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How does servitisation affect supply chain circularity? - A systematic literature review

Abstract

Purpose - The aim of this review is to test the link between servitisation and circular economy (CE) by synthesising the effect of product-service systems (PSS) on supply chain circularity.

Design/methodology/approach - Following a systematic literature review methodology, the study identified 67 studies and synthesised them using content analysis.

Findings – A conceptual model is developed illustrating how PSS business models impact supply chain circularity through increased product longevity, closure of resource loops, and resource efficiency. It also identifies six contextual factors affecting the implementation of supply chain circularity including: 1) Economic attractiveness of supply chain circularity; 2) Firm sustainability strategy; 3) Policy and societal environment; 4) Product category; 5) Supply chain relationships; 6) Technology.

Research limitations/implications – The conceptual model proposes that supply chain circularity increases with servitisation. It also proposes that the main circularity effect stems from increased product longevity, followed by closed resource loops, and finally resource efficiency. The model is deduced from the literature by using secondary data.

Practical implications – The review provides practitioners with a framework to increase supply chain circularity through PSS business models. It also gives insight into the various contextual factors that may affect how a manufacturer's servitisation strategy contributes to supply chain circularity.

Originality/value – This review contributes to the understanding of the relationship between servitisation and supply chain circularity by synthesising the different effects that exist. Moreover, it creates new knowledge by identifying a range of contextual factors affecting the relationship between PSS and supply chain circularity.

Keywords Circular Economy, Product-service system, Supply chain management, Servitisation, Systematic literature review

Paper type Literature Review

1 Introduction

The circular economy (CE) concept advocates that business models should change from selling to renting, leasing, or sharing technical products (Ellen MacArthur Foundation, 2014; Lacy and Rutqvist, 2015). These business models are considered a key enabler to the development of circular supply chains (De Angelis *et al.,* 2018; Batista *et al.*, 2018; Ellen MacArthur Foundation, 2014; Lacy and Rutqvist, 2015). Circular supply chains are defined as 'the coordinated forward and reverse supply chains via purposeful business ecosystem integration for value creation from product/ services, by-products and useful waste flows through prolonged life cycles that improve the economic, social, and environmental sustainability of organisations' (Batista *et al.*, 2018, p.446). They are closely related to reverse logistics (Fleischmann *et al.*, 2001) and closed-loop supply chains (Guide *et al.*, 2003).

The interest in manufacturers moving away from selling products to providing combinations of goods and services emerged in the late 1980s (Vandermerwe and Rada, 1988; Wise and Baumgartner, 1999). The so-called servitisation phenomenon was a response to competitive pressures, as manufacturers sought differentiation opportunities by offering services along the entire product life-cycle (Oliva and Kallenberg, 2003). The most well-known example is the Rolls-Royce's 'power-by-the-hour' scheme. Instead of selling jet engines, Rolls-Royce carries out installation, maintenance, repair, and modernisation services while charging customers only for using the engine (Gebauer *et al.*, 2013). Other examples are: Caterpillar's equipment management services, that include condition monitoring, preventive maintenance, and repair or Xerox' printer fleet management services (Baines and Lightfoot, 2013a). Even though most servitisation cases stem from business-to-business contexts, examples also emerge from consumer markets, such as car- and bike-sharing or washing machines (Gebauer *et al.*, 2017; Vezzoli *et al.*, 2015).

Servitised offerings are often referred to as product-service systems (PSS), which are defined as 'tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs' (Tukker, 2004). Other terms to describe such offerings are basic, intermediate, or advanced services (Baines and Lightfoot, 2013b), outcome-based contracts (Ng *et al.*, 2009), performance-based contracts (Hypko *et al.*, 2010), or solutions (Brady *et al.*, 2005). PSS offerings are usually typified along a product-service continuum, in which the focus of the offering changes from being mainly product-based towards being more service-based (Tukker, 2004). There are three main PSS categories:

- *Product-oriented*: The main focus is still on selling products. The offering is enhanced by product-related services, such as maintenance or insurance contracts (Gaiardelli *et al.*, 2014; Tukker, 2004).
- *Use-oriented*: The focus is on providing functionality or access, for example, through leasing, renting, or sharing instead of selling products (Gaiardelli *et al.*, 2014; Tukker, 2004).

- *Result-oriented:* In these services, a function or pre-determined result is provided and not a product (e.g. pay-per-unit). The provider is completely free to decide how results are delivered (Gaiardelli *et al.*, 2014; Tukker, 2004).

To date, the link between PSS business models and the development of circular supply chains is mainly theoretical. It is based on the assumption that when companies provide services instead of selling products, they are incentivised to optimise their resource utilisation, for example by improving efficiency, increasing product lifetime, or reducing the overall number of products in use (Mont *et al.,* 2006; Reim *et al.*, 2015; Tukker, 2004; Vezzoli *et al.*, 2015). Use- and result-oriented PSS are considered to have the highest potential for CE because the manufacturer retains product ownership and thereby also responsibility for the product over its life cycle (Reim *et al.*, 2015). As a result, the manufacturer has economic incentives to reduce disposal costs or costs of manufacturing new products as well as to recover value at end-of-life, for example through reuse or remanufacturing (Vezzoli *et al.*, 2015).

Supply chains play a critical role in enabling firms' competitiveness (Hassini, 2008). Similarly, increasing supply chain circularity has been shown to reduce costs and generate new revenue streams. In 2017, Hewlett Packard refurbished and remarketed 1.27 million units of hardware, thereby creating new sales opportunities (Strandberg, 2017). JLG industries, a manufacturer of material handling equipment, reduced its equipment costs by 35% by refurbishing old cherry pickers (Ellen MacArthur Foundation, 2017a). Through remanufacturing, Caterpillar is able to get the same performance of components at 50-60% of the cost (Ellen MacArthur Foundation, 2017b). Even though the case for increased net value creation from circular supply chains is quite straightforward, manufacturers may be reluctant to implement PSS business models due to business risks associated with product ownership retention (Linder and Williander, 2015). Moreover, it is questionable how important the environmental concerns for PSS providers are, since servitisation is predominantly driven by strategic and commercial interests (Baines *et al.*, 2009a; Oliva and Kallenberg, 2003). As a result, selling PSS instead of products may not always lead to higher circularity (Kjaer *et al.*, 2018; Tukker, 2004).

The aim of this review is to test the assumed link between servitisation and CE by synthesising the effect of PSS on supply chain circularity (SCC). It aims to answer three review questions: 1) What is SCC? 2) How do PSS business models affect SCC? 3) What contextual factors affect the implementation of SCC? The paper adopts a systematic literature (SLR) methodology to identify and review 67 articles from the CE and PSS/servitisation fields. This review presents the first attempt to bridge the gap between theory and practice of SCC, by reviewing only empirical cases of PSS business model implementation. This helps validate the theoretical claims made about this relationship (Tukker, 2004). It also provides new knowledge by identifying and synthesising the contextual factors that can affect SCC implementation in PSS. The practical rationale for the study stems from the observation that the business case for adopting SCC in practice is not always as straightforward as suggested by the literature (Linder and Williander, 2015).

