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Original citation:
Kühl, C, Tjahjono, B, Bourlakis, M & Aktas, E 2018, 'Implementation of Circular Economy principles in PSS operations' Procedia CIRP, vol. 73, pp. 124-129.
https://dx.doi.org/10.1016/j.procir.2018.03.303

DOI 10.1016/j.procir.2018.03.303
ISSN 2212-8271

Publisher: Elsevier

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 73 (2018) 124–129

www.elsevier.com/locate/procedia

10th CIRP Conference on Industrial Product-Service Systems, IPS^2 2018, 29-31 May 2018, Linköping, Sweden

Implementation of Circular Economy principles in PSS operations

Carl Kühl[a]*, Benny Tjahjono[a], Michael Bourlakis[a], Emel Aktas[a]

[a]*Centre for Logistics and Supply Chain Management, Cranfield University, Cranfield MK430AL, United Kingdom*

* Corresponding author. Tel.: +44-7425626323; *E-mail address:* c.kuhl@cranfield.ac.uk

Abstract

Product-Service Systems (PSS) where customers pay for the functionality of an asset are considered among the most suitable business models for a Circular Economy (CE). The PSS literature assumes that these offerings have potential environmental benefits, because they can break the traditional link between profit and production volume and incentivize resource productivity by the providers. While the theoretical business case for sustainable PSS is clear, it is rather unclear whether manufacturers actually adopt resource efficiency measures in these types of business models. This paper reviews studies from the servitization literature to determine how CE dimensions are implemented in the operations of such PSS offerings. The analysis provides insights into PSS activities and offers new implications for analyzing and improving the circularity of PSS offerings.

Keywords: Product-Service Systems (PSS); Servitization; Circular Economy; Operations

1. Introduction

The increasing environmental degradation exerts pressure on policy-makers and businesses to find ways to de-couple resource consumption from environmental impacts. In this context, the emergent Circular Economy (CE) concept is gaining increasing traction. It suggests an alternative to the currently dominant linear neoclassical model, where resources are extracted, manufactured into products, used and ultimately disposed of. CE provides a new economic model that intends to eliminate waste by introducing assembly, use, disassembly and re-use cycles that minimize recycling and disposal [1]. It postulates that industry can profit from investments in resource productivity by adopting circular business models [2,3]. These are business models where the 'conceptual logic for value creation is based on utilizing economic value retained in products after they are used in the production of new offerings'[3]. One of the staples of these business models is that they focus on providing product functionality instead of ownership [3]. An example are business models around collaborative consumption (e.g. car-sharing or bike-sharing) [8].

Product-service systems (PSS) are the most widely cited potential application of circular business models in practice [3–6]. They are offerings that integrate products and services to fulfill certain customer needs and generate value [6]. PSS is a sub-set of the servitization phenomenon: the process of manufacturers adding value through the provision of services [7]. Servitization is seen as a response to growing and changing consumer demands and increasing product commoditization [7,9,10]. Servitized offerings are considered to provide customer value through higher customization and the improved ability to meet specific needs [11,12]. It also relieves them from non-core activities, such as maintenance or servicing [9]. Providers benefit from building more stable and long-term customer relationships as well as introducing new revenue streams from service provision [9].

PSS variants where the manufacturer retains ownership of the product, while the customer pays for performance of or access to the assets are also considered to have potential environmental benefits [6,13,14]. Compared to traditional business models around product sales, these are considered to be less resource-intensive because they allow manufacturers to meet the same demand with less products [6,11,13]. Since the

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Peer-review under responsibility of the scientific committee of the 10th CIRP Conference on Industrial Product-Service Systems.
10.1016/j.procir.2018.03.303

manufacturer retains ownership, they are also incentivized to optimize resource utilization and minimize the cost per service unit provision [11,15]. Specifically, it is assumed that providers will reduce resource consumption by extending a product's life and potentially revalorizing it at the end-of-life (e.g. reuse or remanufacturing) [1,3,6]. As a result, PSS are believed to close and slow resource loops, thereby contributing to CE [2,11].

While the studies that explicitly refer to PSS are rare [6,16], still a significant amount of studies in the related servitization literature describe similar offerings. Contrary to the PSS literature, which originated from environmental considerations, these other forms of service-led growth stemmed from commercial and strategic considerations [17–19]. At present, it is unclear, however, whether manufacturers that adopt PSS and other servitized business models actually engage in operational practices that support dematerialization of the economy. Our premise is that adoption of business models that provide functionality incentivizes manufacturers to implement CE elements in their operations. By doing so, providers can increase the utilization of their employed resources, reduce costs and create additional value [2,3]. The aim of this paper is to review the literature to determine how circular economy dimensions are implemented in PSS operations. In doing so, it identifies current gaps in the operationalization of CE in PSS and provides avenues for further theoretical and empirical research.

