learning environments. Focusing on the interactions between users and a product or a service, Jørgensen and Remmen (2018) argued that environmental mapping should help differentiate between expected vs. actual user practices, and that an important part of the CE implementation process is dialogue with users. Pialot et al. (2017) proposed to foster user-producer interaction by means of a web platform where both parties are committed through an eco-score.

### 3.2.7. Connection between circular economy and sustainable development

Of the 29 articles, 6 addressed the three pillars of sustainability and expressed clearly how the chosen CE strategy was linked to sustainable development. Three articles provided no mention of the link between CE and sustainable development. In most articles, the link to sustainable development was vague, implicit, or focused only on the environmental dimension of sustainability. The sustainable value proposition framework offered by Kristensen and Remmen (2019) provided value propositions for all three pillars of sustainability. They argued that awareness of how BMs develop is key to making sure that the results contribute to sustainable development. Daddi et al. (2019) explored the tensions and barriers between a firm's competitiveness and CE initiatives in all three dimensions of sustainability. Rossi et al. (2020) developed CE indicators for all three dimensions of sustainability, identifying the specific SDGs their findings contribute to achieving. Pieroni et al. (2019) used indicators to screen the sustainability potential of CE initiatives in case studies.

Focusing on the economic and environmental dimensions of sustainability, Jawahir and Bradley (2016) showed that LCC can be used to evaluate and make 'good' choices on CE strategy. Kaddoura et al. (2019) investigated the environmental and economic consequences of PSS through a combined LCA/LCC for five product cases. Braun et al. (2018) integrated economic and environmental sustainability by addressing tensions that might arise between manufacturers and suppliers when implementing measures to improve material efficiency. Brissaud and Zwolinski (2017) focused on the environmental and social dimensions of sustainability through their scenario for upgrading and repurposing products after end of use.

Other articles focused exclusively on environmental sustainability (Jørgensen and Remmen, 2018; Shahbazi et al., 2016; Tecchio et al., 2017). Poponi et al. (2019) focused on the role of stakeholders in waste reduction and prevention (i.e., environmental sustainability). However, in their focus on stakeholders and users, a weak connection to social sustainability is also present. Other authors (Blomsma et al., 2019; Garza-Reyes et al., 2018; Jørgensen and Remmen, 2018) suggest only implicitly that implementing CE strategies will contribute to sustainable development. Jørgensen and Remmen (2018) did not connect CE with sustainability explicitly and provided a CE implementation strategy based on environmental considerations.

## 3.3. The state of circular economy implementation

This paper had two goals. The first was to investigate the research literature on how CE is implemented in manufacturers' practices with the aim of gaining insight into the status of empirical research on this topic. The amount of published literature on CE started growing in 2007, with a steep increase in 2015. From the articles selected for this review, a picture somewhat different from that drawn by Lieder and Rashid (2016) has emerged. Although the literature on CE implementation in manufacturing is still scarce, recent research has provided more case study examples. The case studies reveal strategies for narrowing the loops, closing them through post-consumer recycling, and slowing them down. From Table 4 it appears that more literature is now focusing on the higher parts of the waste hierarchy. The shift towards the short circles (Reike et al., 2018) requires a move from incremental improvements to more radical solutions or systemic shifts and necessitates incentives from stakeholders and policymakers. Although several authors provided frameworks and recommendations for slowing the loops, many of the case studies featured only a limited number of companies, and the challenges outlined by authors are numerous. There are still many barriers to manufacturing companies' efforts to move towards shorter loops. The barriers documented in the literature appear to be many and seem moreover to be context- and BM-specific (Guldmann and Huulgaard, 2020; Vermunt et al., 2019). The literature, therefore, does not invite any generalised conclusions regarding successful CE implementation. The findings from case studies highlighted CBM as a promising enabler for transitioning towards CE, but also showed that changes in BMs take time and effort. Rather than an 'on-switch', it is a stepwise, continuous process.

Manufacturing companies influence not only the production but the entire life cycle of a product, including use and end of life, by managing product design and development. Indeed, manufacturing companies potentially have the most significant contributions to make towards sustainability through affecting the use stage of products (Wang et al., 2018). Users affect and are affected by manufacturing companies' efforts to adopt more circular practices. However, concerns about users' acceptance of reused and refurbished products curb companies' willingness to take the risk and innovate for CE. Managing this tension is a success criterion for manufacturing companies aiming at CE. The role of manufacturing companies as a part of a larger system is also a recurring theme. Authors recognise that CE does not have one product or one actor as a point of departure; rather, it is a systemic concept rooted in the principle of conservation of resources. This implies that CE implementation in manufacturing companies cannot be done in one department or even one facility. It requires contribution and commitment from the entire organisation and conscious management of stakeholders.