2 Research Method

This study adopts a SLR method (Tranfield *et al.*, 2003) to select, map, and assess existing studies on CE and PSS. Compared to a critical literature review, SLR provides a more rigorous and transparent review process that allows for explanatory or interpretive findings (Denyer and Tranfield, 2009). Using such an approach can reduce bias and increase the legitimacy of the data analysis, thereby leading to reliable results (Becheikh *et al.*, 2006). To ensure the transparency and replicability of this study, a series of steps were followed (Denyer and Tranfield, 2009) and presented in a similar way to Pilbeam *et al.* (2012): 1) planning, 2) searching, 3) screening, 4) extraction and synthesis, and 5) reporting. The search and selection processes are summarised in Figure 1.

Planning

In advance to this study, the authors carried out a scoping study as suggested by Tranfield *et al.* (2003). Based on the results of this scoping study, the research team and a guidance committee consisting of other academic experts in the field defined the research scope, questions, and inclusion/exclusion criteria to answer the aforementioned review questions.

Searching

[INSERT TABLE 1 HERE]

The keywords used in the literature search emerged from the scoping study (see Table 1). They were classified into search strings by using Boolean 'OR' operators, namely, supply chain management, CE, and PSS. To answer the first question ('What is SCC?'), SS1 and SS2 were combined through a Boolean 'AND' operator. The second question ('How do PSS business models affect SCC?') and the third question ('What contextual factors affect the implementation of supply chain circularity?'), were answered by combining all three strings. These search strings were then used to search two bibliographic (Scopus and Web of Science) and two content-based databases (ABI/Proquest and Ebsco). A total of 3,034 articles were identified and alerts were set up in the databases to help identify new publications.

Screening

[INSERT FIGURE 1 HERE]

The paper selection process is described in Figure 1. 3,034 search results were exported from Scopus, Web of Science, ABI/Proquest and Ebsco to the reference management software Mendeley. Following the removal of 559 duplicates, 2,475 articles remained. The first screen of the articles was based on the article title and abstract against pre-determined inclusion (and exclusion) criteria (see Table 2).

[INSERT TABLE 2 HERE]

After rejecting 2,274 articles, 201 articles remained, which were then reviewed in a rigorous full-text screening process against the same inclusion and exclusion criteria. During this screening process, the references of relevant articles were reviewed (snowballing) to identify other potentially relevant articles. The snowballing process identified an additional 10 papers. Following the full-text screening, 78 articles remained. The selected articles were subject to a quality appraisal process that covered the theory robustness, methodology, findings, and contribution (Pittaway *et al.*, 2004). The articles were scored on scale of zero to three in each category. To be included, an article required a score of at least six in total. Eleven articles were rejected in this step leaving 67 articles, which qualify for review.

Extraction and synthesis

There are different approaches to data extraction and synthesis in SLRs. This review is based on heterogeneous qualitative and quantitative data. As a result, it is not suitable to use aggregative synthesis methods (Rousseau *et al.*, 2008). In addition, an integrative approach was also excluded, since the review questions do not focus on exploring when interventions are likely to be appropriate (Rousseau *et al.*, 2008). Instead, a mix of interpretive and explanatory approaches was used (Rousseau *et al.*, 2008). In these methods, descriptive data and exemplars are extracted from studies to create explanations (Denyer *et al.*, 2008). Content analysis is used as an extraction and synthesis method, since it can provide detailed assessments of descriptive and content criteria and also extend the perspective beyond single studies (Gold *et al.*, 2010; Seuring and Müller, 2008).

In the first step of content analysis, papers were classified based on descriptive dimensions. This included the distribution across time, the employed research methodology, geographic context, industry setting, PSS type, and the journal the paper was published in. These categories were selected based on the standard practice for literature reviews (Seuring and Müller, 2008), as well as the inclusion and exclusion criteria of the study. In addition, analytic categories for the supply chain processes and the contextual factors affecting SCC were developed from the reviewed papers by means of generalisation (Seuring and Müller, 2008). One of the weaknesses of content analysis is that it relies on the researcher to judge how a paper is to be comprehended (Seuring and Müller, 2008). To account for this, the first author regularly discussed findings and coding matters with the other authors and resolved any disagreements through discussion. The dimensions and categories were iteratively revised during the analysis process.

3 Descriptive Analysis

This section presents the descriptive analysis of the literature review. The papers were classified in three categories: CE, PSS and circular PSS, where both themes overlapped. The CE and circular PSS papers answered the first review question, all papers answered the second and third review question. Figure 2 depicts the distribution the 67 reviewed papers.

[INSERT FIGURE 2 HERE]

Figure 2 shows that between 2005 and 2013, the publications exclusively focused on PSS and servitisation. In 2014, publications on CE slowly started to emerge, with the number of publications rising sharply between 2017-2018. Indeed, there was a particular increase in 2018 of those papers addressing both CE and PSS. This shows that the link between circular economy and the PSS/servitisation literature emerged only very recently.

The selected papers were categorised and analysed in regard to methodology, geographic context, industry setting, PSS type and journal (see Table 3). The methodologies were categorised based on the study types provided by Habib *et al.* (2015). The selected articles were divided across non-empirical papers (21) and empirical papers (46). In the non-empirical papers, the dominant type were literature reviews (12) and conceptual papers (8), while one was classified as mathematical. The majority of these papers focused on CE and circular supply chains (De Angelis *et al.*, 2018; Batista *et al.*, 2018). The empirical papers were predominantly case studies (42) compared to four papers based on surveys. Of the case studies, 39 focused on PSS of which 9 focused more specifically on circular PSS implementation. The dominance of case study methodologies underscores that this research area is in a nascent stage and still exploring the manifestation of this phenomenon in its real-life context.

[INSERT TABLE 3 HERE]

The non-empirical papers were not classified according geographic context, since they did not provide any specifications in this category. Almost all empirical papers focused on cases from European countries (40), especially from the United Kingdom (17) or Sweden (7), and only few exceptions from other contexts, such as Brazil (3) or China (1). The empirical papers were mainly from industries related to manufacturing, such as capital equipment, defence, or household appliances. Nevertheless, a growing number of publications focused on lower value product industries, such as textiles (Corvellec and Stål, 2017; Pal, 2016). The 39 empirical PSS papers were also differentiated based on the type of PSS. This total number exceeds 39 since some papers employed multiple case studies of different PSS types. There were 14 cases of product-oriented PSS, 12 cases of use-oriented

PSS and 24 cases of result-oriented PSS indicating the high level of interest that PSS/ servitisation scholars have in these. The analysis also reveals that the discussion around supply chain and CE has primarily taken place in journals, such as the Journal of Cleaner Production, Production Planning & Control, or Sustainability. The PSS and servitisation literature, however, is focused primarily on the International Journal of Operations & Production Management, Industrial Marketing Management and the International Journal of Production Economics.

4 Thematic Analysis

This section presents the thematic findings of the review. In the first part, the CE literature was reviewed to identify relevant circular supply chain aims, indicators, and practices. In the second part, empirical PSS papers were reviewed to identify circular supply chain practices. In the final part of this analysis, contextual factors for the implementation of supply chain circularity were deduced from the CE and PSS literature. The main purpose of the review is to develop a conceptual model of SCC in PSS business models. The final framework is presented in Figure 3.