2. Theoretical Background

2.1. PSS and related concepts in literature

PSS where ownership is retained and customers pay for access or performance are considered the most suitable business models for CE. These types of offerings typically classified as use- or result-oriented PSS [14]. In use-oriented PSS, the focus is on providing functionality or access, for example, through leasing, renting or sharing instead of selling products, such as car- or bike sharing schemes [20]. In result-oriented PSS, the provider and customer decide on the delivery of results without specifying the products involved [14]. Here, the offering includes the complete life-cycle of the offering, from the design to manufacturing, as well as maintenance and servicing [21]. There are three types of result-oriented PSS:

- *Pay-per-use*: Here, the user only buys a product's level of use, but still decides how and when to use the product [20]. The most ubiquitous example is Rolls-Royce's 'power-by-the-hour' offering. Instead of selling jet engines, Rolls-Royce charge their customers a fixed fee for the effective run time of their engine [22]. In return, Rolls-Royce carry out installation, maintenance, repair and modernization services together with its network of partners and suppliers [22].
- *Outsourcing*: The provider is solely responsible for the management of an end-user's process. An example is ABB taking responsibility for planning and executing maintenance activities for an entire plant under a shared risk and reward contract [20].
- *Functional-result service*: Provider owns and uses products and decides how results should be delivered. An example is Thales Training & Simulation solution offering focused on the training of pilots and the management of simulator facilities [20].

These types of offerings have some characteristics, namely that the provider is the product owner, that they focus on supporting the customer's end-processes and that most of them employ long-term relational contracts with their customers [20]. Most empirical cases of such business models stem from industries that produce expensive and complex capital goods, such as in the aerospace or defense [6,23]. Complex capital goods lend themselves to these types of business models, because they usually require significant maintenance and servicing over their lifetime [6]. Even though the majority of empirical cases in the servitization stem from the business-to-business and manufacturing context, there are also emerging examples from consumer markets, such as textiles or whitegoods [4,24]. One example is the Danish clothing company Vigga, which provides organic baby clothes based on size, replaces them once they become too small, washes them and then reuses the clothes with other consumers [24]. Another is Electrolux which offers a pay-per-wash scheme [25].

As mentioned in the introduction, PSS offerings are part of the larger servitization process of manufacturing companies. There are other forms of servitized offerings found in literature that are similar to use- and result-oriented PSS, such as advanced services [17,26], performance-based or outcome-based contracting [27,28], as well as integrated solutions [29]. The main difference between PSS and these other forms of servitized offerings is their point of departure. As a research field, PSS is closely linked to the sustainability field, with most publications focusing on its potential to simultaneously secure competitiveness and sustainability [8,17]. The servitization literature on the other hand derived from Western manufacturing companies needing to innovate their production-based business models to differentiate against the entry of low-cost rivals [17,18]. It follows that this field of research focuses on the commercial and strategic potential of delivering integrated solutions of products and services. Even though PSS offerings are similar to other servitized offerings, they have different underlying narratives and areas of focus.

2.2. CE principles in PSS implementation

The CE concept is defined as "an economic system that replaces the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes. It operates at the micro level (products, companies, consumers), meso level (eco-industrial park) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, thus simultaneously creating environmental quality, economic prosperity and social equity to the benefit of current and future generations. It is enabled by novel business models and responsible consumers" [30]. Business models, such as PSS, enable the implementation of CE principles by promoting a new perspective on the role of resources in the economy [30,31]. There are two core principles in CE: the *systems perspective* and the *waste hierarchy* or 4R's (i.e. reduce, reuse, recycle, recover) [30]. The former focuses primarily on the importance of change occurring at different societal levels, while the latter provides the core idea behind the closure of resource loops. Operationalizing CE in PSS in the context of manufacturing industries is connected to three aspects [31,32]:

- *Supply chain:* CE requires the development of supply chains that prolong the life of assets (e.g. maintenance, repair), increase performance, as well as ensure their return from their context of use (i.e. reuse, remanufacture or recycle). It also encourages cascading or downcycling products and components across different value streams, for example in another use context, thereby leading to systemic change at different societal levels [33].
- *Product design*: Products will need to be designed with multiple usage phases in mind. This means designing for maintainability, multiple life-cycles, as well as ensuring the use of refurbished components and recycled materials.
- *Information and Communication Technology (ICT)*: Innovative ICT are a significant enabler to CE, because they facilitate the management of product life-cycles. Specifically, companies should employ technologies that allow the monitoring of products in different life-cycles, by providing relevant information regarding condition and use. This can facilitate the identification of suitable recovery options.