### 3.4. Circular economy and sustainable development in manufacturing

The second research question was to examine the relationship between CE and sustainable development in manufacturing companies. CE is suggested as a route for progressing towards sustainable development (Schroeder et al., 2019). By definition (Kirchherr et al., 2017), all CE initiatives should be linked to sustainable development. This review shows that the link between CE and sustainable development cannot be taken for granted. Frishammar and Parida (2019) argue that CE has become the primary framework for assessing sustainability and that many manufacturing companies seek to implement CE to contribute positively to economic, social, and environmental sustainability. Even though sustainability is introduced in many articles as the goal, and the reason for implementing CE, most authors do not include the three dimensions of sustainability in their research. Authors referring to sustainability most commonly mean only the environmental dimension. This implies that implementation of CE in manufacturing is focused only the environmental dimension, as well, suggesting a gap in the drive towards economic, social, and environmental sustainability. This is especially true for social sustainability, which was rarely touched upon in the literature. The need for a clear link between CE strategies and sustainable development is highlighted by several authors (Brissaud and Zwolinski, 2017; Jawahir and Bradley, 2016). This is also the key message from this work: promoting concrete actions at the company level while at the same time securing the link to sustainable development cannot be assumed to be a straightforward task.

## 4. Conclusions and future prospects

### 4.1. The role of manufacturing companies in the circular economy

The aim of this paper was to provide a review of the empirical literature on CE in manufacturing, and to address the research collaborations taking place between industrial actors and academics to promote CE. Lieder and Rashid (2016) found that most published literature from before 2015 was conceptual; this review-study finds that literature based on case studies has grown. All case studies reviewed are from after 2015, showing that there is progress towards more empirical research on manufacturing companies relating to CE implementation.

The increased focus on CBMs shows that manufacturing companies are asking for support in managing tensions, reducing barriers, and realising the potential benefits of the CE transition. More specifically, the possible tensions that might occur between suppliers and manufacturers can be managed by implementing CBMs, as suggested by Braun et al. (2018). For manufacturers, a holistic framework for CE implementation, such as the one provided by Blomsma et al. (2019), can provide support in selecting, targeting, and promoting CE strategies. More specifically, insights into a variety of CE strategies, ranging from the lower parts of the waste hierarchy to the higher, can encourage efforts in new areas. This might nudge efforts higher up in the waste hierarchy. The approach suggested by Jørgensen and Remmen (2018) includes an analysis of the potentials and barriers for CE. The two-stage framework presented by Parida et al. (2019), with the manufacturers as an ecosystem orchestrator, can also be a fruitful path for transition to CE, while at the same time managing potential tensions among stakeholders. This review reveals a weak link between CE and sustainable development in most studies. This is especially true for the social dimension of sustainability. The prevalence of narrow approaches to sustainability in manufacturing leads to a risk of CE implementation efforts failing to provide solutions that are beneficial in the societal, environmental and economic dimensions. Implementation of solutions that are framed as circular, but which neglect the sustainability component, should be avoided.

### 4.2. Limitations of the current study

When performing a literature review, there is risk of the researcher's background, perspectives, and perceptions affecting data selection and analysis. To avoid bias in this work, efforts have been made to design clear inclusion/exclusion criteria and a framework with specific and neutral assessment points. A research protocol was used to maintain focus. Collaboration among multiple researchers was also undertaken to ensure the validity of the work. All included literature has been through a peer-review process. There is, however, a risk that the scientific literature base represents success stories, rather than implementation failures (Diaz Lopez et al., 2019). The selected research Methodology will always influence the findings. This literature review does not attempt to provide an overview of the status of CE in the manufacturing industry; rather, it sheds light on the status of research into CE as it relates to manufacturing companies. The literature has also been subject to the authors' subjective interpretations, which may not be the same as the original authors' intentions. To make this work manageable, several related topics that could have been addressed were left out. Significant omitted topics include regulations, policy, and consumption - arguably, key issues for manufacturing in a CE context, since they are providers of the ‘pull’ in the push-and-pull mechanisms of sustainable production and consumption.

### 4.3. Suggestions for further research

We suggest a continued effort to build a solid base of empirical research on CE in the manufacturing sector. Although the amount of literature has increased markedly, there is room for more groundwork. Considering the risk of only describing and showing success stories, efforts to target ’failures’ to learn from are welcome. Regarding the empirical base on CBM in manufacturing, PSS is by far the most extensively explored (Sousa-Zomer et al., 2018; Rosa et al., 2019). Other types of CBM (Bocken et al., 2016) with potential for manufacturing companies might be easier to implement; this should be further explored. Rosa et al. (2019) still highlights the lack of support in transitioning from a linear BM to a CBM. Investigations into the effects of CE strategies in general and of CBMs specifically would be welcomed.

Quantifying the effects of CE initiatives and CBMs is difficult (Frishammar and Parida, 2019); there is still a lack of suitable measuring tools. Nevertheless, environmental impact assessments can be exploited throughout the process as a point of departure for circular strategies (Jørgensen and Remmen, 2018). This may be a fruitful path to follow, but at minimum, reflections on the implications for social and economic sustainability should also be made. Future studies should look at the connections among the social, environmental, and economic issues, as well as the effects on user behaviour. We recommend a holistic approach to research on CE in the manufacturing sector. Although manufacturing companies play a small part in a product’s life cycle, they exert great influence on both the user and the product’s final destiny (at end of life) through product development and design. As Kirchherr et al. (2017) warns against putting a CE label on small incremental changes, so do we.

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## CRediT authorship contribution statement

**Marit Moe Bjørnbet:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing. **Christofer Skaar:** Conceptualization, Methodology, Writing - original draft, Writing - review & editing, Validation. **Annik Magerholm Fet:** Conceptualization, Methodology, Validation. **Kjersti Øverbø Schulte:** Conceptualization, Methodology, Writing - original draft, Validation.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

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