4.1 Supply Chain Circularity (SCC)

This section focuses on identifying relevant aims, performance measures, and practices of supply chain circularity (see Table 4).

[INSERT TABLE 4 HERE]

Circular supply chains focus on the creating value from prolonging product, component, and material life cycles through coordinated forward and reverse supply chains (Batista *et al.*, 2018; Lieder and Rashid, 2016). They aim to close resource loops through recycling or remanufacturing, extend the lifetime of products through design changes or repairs, and increase resource efficiency by using fewer resources over the entire product life-cycle (Geissdoerfer *et al.*, 2018; Yang *et al.*, 2018).

[INSERT TABLE 5 HERE]

There are fifteen practices related to the principal aims of circular supply chains (see Table 5). These can be classified according to the supply chain processes along the product life cycle: material sourcing, design, production, distribution, use, and recovery. During the material sourcing and recovery processes, the practices are focused around the aim of closed resource loops. In the other processes, however, the practices are aimed at increasing resource efficiency and product longevity.

4.2 PSS business models and Supply Chain Circularity

The review of Supply Chain Circularity in PSS business models focused on identifying circular supply chain practices implemented in the different PSS models: product-oriented, use-oriented, and result-oriented (see Table 6).

[INSERT TABLE 6 HERE]

The identified practices in the fourteen *product-oriented PSS* cases are almost all associated with the product longevity aim. Maintenance and repair occurred in all fourteen cases, while refurbishing was mentioned in four. In one case, however, the manufacturer of complex-engineered products decided against refurbishing components and instead fit new ones to boost sales (Lockett *et al.*, 2011). The review also identified design practices associated with product longevity. In the case of soil compactors in Sweden, the company aimed to save costs by designing their products to increase the service intervals and to decrease the need for maintenance and remanufacturing (Sundin *et al.*, 2009). In a capital equipment case, the manufacturer designed products for reliability and maintainability to ensure that the product had a low failure rate and that service activities could be conducted with ease and at low cost (Colen and Lambrecht, 2013). The dominance of practices associated with product longevity can be explained by the sample's focus around maintenance and technical support services. The review also identified some practices associated with resource loop closure. Two cases mentioned remanufacturing of products and components, which were implemented to facilitate spare-part provision and to rejuvenate the employed equipment (Colen and Lambrecht, 2013; Sundin *et al.*, 2009). Recycling activities were only mentioned in cases of textile PSS, in which H&M and other companies implemented take-back schemes for clothes to either use them to produce lower value textiles or give them to charity (Corvellec and Stål, 2017; Pal, 2016). One case mentioned training activities to increase resource efficient product use (Chakkol *et al.*, 2014).

Even though there are two cases less in *use-oriented PSS* (twelve) compared to product-oriented PSS, the total identified practices in this sample increased from 25 to 33. As with product-oriented PSS, the most widely mentioned activities were around product longevity, especially maintenance and repairs. In comparison to the previous sample, however, there were more design related practices (Fargnoli *et al.*, 2018; Geissdoerfer *et al.*, 2018; Sousa-Zomer *et al.*, 2018a). In addition, the amount of closed resource loop practices increased. Recycling was identified in four cases, while remanufacturing occurred in five. In a bicycle case in Sweden, however, the manufacturer failed to expand its circular business model based on remanufacturing beyond the pilot phase due to the difficulty of forecasting demand for multiple product life-cycles (Linder and Williander, 2015). Cascades were also mentioned in the case of a water filtration equipment manufacturer in Brazil, where the firm created a spin-off, to sell by-products and waste resources to external partners (Sousa-Zomer *et al.*, 2018a). This case had the most identified practices across all empirical PSS papers. For example, they also increased resource efficiency by reducing the use of chemicals in manufacturing processes, using energy-saving production equipment, systematically reducing waste in production, and incorporating environmental aspects into the logistics design (Sousa-Zomer *et al.*, 2018a). Contrary to the other empirical papers in this review, it specifically focused on implementing circularity across the entire supply chain. This can be explained by the manufacturer's strong commitment to sustainability and CE. In one case, the manufacturer supported the customer in the resource efficient use of the product (Bressanelli *et al.*, 2018).

The most practices were identified in result-oriented PSS (62), which was expected since these are the largest number of cases (24). Similar to the previous two PSS types, the vast majority of practices were around product longevity, especially maintenance and repairs. In some, products were also designed for disassembly and for longevity (Manninen *et al.*, 2018; Sundin *et al.*, 2009). Two practices that were not previously identified were design for modularity and customisation. This was expected, because result-oriented PSS are less defined and focused on solving specific business needs (Saccani *et al.*, 2014). Even though customisation is expected to reduce resource use by preventing waste and overproduction (Kalmykova *et al.*, 2018), Yang *et al.* (2018) note that product customisation made remanufacturing and recycling costlier, thereby presenting a potential trade-off between customisation and the closure of resource loops. There were also a number of practices identified with the closure of resource loops. In the case of a gas generator manufacturer in China providing services around industrial gases, the company was able to cascade by-product gases to other supply chains (Yang *et al.*, 2018). According to them, this was only possible in result-oriented PSS, since the manufacturer was able to control the production processes and thereby also the by-products. This sample also identified the highest number of practices associated with operational efficiency in the use phase. This can be explained by the manufacturer having control over product use to deliver results or by implementing comprehensive risk and reward sharing schemes, which can help ensure a customer's efficient product use (Gebauer *et al.*, 2017a; Smith *et al.*, 2014).

Overall, the results in this section show that there is an increase in amount and type of circular supply chain practices identified as PSS business models move from product- to result-oriented. Overall, the increase in supply chain circularity can be explained by: 1) The manufacturer internalising operational risks, resulting in the need for higher product reliability and maintainability (Colen and Lambrecht, 2013; Reim *et al.*, 2016); 2) Product ownership retention incentivising manufacturers to maximise value capture across the product life cycle (Gebauer *et al.*, 2017; Yang *et al.*, 2018); 3) Having more information and control regarding the quantity and quality of product flows compared to traditional sales business models (Sundin and Bras, 2005; Yang *et al.*, 2018).

4.3 Contextual factors affecting supply chain circularity

This section reviews the contextual factors that can influence the implementation of circular supply chain practices. Thirteen factors were identified through the content analysis of the CE and PSS papers. These factors were classified into six categories based on their nature and meaning (see Table 7).