3. Research method

The aim of this paper is to determine how CE dimensions are implemented in PSS variants. The unit of analysis in this paper are the operational aspects of CE principles in PSS business model. The paper keywords around PSS (i.e. servitization, advanced services, outcome-based contracts, performance-based contracts, integrated solutions) and aspects around their implementation (i.e. supply chain, value chain, reverse supply chain, closed-loop, product design, ICT) were used to generate search strings. Search strings were then used to search Scopus, Proquest (ABI/Inform), EBSCO, and Web of Science databases for relevant scholarly (peer-reviewed) publications. In addition, other articles were identified through a review of the references of previously identified articles. To be included in the study, the articles needed to focus on product-service offerings that provide functionality. In addition, they had to provide insights about the nature of supply chains, the design of products as well as the use of ICT in the implementation of these offerings. The findings are summarized in Table 1, which exposes the waste hierarchy principle and the systems perspective principles of CE and the extent to which the current PSS literature previously discussed them.

4. Findings

The results of the literature are presented based on the previously identified framework. They are organized in their respective sub-categories. The findings are summarized in Table 1.

4.1. Supply Chain

In PSS, the manufacturer still produces the equipment and also takes the responsibility for the operation of the equipment, including maintenance, repair, servicing and disposal [12,15]. In return, the customer pays the manufacturer for the use or functionality of the equipment [12]. To deliver PSS successfully, manufacturers rely on extensive supply networks across multiple life-cycle stages [15,22]. The structure of these networks is dependent on the value proposition [22]. The network types are differentiated based on their horizontal structure (i.e. number of different value chains), vertical structure (i.e. hierarchical levels in value chain), as well as life-cycle stages [22]. Potential partners during the use phase can, for example, be local maintenance and repair specialists or logistics service providers who can support material handling and storage [22,26,34]. Supply network partners are critical in providing the knowledge and competencies necessary to effectively and efficiently deliver a PSS offering [22,35]. By outsourcing activities manufacturers can potentially save costs, thereby increasing overall resource utilization [36]. In one study, the manufacturer even included the customer in maintenance and repair activities [37]. Partnering and collaboration decisions within the different product life-cycle stages are dependent on the manufacturer's access to skills and resources as well as their position in the supply chain [22,35,36].

The most widely mentioned CE-related practices focus on prolonging asset life, for example through predictive and preventive maintenance or repairs. These are important to satisfy customer expectations, reduce costs and manage operational risks associated with the offering [26,38]. One of the biggest challenges is forecasting the planned and unplanned demand for these types of services [39,40]. To ensure a high level of responsiveness, manufacturers can deploy facilities closer to the customer's operation or vertically integrate downstream [26,34,41]. Providers can also extend the product life by influencing customer knowledge and behavior regarding optimal asset use [37,39]. This requires providers to deploy staff that are technically skilled as well as proficient at customer relationship building [26,39].

Even though product disposal is a provider's responsibility, few papers provide detail on end-of-life processes. In one paper, the case companies did not have any formalized processes for dealing with products upon their return and made repurposing decisions to scrap or sell on secondary markets on an ad-hoc basis [34]. In another study, the offering clearly included reuse and recycling, but the providers' limited capabilities in waste collection and treatment hindered the effective closure of material loops [24]. One case mentioned the risk and the complexity related to planning and forecasting for multiple life-cycles as a major barrier for allowing reverse flows [3]. Downcycling and cascading products into new use contexts and networks were almost completely absent in the literature. Only one paper described how used components were sold on secondary markets to other use contexts [34]. The review shows that aspects relating to disposal and product recovery are currently underdeveloped in the literature.

4.2. Product Design

Product and service design are important because they enable the customization of the offering according to customer requirements and improve service delivery [22]. It is important for the provider to develop a clear understanding of the customer needs and preferences as well as different use contexts in which the customers operate [42]. Some papers showed that providers take on a life-cycle perspective in the development of new products. They included service personnel and field service data to improve product and service designs [21,34,43]. Others outlined that products were specifically designed with the recovery of value at end-of-life in mind [4,24]. This is limited by the product's basic material characteristics as well as the required functionality [44]. In addition, collaboration and reliance on the competencies of actors within the supply chain are considered critical for developing circular products [24]. In some cases, however, manufacturers still only consider the use phase in product design without considering after-sales service requirements [45]. This can result in suboptimal service delivery and missed value creation opportunities [45]. Some papers also mentioned improving performance. In one paper, a provider had a policy of upgrading employed assets at the lifetime mid-point [34]. Others focused especially on the use of big data (e.g. asset location, condition and use) to make improvements to product and service design [26,38,46].