[INSERT TABLE 7 HERE]

- The *economic attractiveness of SCC practices* can have a positive effect on supply chain circularity. For example, Toyota Material Handling Group in Sweden increased its revenues by selling remanufactured forklift trucks it previously used in its PSS (Sundin *et al.*, 2009). In addition, designing products for longevity can help reduce maintenance costs (Colen and Lambrecht, 2013; Sundin *et al.*, 2009). But economic aspects can also have a negative effect on supply chain circularity. In one PSS case of gas generators in China, the potential value from end-of-life recovery was too little compared to the costs due to the long product lifetime and high degree of customisation (Yang *et al.*, 2018). Another potential negative effect on SCC can stem from the risk of cannibalising existing product or component sales (Lockett *et al.*, 2011).
- The *firm sustainability strategy* can positively affect the implementation of circular supply chain practices. This manifested itself in the case of a use-oriented PSS of water filtration equipment in Brazil (Sousa-Zomer *et al.*, 2018a). The manufacturer received multiple awards for its commitment to sustainability, which was exemplified by the implementation of circular practices across all supply chain processes.
- The *policy and societal environment* can negatively affect circularity through customer concerns over the quality of refurbished or remanufactured products (Lieder and Rashid, 2016) as well as through laws and regulations that stifle waste recovery and/or cross-sector collaboration (De Angelis *et al.*, 2018; Govindan and Hasanagic, 2018). Laws and regulations can also positively influence SCC through tax benefits and/or recycling requirements (Brown and Bajada, 2018; Lieder and Rashid, 2016). In addition, a well-developed waste management sector can provide the necessary infrastructure to implement circular supply chain practices (Corvellec and Stål, 2017).
- The *product category* can have a positive effect on SCC. Remanufacturing, for example, is considered most beneficial when the product has a core that can be restored, the associated technology is relatively stable, it can be easily disassembled and restored, and has relatively high recoverable value (Andreu, cited in Sundin, Lindahl and Ijomah, 2009). Nevertheless, it can also have a negative effect if the materials are unsuitable for

recycling, too complex or when the product is subject to fashion changes (Ghisellini *et al.*, 2016; Linder and Williander, 2015).

- *Supply chain relationships* can have a positive effect on circularity through cross-sector collaboration and the implementation of cascading resource flows (De Angelis *et al.*, 2018). In addition, supply chain integration can positively affect SCC by enabling information sharing and the alignment of actors towards desired circularity outcomes. This is exemplified by sharing of materials and information between manufacturer and customer to minimise product failure (Fargnoli *et al.*, 2018; Smith *et al.*, 2014). The review also identified a number of PSS cases studies, where misalignment across the supply chain and resistance to share information prevented suppliers from effectively supporting maintenance services (Finne and Holmström, 2013; Lockett *et al.*, 2011).
- The use of digital *technology*, such as internet of things or tracking and monitoring, can have a positive effect on SCC by facilitating maintenance and repair activities as well as facilitating product design improvements or facilitating recovery (Bressanelli *et al.*, 2018; Spring and Araujo, 2017).

4.4 PSS and Supply Chain Circularity – A conceptual model

Based on the literature review presented, a conceptual model is presented (see Figure 3).

[INSERT FIGURE 3 HERE]

The conceptual model posits that servitisation and the transition from a product-oriented to a result-oriented PSS increases SCC. The first aim of SCC is product longevity. In product-oriented PSS, maintenance practices help increase the durability of the products and reduce the failure rate (Colen and Lambrecht, 2013). In use-oriented PSS, the product longevity increases. Here, the manufacturer retains ownership and is thus incentivised to prolong the product lifecycle through repairs and maintenance (Bressanelli *et al.*, 2018; Reim *et al.*, 2015). Longevity is also increased by refurbishing and reselling products in secondary markets (Gebauer *et al.*, 2017a). In result-oriented PSS, the longevity potential is the highest, because the manufacturer is responsible for the delivery of specific outcomes. This is exemplified by extensive predictive and preventive maintenance as well as faster fault diagnostics and rectification (Baines and Lightfoot, 2013b; Johnstone *et al.*, 2009). This argument leads to the following proposition:

Proposition 1: Product longevity is the highest in result-oriented PSS followed by use-oriented PSS, which has a higher product longevity than product-oriented PSS.

The second aim of SCC is the closure of resource loops. In product-oriented PSS, the review identified practices around the remanufacturing or recycling of old components that were recovered in repair or maintenance activities (Colen and Lambrecht, 2013). In use-oriented PSS, the manufacturer retains product ownership and is incentivised to recover products, components, and materials to maximise profits (Yang *et al.*, 2018). The potential for closed resource loops increases in result-oriented PSS because the manufacturer has more control over resource flows in the use phase (Yang *et al.*, 2018). This argument leads to the following proposition:

Proposition 2: Closure of resource loops is the highest in result-oriented PSS followed by use-oriented PSS, which has a higher closure of resource loops than product-oriented PSS.

The third aim of SCC is resource efficiency. In product-oriented PSS, there is limited potential for increasing resource efficiency, since the PSS provider has no formal interaction or control on the customer's use of the product. In use-oriented PSS, the PSS provider retains ownership, monitors user behaviour and supports the customer in efficient and sustainable usage (Bressanelli *et al.*, 2018). In result-oriented PSS, the potential for increasing resource efficiency is the highest. Here, the manufacturer can control how products are used and can find innovative and efficient ways to deliver results (Reim *et al.,* 2015; Yang *et al.*, 2018). In addition, these offerings are highly customised, which can potentially prevent waste and over-production (Kalmykova *et al.*, 2018). This argument leads to the following proposition:

Proposition 3: Resource efficiency is the highest in result-oriented PSS followed by use-oriented PSS, which has a higher resource efficiency than product-oriented PSS.

Finally, the review suggests that the strength of the application of the circular supply chain practices differs. This was determined by the number of practices that were identified in the empirical PSS papers (see Table 6). The dominance of product longevity can be explained by the strategic importance of product reliability and maintainability in the delivery of PSS business models, especially result-oriented PSS (Baines and Lightfoot, 2013b; Colen and Lambrecht, 2013). In comparison, there were significantly fewer identified practices around closed resource loops. Evidence of difficulties in implementing remanufacturing and recycling (Linder and Williander, 2015; Yang *et al.*, 2018) support the notion that a PSS business model adoption is not a guarantee for increased circularity (Kjaer *et al.*, 2018). This argument leads to the following proposition:

Proposition 4: The main effect of servitisation on SCC stems from increased product longevity, followed by closed resource loops, and finally resource efficiency.

This model also identifies a number of contextual factors that can influence the degree to which PSS affects SCC (see Table 7).These are represented by the up- and down- ward facing arrow on the right side of the model and are as follows: 1) Economic attractiveness of SCC; 2) Firm sustainability strategy; 3) Policy and societal environment; 4) Product category; 5) Supply chain relationships; 6) Technology. As mentioned in section 4.3, the contextual factors can influence the implementation of circular supply chain practices. This argument leads to the following proposition:

Proposition 5: Contextual factors can have positive or negative effects on the relationship between servitisation and SCC.

5 Discussion and conclusion

5.1 Research synthesis

The CE concept considers servitised business models around renting, leasing, and sharing as a core enabler of circular supply chains. When customers only pay for the service they receive and manufacturers retain product ownership, the manufacturer will aim to reduce the amount of resources used (Reim *et al.*, 2015; Vezzoli *et al.*, 2015). To the authors' knowledge, this is the first attempt to synthesise existing research on PSS implementation and its effect on supply chain circularity.

This study answers the first review question ('What is SCC?') by identifying and linking the principal aims of supply chain circularity – close resource loops, increase product longevity, increase resource efficiency – and their performance indicators with fifteen supply chain practices. This contributes to previous conceptualisations of circular supply chains (De Angelis *et al.*, 2018; Batista *et al.*, 2018), which focused predominantly on defining and delineating circular supply chains from other concepts found in literature, such as closed-loop supply chains. In addition, it contributes by providing an approach to assessing SCC, a need that was previously identified (Elia *et al.*, 2017).

In regard to the second question ('How do PSS business models affect SCC?'), the review synthesises the effects of servitisation on SCC. The findings are translated into five propositions. They confirm previous claims that the supply chain circularity potential increases as manufacturers move from offering product-oriented to result-oriented PSS and retain product ownership (Tukker, 2004, 2015; Vezzoli *et al.*, 2015). The fourth proposition is based on the finding that more practices are identified as business models move from product- to result-oriented PSS. The relative lack of practices associated with closed resource loops and resource efficiency support the notion that PSS business model adoption is not a guarantee for increased circularity (Kjaer *et al.*, 2018).

This ties into the findings for the third review question ('What contextual factors affect the implementation of supply chain circularity?'). The review contributes new knowledge by identifying a range of contextual factors that can positively and negatively influence the implementation of SCC practices. These are: 1) Economic attractiveness of SCC circularity; 2) Firm sustainability strategy; 3) Policy and societal environment; 4) Product category; 5) Supply chain relationships; 6) Technology. These findings are expressed in the fifth proposition.

5.2 Theoretical implications

This review contains a plethora of theoretical implications. SCC introduces new supply chain aims and practices, resulting in the need to be harmonised with traditional measures and metrics used for efficient and effective supply chain management (Sambasivan *et al.*, 2009). This also implies an extension in the evaluation of information systems around sustainability outcomes (Piotrowicz and Cuthbertson, 2009). The findings also demonstrate the potential of servitisation and PSS business models to contribute to SCC. Nevertheless, the scarcity of circular supply chain practices suggests that there is still potential for the SCC concept to guide upstream and downstream process and product innovation in servitised supply chains (Walters and Rainbird, 2007). The review also gives insights into the various contextual factors that may affect how a manufacturer's servitisation strategy contributes to SCC. In doing so, it begins to bridge a previously identified gap in the literature (Reim *et al.*, 2015). One finding from the review is that an organisation's strategy and culture around sustainability can potentially affect SCC implementation (Sousa-Zomer *et al.*, 2018a, 2018b). This ties into existing findings on the effect of organisational culture on supply chain strategy formulation and implementation (Roh *et al.*, 2008).

5.3 Practical implications

This review bridges the gap between theory and practice in two ways: Firstly, it provides comprehensive empirical evidence about the effect of servitisation and PSS implementation on SCC, thereby validating the theoretical claims made about this relationship. This study impacts upon society, because it highlights the need to move away from ownership- to access- or functionality-based business models in the transition to a more sustainable and circular economy. It helps inform policy-makers on the importance of facilitating the implementation of PSS business models for SCC. The study also provides practitioners with a framework to increase supply chain circularity through PSS business models. Secondly, the review also gives insight into the various contextual factors that may affect how a manufacturer's servitisation strategy contributes to SCC. This gives PSS providers a roadmap to implement new business models and to reduce the uncertainties related to their implementation (Linder and Williander, 2015). It also provides governments with insights into the circumstances required for SCC in PSS business models and can therefore help inform effective policy-making.

5.4 Research limitations

The study has a few limitations to be considered. Firstly, this study draws on a body of literature around circular PSS implementation, which is still nascent and currently emerging. At present, there are few empirical studies that focus specifically on the relationship between PSS and supply chain circularity. This has implications for the findings around the practices associated with the closure of resource loops and resource efficiency. One possible explanation for the relative lack of empirical evidence is that these practices are not directly related to the provision of service outcomes. Product longevity on the other hand helps ensure a product's functionality and is therefore critical to a successful service delivery. As a result, existing studies may have simply not focused on aspects related to resource loop closure and resource efficiency in servitisation and PSS business model implementation. Another possible explanation is that product longevity is easier to grasp and to assess than the closure of resource loops and resource efficiency. Secondly, the review focused on peer-reviewed articles written in English, thereby not considering outputs published in other languages.

5.5 Recommendations for future research

This review provides the following future research avenues:

- The present study developed a conceptual model of PSS SCC which needs to be tested and empirically validated, for example, through conducting case study research.

- The effect of PSS business model implementation on SCC can vary based on contextual factors. Further research is recommended to examine these contextual factors and understand the extent of their impact.
- The majority of articles in this review employed qualitative research methods. More quantitative studies are needed to further evaluate the link between PSS business models and specific circularity practices.
- Finally, more studies are needed beyond the European context as most studies in this review were predominantly from Europe.

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Table 1 – Search strings

SS1: Supply Chain Management		SS2: Circular Economy		SS3: Product-service systems
Supply Chain* Value Chain* Demand Chain* Logistics Supply Network* Value Network* Operations*	**AND**	Circular Economy	**AND**	Product?service?system PSS Serviti?ation Outcome?based Advanced services Industrial service Hybrid solution Functional sales Performance?based

Running Head: Effect of servitisation on supply chain circularity

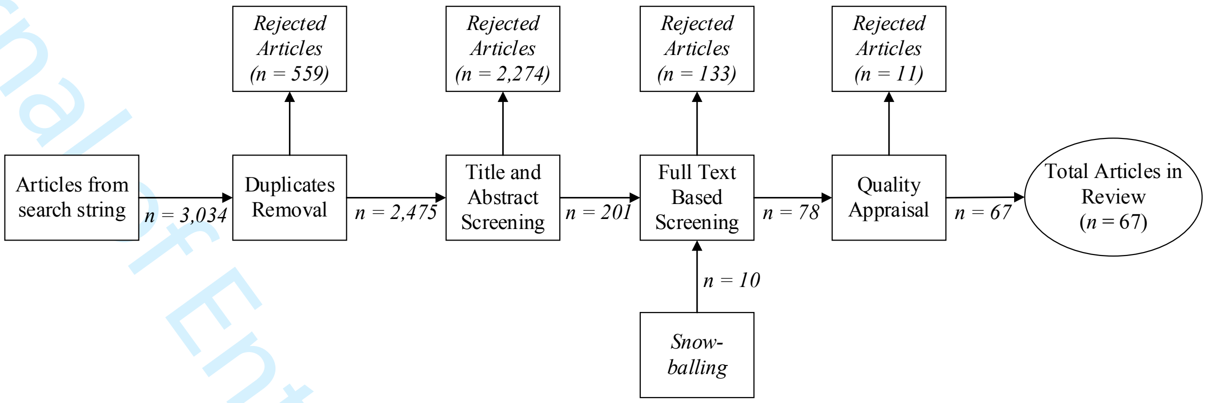

Figure 1 - Paper search and selection process

Table 2 – Criteria for including papers in the review

Criteria	Rationale
Published in peer-reviewed journals	Peer-reviewed journal articles are likely to have a higher quality than non-peer reviewed publications, such as conference papers or reports.
Studies that are written in English	Language skills of the authors.
Open to any time frame	The field developed significantly since the 1980s, but some seminal papers predate this.
Open to any geography	Contributions to the research area stem from around the world.
Theoretical, empirical studies and review papers, either qualitative or quantitative	Different methodological approaches contribute to the research domain.
Focused on (‘supply chain management’ AND ‘circular economy’) OR (‘supply chain management’ AND ‘product-service systems’) OR (‘supply chain management’ AND ‘circular economy’ AND ‘product-service systems’)	Different search string combinations are required to answer the review questions.