4.3. ICT

Digital technologies play a significant role in supporting the servitization process of manufacturers [26,47,48]. The most widely mentioned use of digital technology is around the Internet of Things (IoT) and the connection of devices [23,37,38,45,47,49,50]. It has a foundational role in supporting PSS implementation because it allows companies to collect and transmit data from widespread fleets regarding asset condition, use and location [26,37,46–48]. Providers of use-oriented PSS can use cloud computing (CC) technology to amass big data about product use, resource consumption and to bill customers [47]. Providers of result-oriented PSS can use IoT and CC in conjunction with predictive analytics (PA) to predict customer behavior and product faults [47]. This helps anticipate required activities and can simulate the effects of different operational policies and configurations [47]. It can support value co-creation through system modification, modernization and optimization [21,22,46]. Similar practices were found in reviewed case studies [26,34,37,50]. Possible tools that can be used for system improvements are: lifecycle costing, activity-based costing, business process modeling, agent-based modeling or system dynamics [51]. They model PSS' dynamic behaviors and help facilitate maintenance and repair activities, improve product designs as well as reduce technical and operational risks [26,38,48]. Customers benefit from improved availability, performance and potential cost reductions [48]. Drivers of these technologies are: properly managed skills, experience and knowledge by manufacturers, customers and suppliers [50]. It is inhibited by: a limited technological understanding by customers as well as service personnel, inadequate knowledge management and a misalignment between services and manufacturing strategies [50].

Table 1 - Operationalization of CE principles in PSS literature

CE Principles	Waste Hierarchy and Systems Perspective					
Domain	Supply Chain			Product Design		ICT
CE dimensions	*Prolong product life (maintenance etc.,)*	*Remanufacture/ Recycle products*	*Downcycle/ cascade products*	*Adopt life-cycle perspective*	*Increase product performance*	*Use IoT, big data, and predictive analytics technology*
[3]	✓	✓		✓	✓	
[21]	✓	✓		✓	✓	✓
[22]	✓			✓		
[23]	✓					✓
[24]	✓	✓		✓	✓	
[25]	✓					✓
[26]	✓			✓	✓	✓
[34]	✓	✓		✓	✓	✓
[36]	✓					
[37]	✓					✓
[38]	✓		✓		✓	✓
[41]	✓			✓		✓
[42]	✓			✓		
[45]	✓					✓
[46]	✓				✓	✓
[47]						✓

5. Discussion and Conclusion

This paper addressed the need for insights regarding the operationalization of CE in PSS [4,24,52]. Existing reviews on the matter focus on the conceptualization and definition of the concepts as well as provide an overview of the development of the literature domain [1,5,6,8,17]. This is the first review to offer a more in-depth analysis of the current contribution of PSS operationalization towards CE. In doing so, it makes two key theoretical contributions to these literature domains. Firstly, it provides insights into the activities and initiatives that PSS providers engage in to increase resource utilization. The employed framework guides the inquiry into CE-related operational practices. In doing so, the paper extends the current understanding of how PSS business models are adopted and implemented. This knowledge was previously fragmented and distributed across different empirical studies and literature domains. Secondly, it identifies current gaps in the operationalization of CE in PSS. A key finding of this review is the lacking development of product recovery activities as well as downcycling and cascading into other use contexts. This is surprising, because environmental impact reduction is traditionally considered a key motivation for PSS implementation [8]. In our opinion, this can be explained by the dominance of empirical research from the servitization domain, where environmental considerations tend to be less prevalent

[17]. Even though providers are responsible for disposal, their reverse operations are often not developed or formalized enough for collection and recovery to happen systematically [34]. In the PSS domain, however, there is also an emerging literature that points to the difficulties of closing material cycles in PSS implementation [3,4,24]. They point to the additional risks of forecasting and planning for multiple life-cycles as well as the capabilities required to set-up reverse supply chains. Overall, the results suggest that there is currently a suboptimal retention of utility and value at end-of-life. This is also supported by the relative absence of downcycling and cascading, which suggests a lacking development of open networks of circulation and exchange as the CE principle of systems thinking demands [1,30].

In our opinion, enabling supply chains to close material cycles effectively and efficiently is the biggest challenge in the current research around developing circular production systems with PSS. There are many interesting avenues for further research to contribute towards solving this challenge. One aspect is the clear definition of operational CE principles for PSS supply chains. It would be intriguing to see how these would impact the structure and operation of PSS supply chains. Another interesting question is how downcycling and cascading to other use contexts can be increased to improve the performance of the PSS business model. Both questions can be explored both qualitatively and quantitatively through the use of multiple case studies or simulation tools.

Managers of PSS providers can use the above-mentioned framework as well as the activities and practices to evaluate the circularity of their own PSS offering. This can help a firm's decision-makers re-evaluate their own operations and find opportunities for increasing the circularity of their own operation.

Acknowledgements

The research leading to these results is part of Circ€uit, the Circular European Economy Innovative Training Network. It is an action funded by the European Commission under the Horizon 2020 Marie Skłodowska Curie Action 2016 (Grant Agreement number 721909).

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