Running heads: Effect of servitisation on supply chain circularity

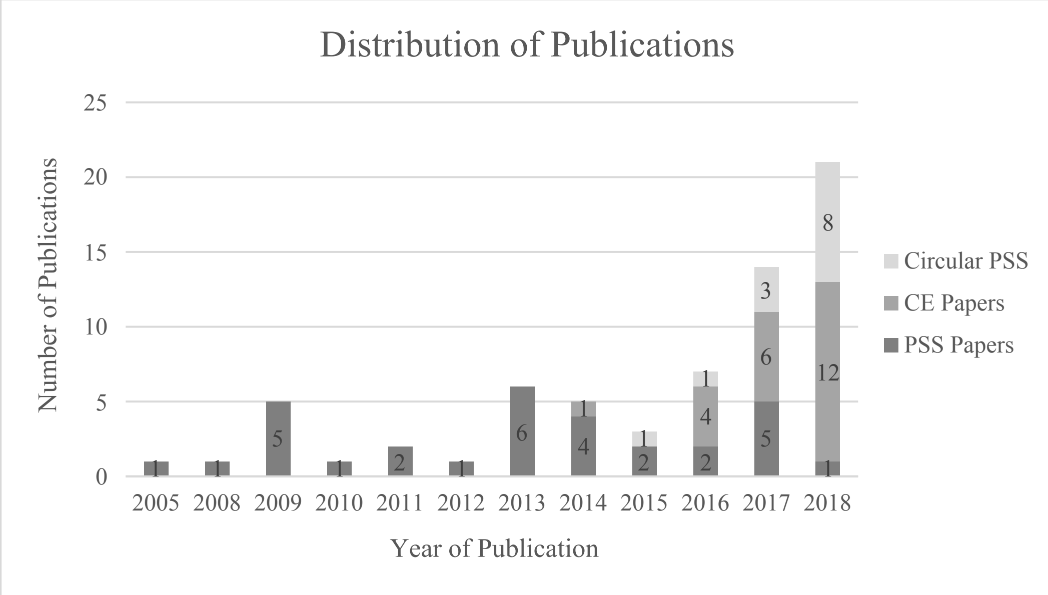

Figure 2 - Distribution of publications

Table 3 - Descriptive analysis of the literature review

Descriptive Category	*Sub-Category*	*Number of Papers*
Research Methodology	*Non-Empirical*	
	Conceptual	8
	Literature Review	12
	Mathematical	1
	Empirical	
	Case studies	42
	Survey	4
Geographic Context*	None	21
	Asia	2
	Australia	1
	Europe	40
	North America	1
	South America	3
	Worldwide	1
Industry setting*	Aerospace	2
	Automotive	3
	Bicycles	2
	Capital equipment	14
	Chemical/food	1
	Construction equipment	4
	Defence	6
	Household appliances	6
	Material handling equipment	3
	Medical equipment	3
	Office equipment	1
	Textiles	3
	Transportation equipment	3
PSS Type*	Product-Oriented	14
	Use-Oriented	12
	Result-Oriented	24
Journal**	Journal of Cleaner Production	15
	International Journal of Operations & Production Management	9
	International Journal of Production Economics	5
	Industrial Marketing Management	5
	Production Planning & Control	5
	Sustainability	5

*May vary since some papers employed multiple case studies.
**Includes top six most frequently included journals

Table 4 –SCC principal aims, practices and performance measures

Aim	Associated Practices	Performance Measure	Performance Measure Source
Close resource loops	Source secondary materials; Cascading; Recycling; Remanufacturing	Circularity = (economic value of recirculated parts) / (economic value of all parts)	(Linder *et al.*, 2017)
Increase product longevity	Design for disassembly; Design for longevity; Design for modularity; Reuse/Resell; Maintenance and Repair; Refurbish	Longevity = A + B + C A is initial life time of the product; B is refurbished lifetime contribution; C is recycled lifetime contribution.	(Franklin-Johnson *et al.*, 2016)
Increase resource efficiency	Source secondary materials; Customisation; Reduce resource use; Eco-efficient production processes / technology; Sustainable design of distribution system; Operational efficiency	Decreasing emissions (e.g. GHG emissions; Air) Decreasing energy consumption (e.g. Energy consumption; use of renewable energy sources) Decreasing waste (e.g. solid; liquid/water; hazardous/harmful/toxic)	(Genovese *et al.*, 2017; Kazancoglu *et al.*, 2018; Nuñez-Cacho *et al.*, 2018; Sousa-Zomer *et al.*, 2018a)

Table 5 – Circular supply chain practices related to the principal aims

Supply Chain Process	Practice	Aim	Practice Description	Practice Source
Material Sourcing	Source secondary materials	Closed resource loops	Replace materials with more abundant secondary materials or renewable ones.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Franco, 2017; Genovese *et al.*, 2017; Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Masi *et al.*, 2018; Perey *et al.*, 2018; Spring and Araujo, 2017)
Design	Customisation	Resource efficiency	Products are bespoke and meet the needs and preferences of the customer. This can help reduce waste and prevent over-production.	(Kalmykova *et al.*, 2018)
	Design for disassembly	Product longevity	Design products in a way that considers disassembly for repair, remanufacturing, recycling.	(De Angelis *et al.*, 2018; Elia *et al.*, 2017; Ghisellini *et al.*, 2016; Govindan *et al.*, 2018; Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Lieder and Rashid, 2016; Masi *et al.*, 2018)
	Design for longevity	Product longevity	Design products to last longer, considering the physical and emotional durability.	(De Angelis *et al.*, 2018; Franklin-Johnson *et al.*, 2016; Ghisellini *et al.*, 2016; Kazancoglu *et al.*, 2018; Kjaer *et al.*, 2018; Lieder and Rashid, 2016; Lüdeke-Freund *et al.*, 2018; Manninen *et al.*, 2018; Spring and Araujo, 2017)
	Design for modularity	Product longevity	Products are designed to include functional modules so that they can be more easily serviced, repaired or replaced, also upgraded.	(Kalmykova *et al.*, 2018; Lieder and Rashid, 2016; Lüdeke-Freund *et al.*, 2018; Spring and Araujo, 2017)
	Reduce resource use	Resource efficiency	Design that minimises the amount of materials used, especially toxic or hazardous substances.	(Kjaer *et al.*, 2018; Lieder and Rashid, 2016; Masi *et al.*, 2018; Reike *et al.* 2018)
Production	Eco-efficient production processes/ technology	Resource efficiency	Manufacturing processes and technology are designed to maximise energy efficiency / minimise waste / minimise water & energy consumption. Use renewable energy sources.	(Elia *et al.* 2017; Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Masi *et al.*, 2018; Reike *et al.*, 2018; Sousa-Zomer *et al.*, 2018a)
Distribution	Reuse/ Resell	Product longevity	Resell products, components for same purpose, second-hand.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Govindan and Hasanagic, 2018; Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Kirchherr *et al.*, 2017; Kjaer *et al.*, 2018; Lieder and Rashid, 2016; Linder *et al.*, 2017; Lüdeke-Freund *et al.*, 2018; Manninen *et al.*, 2018; Masi *et al.*, 2018; Reike *et al.*, 2018)
	Sustainable design of distribution system	Resource efficiency	Includes switching to more sustainable modes of transportation, route optimisation or eco-driving. Design packaging material to reduce overall resource use.	(Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Sousa-Zomer *et al.*, 2018a)
Use	Maintenance and Repairs	Product longevity	Conduct maintenance, repair activities or product upgrades. The purpose is to extend the product lifetime.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Bressanelli *et al.*, 2018; Geissdoerfer *et al.*, 2018; Kalmykova *et al.*, 2018; Kirchherr *et al.*, 2017; Kjaer *et al.*, 2018; Lüdeke-Freund *et al.*, 2018; Reike *et al.*, 2018)
	Operational efficiency	Resource efficiency	Decreasing emissions, resource consumption, waste during use phase	(Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Kjaer *et al.*, 2018; Reike *et al.*, 2018)
	Refurbish	Product longevity	Overall structure of a complex product remains more or less intact, while a number of components	(De Angelis *et al.*, 2018; Franklin-Johnson *et al.*, 2016; Govindan and Hasanagic, 2018; Kalmykova *et al.*, 2018; Kirchherr *et al.,* 2017; Kjaer *et al.*, 2018; Lüdeke-Freund *et al.*, 2018; Masi *et al.*, 2018; Reike *et al.*, 2018)

Supply Chain Process	**Practice**	**Aim**	**Practice Description**	**Practice Source**
			are replaced, repaired, or upgraded. Expected product lifetime to be similar to new product.	
Recovery	Cascading	Closed resource loops	Occurs when a product, component, or material are used in an entirely different context and effectively transfer across to a different value chain. For example, when a by-product of a production process is used as an input of a different process.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Kalmykova *et al.*, 2018; Lüdeke-Freund *et al.*, 2018; Masi *et al.*, 2017; Perey *et al.*, 2018)
	Recycling	Closed resource loops	Recovery usable materials from waste stream, use of recovered materials for production inputs.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Brown and Bajada, 2018; Elia *et al.*, 2017; Franklin-Johnson *et al.*, 2016; Geissdoerfer *et al.*, 2018; Genovese *et al.*, 2017; Ghisellini *et al.*, 2016; Govindan and Hasanagic, 2018; Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Kirchherr *et al.*, 2017; Kjaer *et al.*, 2018; Lieder and Rashid, 2016; Linder *et al.*, 2017; Lüdeke-Freund *et al.*, 2018; Manninen *et al.*, 2018; Masi *et al.*, 2018; Nuñez-Cacho *et al.*, 2018; Perey *et al.*, 2018; Spring and Araujo, 2017)
	Remanufacturing	Closed resource loops	Product is disassembled, checked, cleaned and repaired in a full industrial process. Compared to refurbished product, expected lifetime to be shorter than for new products.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Elia *et al.*, 2017; Franklin-Johnson *et al.*, 2016; Ghisellini *et al.*, 2016; Govindan and Hasanagic, 2018; Kalmykova *et al.*, 2018; Kazancoglu *et al.*, 2018; Kirchherr *et al.*, 2017; Kjaer *et al.*, 2018; Lieder and Rashid, 2016; Linder *et al.*, 2017; Linder and Williander, 2015; Lüdeke-Freund, Gold and Bocken, 2018; Masi *et al.*, 2018; Perey *et al.*, 2018; Reike *et al.*, 2018; Spring and Araujo, 2017)

Table 6 - Evidence of supply chain circularity practices in empirical PSS papers

PSS	Source	Industry	Geographic context	SCC Practices: Materials Sourcing	Design					Production	Distribution		Use			Recovery		
				*	***	**	**	**	***	***	**	***	**	***	**	*	*	*
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Product-Oriented PSS	Baines *et al.* (2009b)	Capital equipment	Europe										×		×			
	Bastl *et al.* (2012)	Capital equipment	Europe										×		×			
	Chakkol *et al.* (2014)	Automotive	Europe										×	×				
	Colen and Lambrecht (2013)	Capital equipment	Europe				×						×					×
	Corvellec and Stål (2017)	Textiles	Europe								×		×				×	
	Durugbo (2013)	Capital equipment	Europe										×					
	Finne and Holmström (2013)	Capital equipment	Europe										×		×			
	Gebauer *et al.* (2013)	Capital equipment	Europe										×		×			
	Lockett *et al.* (2011)	Capital equipment	Europe										×					
	Pal (2016)	Textiles	Europe										×				×	
	Reim *et al.* (2016)	Construction equipment	Europe										×					
	Smith *et al.* (2014)	Capital equipment	Europe										×					
	Sundin *et al.* (2009)	Construction equipment	Europe				×						×					×
	Yang *et al.* (2018)	Capital equipment	Asia										×					
Use-Oriented PSS	Bressanelli *et al.* (2018)	Household appliances	Europe										×	×	×		×	×
	Corvellec and Stål (2017)	Textiles	Europe								×						×	
	Fargnoli *et al.* (2018)	Medical equipment	Europe			×							×					
	Geissdoerfer *et al.* (2018)	Bicycle	S. America				×						×					
	Johnson and Mena (2008)	Material handling equipment	Europe								×		×					
	Lindahl *et al.* (2014)	Construction equipment	Europe				×											×
	Linder and Williander (2015)	Bicycle	Europe										×					×
	Pal (2016)	Textiles	Europe										×		×			
	Sousa-Zomer *et al.* (2018a, 2018b)	Household appliances	S. America	×		×	×			×	×	×	×			×	×	
	Sundin and Bras (2005)	Household appliances	Europe										×					×
	Yang *et al.* (2018)	Capital equipment	Asia								×		×				×	×

PSS	Source	Industry	Geographic context	SCC Practices														
				Materials Sourcing	Design					Production	Distribution		Use			Recovery		
				*	***	**	**	**	***	***	**	***	**	***	**	*	*	*
				1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Result-Oriented PSS	Baines and Lightfoot (2013b)	Transportation equipment, automotive, construction equipment and office equipment	Europe/N. America					×					×					×
	Batista *et al.* (2017)	Defence	Europe										×					
	Brax and Jonsson (2009)	Capital equipment	Europe										×					
	Corvellec and Stål (2017)	Textiles	Europe								×						×	
	Datta and Roy 2011)	Defence	Europe										×	×				
	Gebauer *et al.* (2017)	Construction equipment, capital equipment	Europe								×		×	×	×			
	Gebauer *et al.* (2013)	Transportation equipment, capital equipment	Europe		×								×					
	Gebauer *et al.* (2017)	Capital equipment	Asia/Europe										×					
	Johnson and Mena (2008)	Aerospace, capital equipment, automotive, transportation equipment	Europe			×		×			×		×					×
	Johnstone *et al.* (2009)	Aerospace	Europe										×					
	Kapletia and Probert (2010)	Aerospace	Europe										×					
	Kleemann and Essig (2013)	Defence	Europe										×					
	Lindahl *et al.* (2014)	Paper and pulp	Europe	×							×						×	
	Manninen *et al.* (2018)	Household appliances	Europe			×					×		×	×	×		×	×
	Ng *et al.* (2009)	Defence	Europe										×					
	Oghazi and Mostaghel (2018)	Medical equipment	Europe										×					
	Rabetino *et al.* (2015)	Capital equipment	Europe		×								×				×	
	Saccani *et al.* (2014)	Household appliances	Europe		×								×					
	Settanni *et al.* (2017)	Defence	Europe										×					
	Smith *et al.* (2014)	Capital equipment	Europe		×								×	×				
	Story *et al.* (2017)	Transport equipment, medical equipment	Europe										×					
	Sundin and Bras (2005)	Material handling equipment	Europe		×	×					×		×		×		×	×

PSS	Source	Industry	Geographic context	SCC Practices														
				Materials Sourcing	Design					Production	Distribution		Use			Recovery		
				*	***	**	**	**	***	***	**	***	**	***	**	*	*	*
				1	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**	**13**	**14**	**15**
	Sundin *et al.* (2009)	Material handling equipment	Europe		×	×	×	×	×				×					×
	Yang *et al.* (2018)	Capital equipment	Asia		×						×		×			×	×	×

Notes: 1. In the third row in the header: * = Close resource loops, ** = Increase product longevity, *** = Increase resource efficiency; 2. In the fourth row of the header: 1 is Source secondary materials; 2 is Customisation; 3 is Design for disassembly; 4 is Design for longevity; 5 is Design for modularity; 6 is Reduce resource use; 7 is Eco-efficient production processes/ technology; 8 is Reuse/ Resell; 9 is Sustainable design of distribution system; 10 is Maintenance and Repairs; 11 is Operational efficiency; 12 is Refurbish; 13 is Cascading; 14 is Recycling; 15 is Remanufacturing.

Table 7 - Contextual factors affecting SCC

Category	Contextual Factor	Description	Effect on circular supply chain practices	Source
Economic attractiveness of SCC	Cost impact	Additional costs for implementing circular supply chain practices.	Negative – by increasing operational, planning, and/or sourcing costs. Positive – by reducing maintenance and/or after-sale service costs.	(Colen and Lambrecht, 2013; Franco, 2017; Govindan and Hasanagic, 2018; Lieder and Rashid, 2016; Linder and Williander, 2015; Masi *et al.*, 2017; Masi *et al.*, 2018; Oghazi and Mostaghel, 2018; Rizos *et al.*, 2016; Sundin *et al.,* 2009; Yang *et al.*, 2018)
	Growth opportunities	Economic opportunities stemming from selling products multiple times.	Positive – by creating new revenue sources.	(Gebauer *et al.*, 2017; Reim *et al.*, 2015; Sundin *et al.,* 2009)
	Risk of cannibalisation	Risk that circular practices may reduce product sales.	Negative – by threatening sales.	(Linder and Williander, 2015; Lockett *et al.*, 2011)
Firm sustainability strategy	Firm sustainability strategy	Firm internal sustainability strategy and circular economy policy.	Positive – by increasing the organisational and individual commitment to circular supply chain practices.	(Corvellec and Stål, 2017; Geissdoerfer *et al.*, 2018; Masi *et al.*, 2017; Perey *et al.*, 2018; Rizos *et al.*, 2016; Sousa-Zomer *et al.*, 2018b)
Policy and societal environment	Customer acceptance	Customer acceptance of innovative business models and/or refurbished/remanufactured products.	Negative – due to customer perception that refurbished/remanufactured products have inferior quality.	(Govindan and Hasanagic, 2018; Lieder and Rashid, 2016)
	Laws and regulations	Relevant existing laws and regulations.	Negative – by preventing waste recovery; stifling collaboration through competition laws. Positive – by supporting practices, for example, through tax benefits and/or recycling requirements.	(De Angelis *et al.*, 2018; Brown and Bajada, 2018; Fargnoli *et al.*, 2018; Franco, 2017; Genovese *et al.*, 2017; Lieder and Rashid, 2016; Linder and Williander, 2015; Masi, Day and Godsell, 2017)
	Waste management infrastructure	Existing infrastructure for collection and processing of wastes.	Positive – by providing the necessary infrastructure to implement collection, recovery activities.	(Corvellec and Stål, 2017)
Product category	Product characteristics	Includes product lifetime, complexity of product designs, as well as functional, economic and aesthetic deterioration over time.	Positive – by having stable technology; a core that can be reused; low deterioration of economic value. Negative – by limiting recovery options (e.g. material restrictions); being subject to fashion changes.	(Franco, 2017; Ghisellini *et al.*, 2016; Linder and Williander, 2015; Andreu, cited in Sundin *et al.*, 2009)
Supply chain relationships	Cross-sector supply chain collaboration	Actors engage in collaboration with actors outside their supply chain to prevent impacts, resources from becoming wastes.	Positive – by enabling the development of cascading resource flows.	(De Angelis *et al.*, 2018; Batista *et al.*, 2018; Bernon *et al.*, 2018; Brown and Bajada, 2018; Elia *et al.*, 2017; Koh *et al.*, 2017; Perey *et al.*, 2018; Yang *et al.*, 2018)
	Supply chain integration	Degree to which intra- and inter-organisational processes are managed collaboratively.	Positive - by facilitating information sharing and alignment of actors towards desired outcomes.	(Baines and Lightfoot, 2013b; Batista *et al.*, 2017; Bernon *et al.*, 2018; Chakkol *et al.*, 2014; Fargnoli *et al.*, 2018; Finne and Holmström, 2013; Kleemann and Essig, 2013; Liu *et al.*, 2014; Lockett *et al.*, 2011; Saccani

				et al., 2014; Smith *et al.,* 2014; Sousa-Zomer *et al.*, 2018b; Spring and Araujo, 2017)
Technology	Digital technologies	Digital technologies around the internet of things, big data, tracking and monitoring.	Positive – by providing information on asset use, condition, and location; facilitating maintenance, repair activities; providing information to improve product design; facilitating recovery.	(Baines and Lightfoot, 2013b; Bressanelli *et al.*, 2018; Colen and Lambrecht, 2013; Lieder and Rashid, 2016; Spring and Araujo, 2017)

Running Head: Effect of servitisation on supply chain circularity

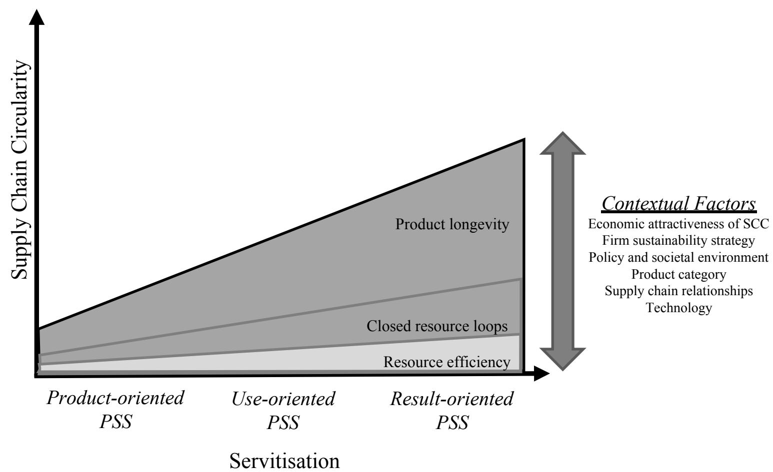

Figure 3 – Conceptual model of the relationship between servitisation and SCC